Beam Delivery Review

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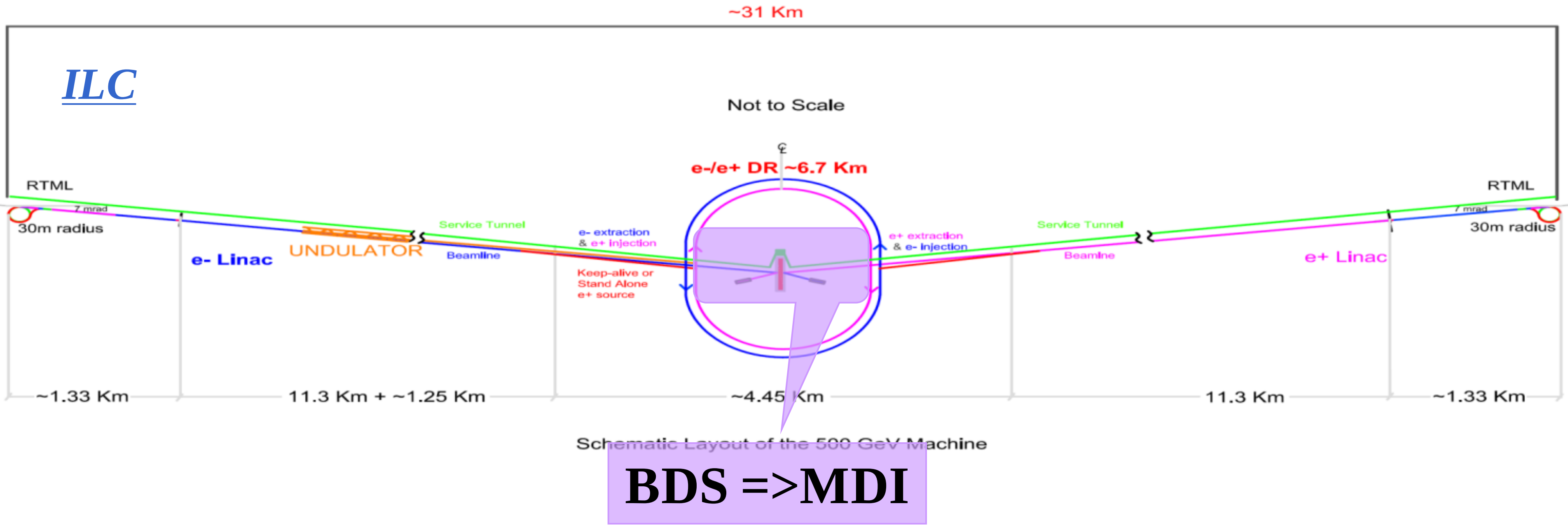
With many thanks to GDE BDS team
And in particular Deepa Angal-Kalinin

25 April 2012

Info about this presentation

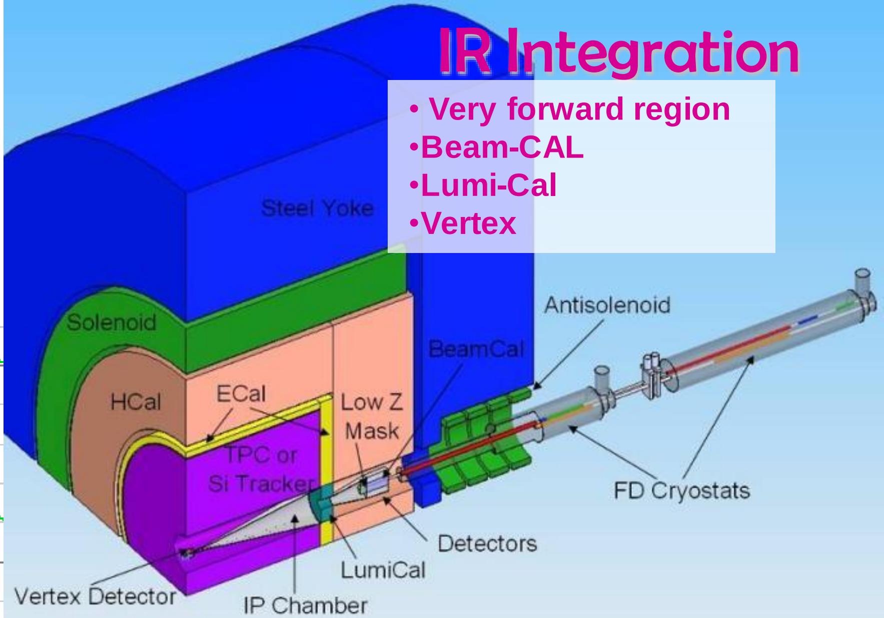
- This presentation is based on BDS review slides given on Oct 24-25 2011 in DESY, during baseline review
- Substantial progress, since then, is in
  - MDI/CFS design (reviewed separately)
  - ATF2 progress (special sessions)
  - Beam dump system
    - NIM review paper published (linked to the agenda)
    - BARC is ready to build the beam dump system if needed
- We have created a plan to finish the remaining optics and cost estimation work this summer, to fit in the timescale of the TDR

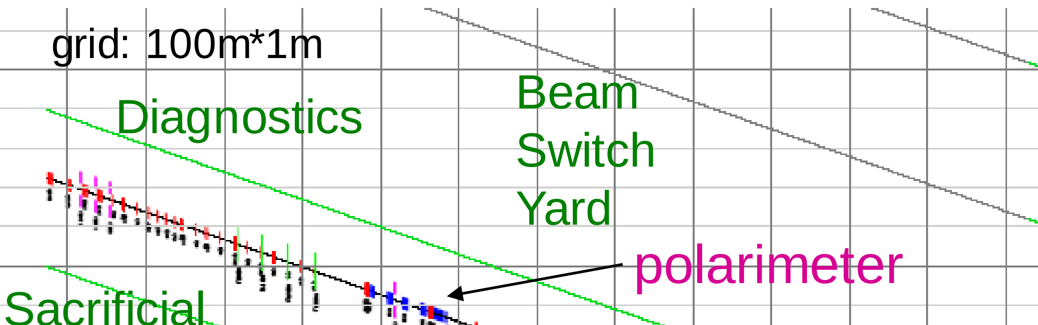
Beam Delivery System & MDI in ILC

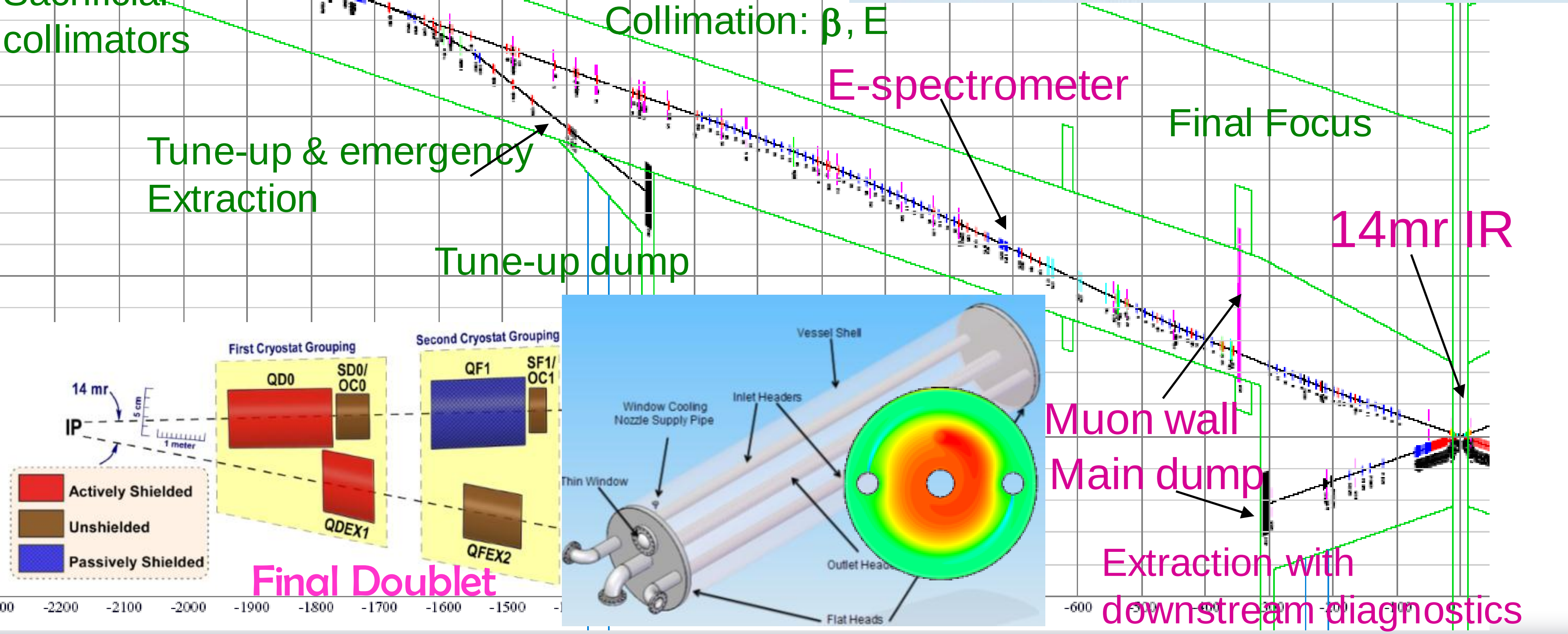


Beam Delivery & MDI elements

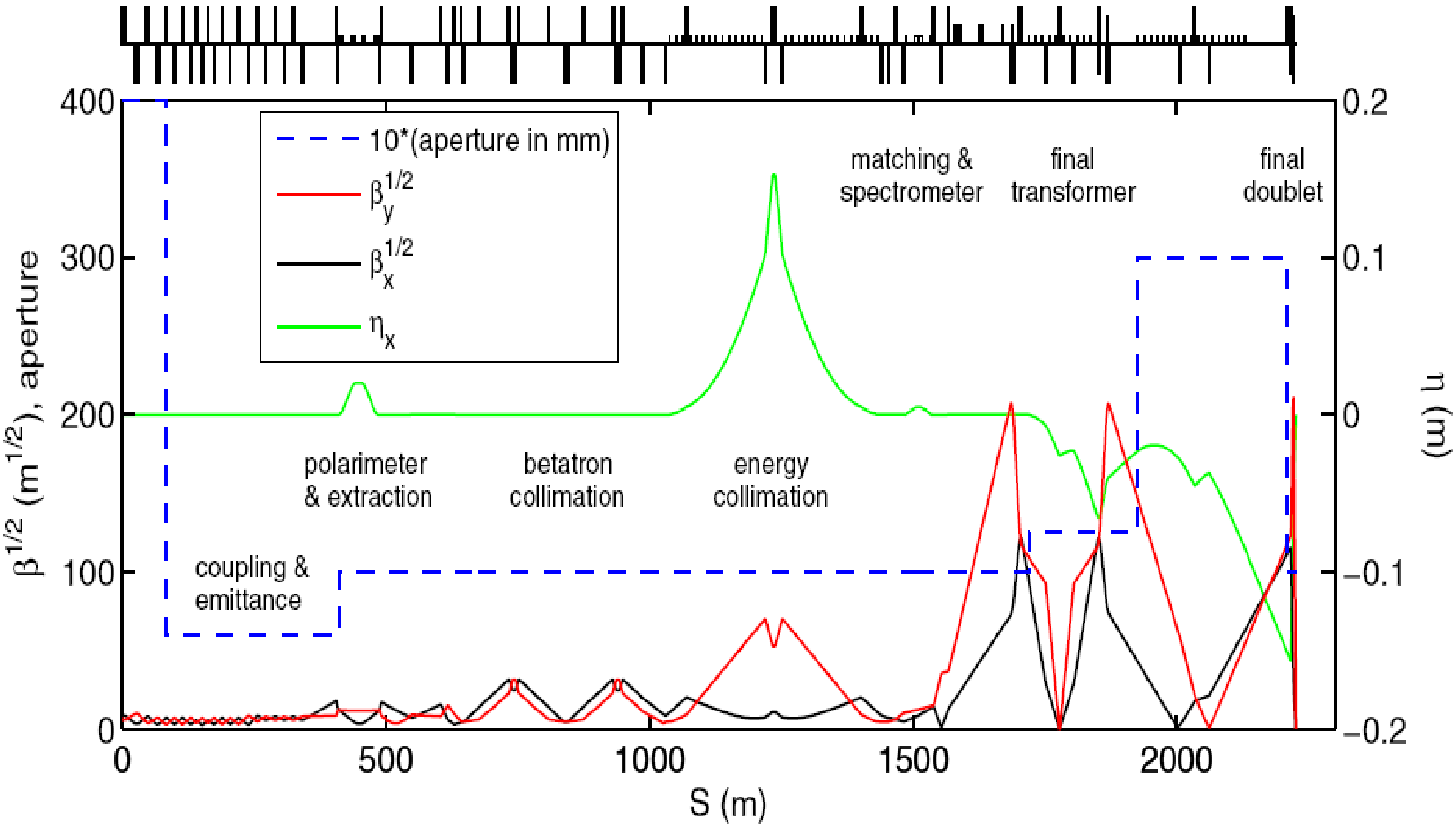
1TeV CM, single IR, two detectors, push-pull







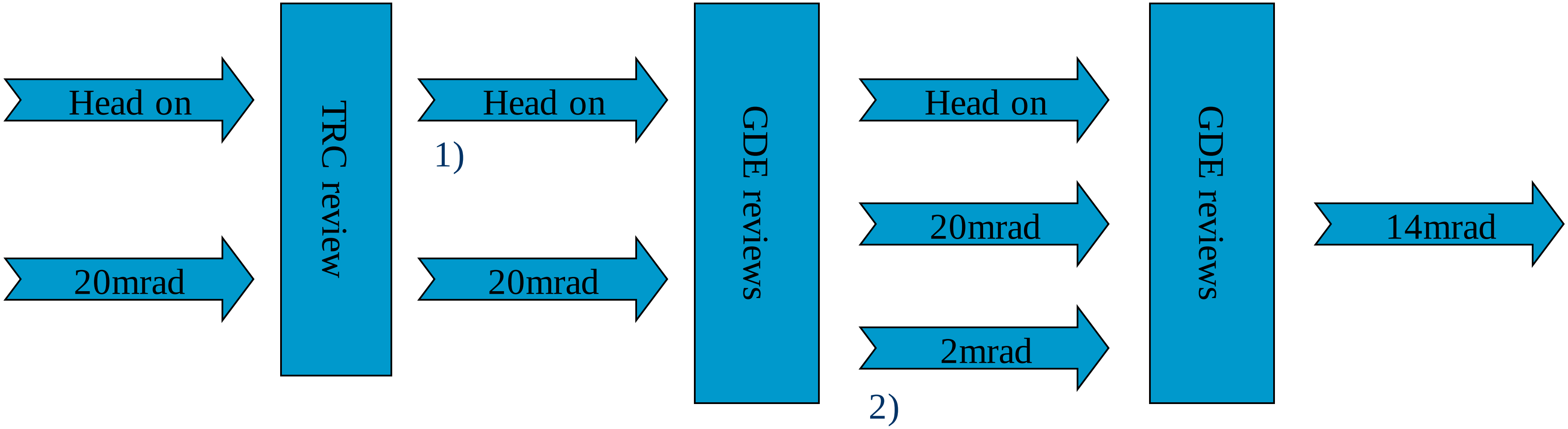
ILC BDS Optical Functions



ILC BDS RDR Parameters

Length (linac exit to IP distance)/side	m	2226
Length of main (tune-up) extraction line	m	300 (467)
Max Energy/beam (with more magnets)	GeV	250 (500)
Distance from IP to first quad, L*	m	3.5-(4.5)
Crossing angle at the IP	mrad	14
Nominal beam size at IP, σ^*, x/y	nm	655/5.7
Nominal beam divergence at IP, θ^*, x/y	μrad	31/14
Nominal beta-function at IP, β^*, x/y	mm	21/0.4
Nominal bunch length, σ_z	μm	300
Nominal disruption parameters, x/y		0.162/18.5
Nominal bunch population, N		2×10^{10}
Max beam power at main and tune-up dumps	MW	18
Preferred entrance train to train jitter	σ	< 0.5
Preferred entrance bunch to bunch jitter	σ	< 0.1
Typical nominal collimation depth, x/y		8–10/60
Vacuum pressure level, near/far from IP	nTorr	1/50

BDS & MDI Configuration Evolution

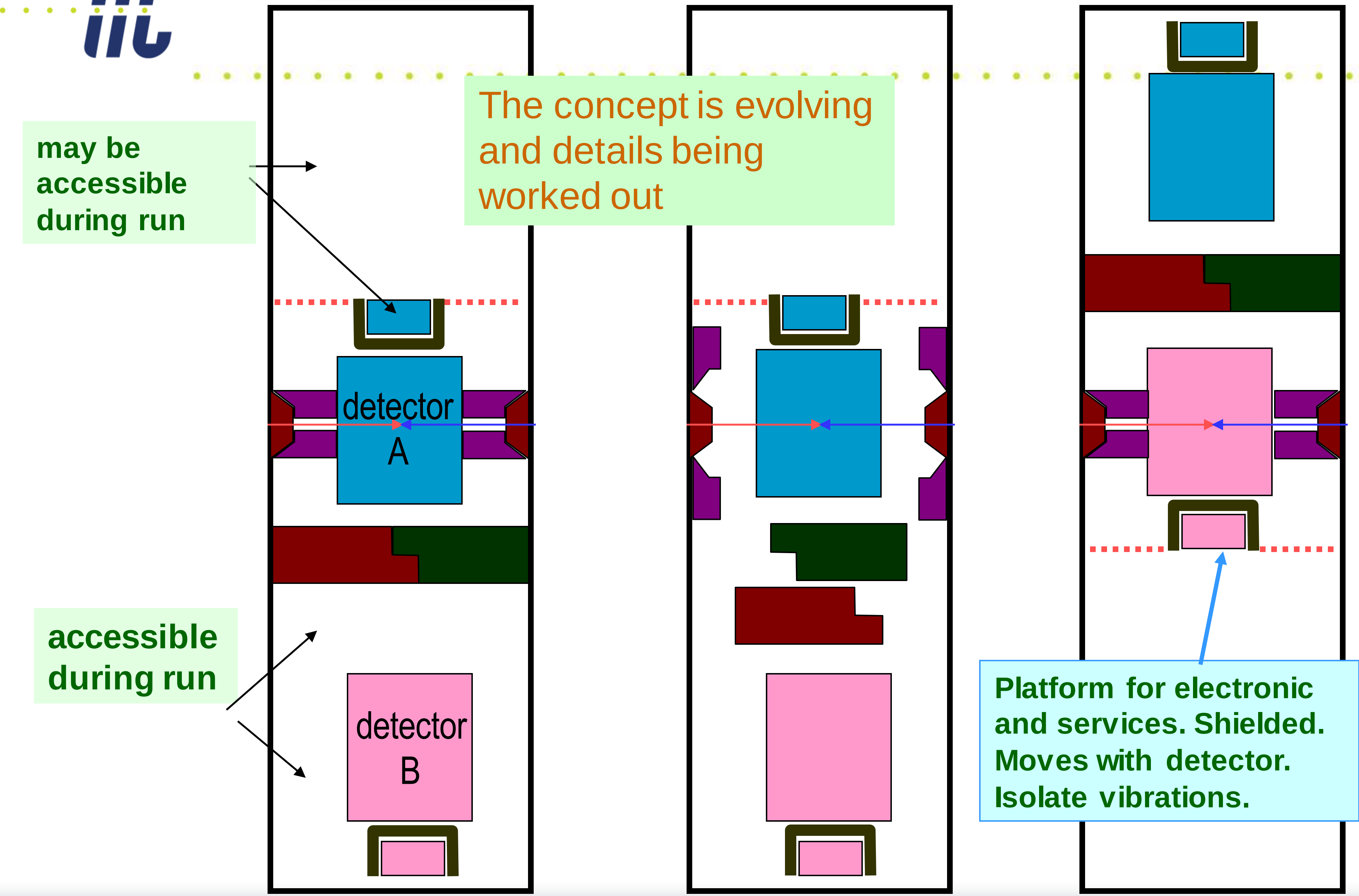


- **Evolution of BDS MDI configuration**
  - Head on; small crossing angle; large crossing angle

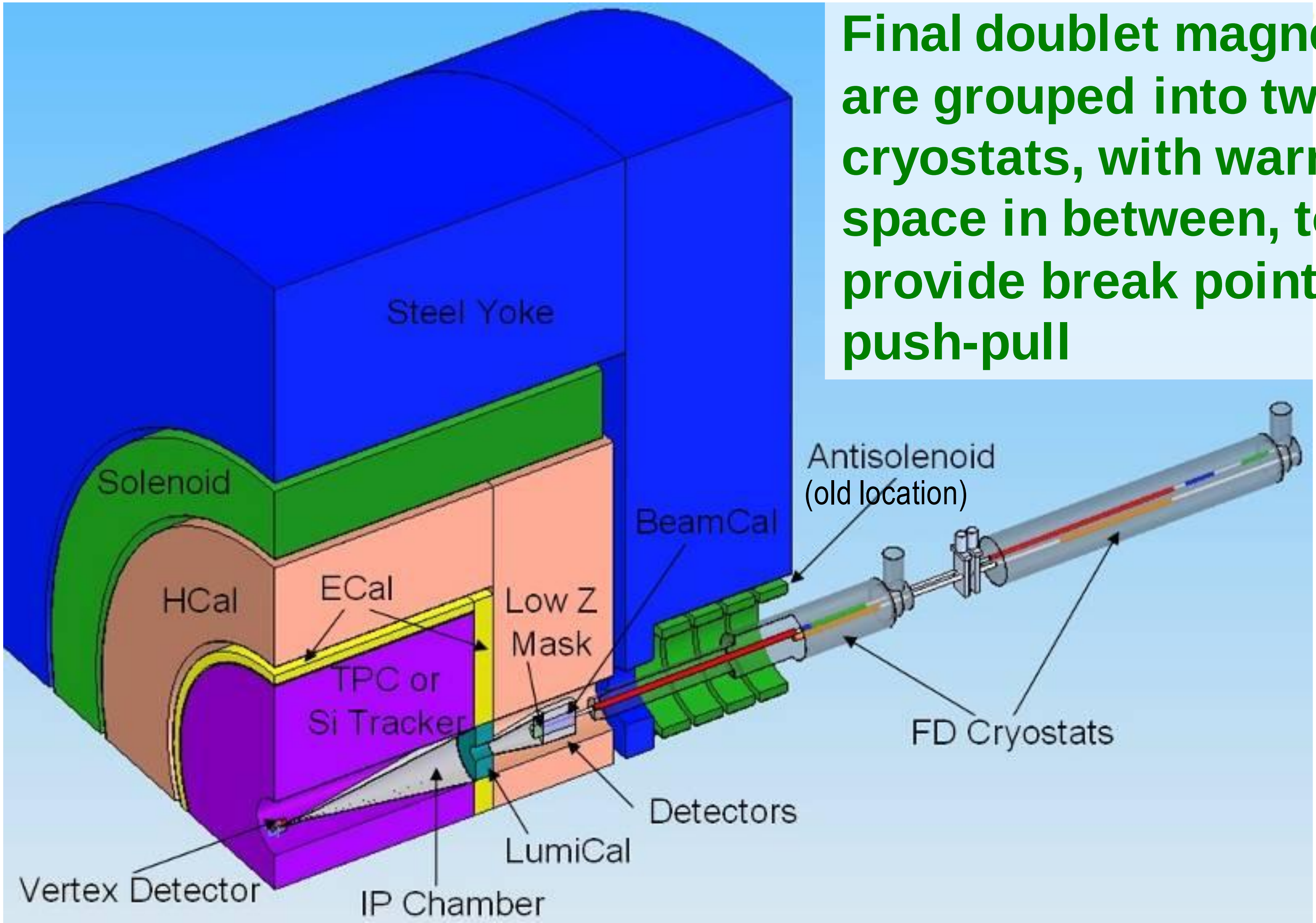
  - MDI & Detector performance were the major criteria for selection of more optimal configuration at every review or decision point

1) Found unforeseen losses of beamstrahlung photons on extraction septum blade
2) Identified issues with losses of extracted beam, and its SR; realized cost non-effectiveness of the design

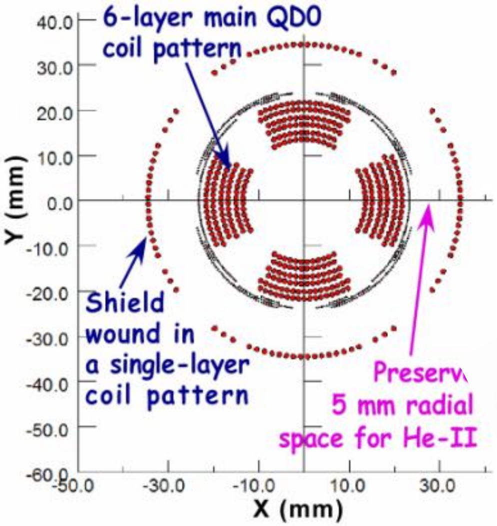
Concept of single IR with two detectors



IR integration

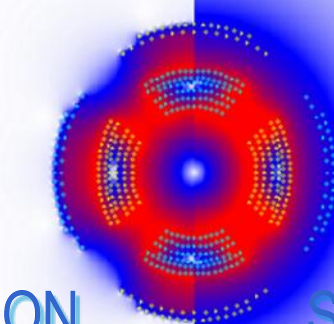


Final doublet magnets are grouped into two cryostats, with warm space in between, to provide break point for push-pull



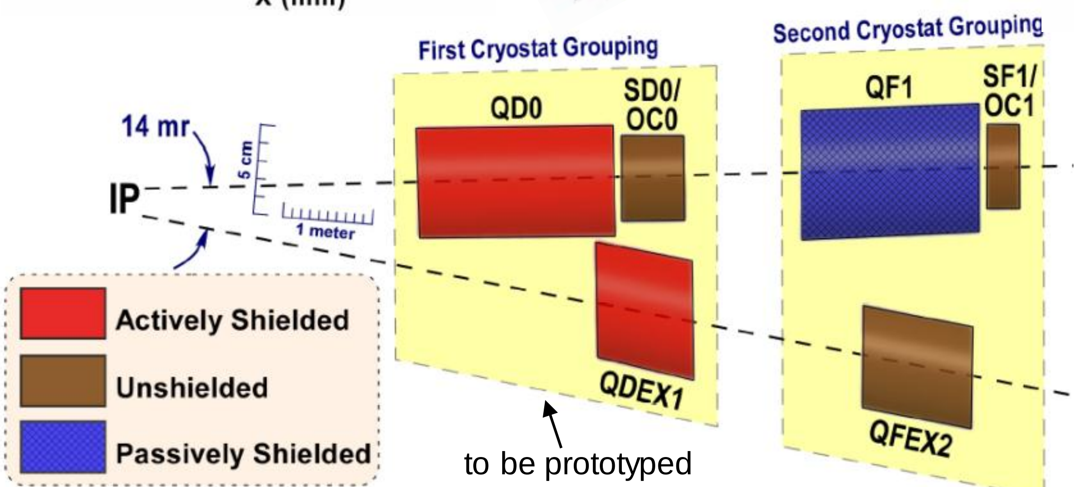
Actively shielded QD0

BNL

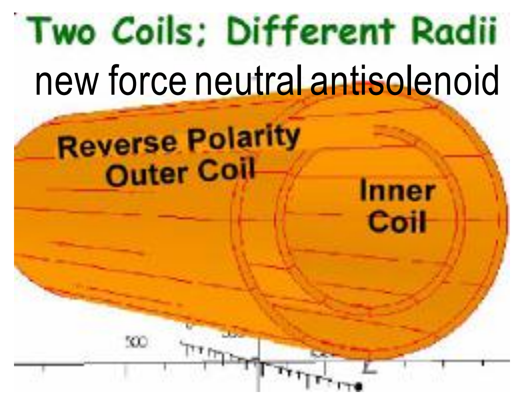


Shield ON Shield OFF

Intensity of color represents value of magnetic field.



to be prototyped during EDR

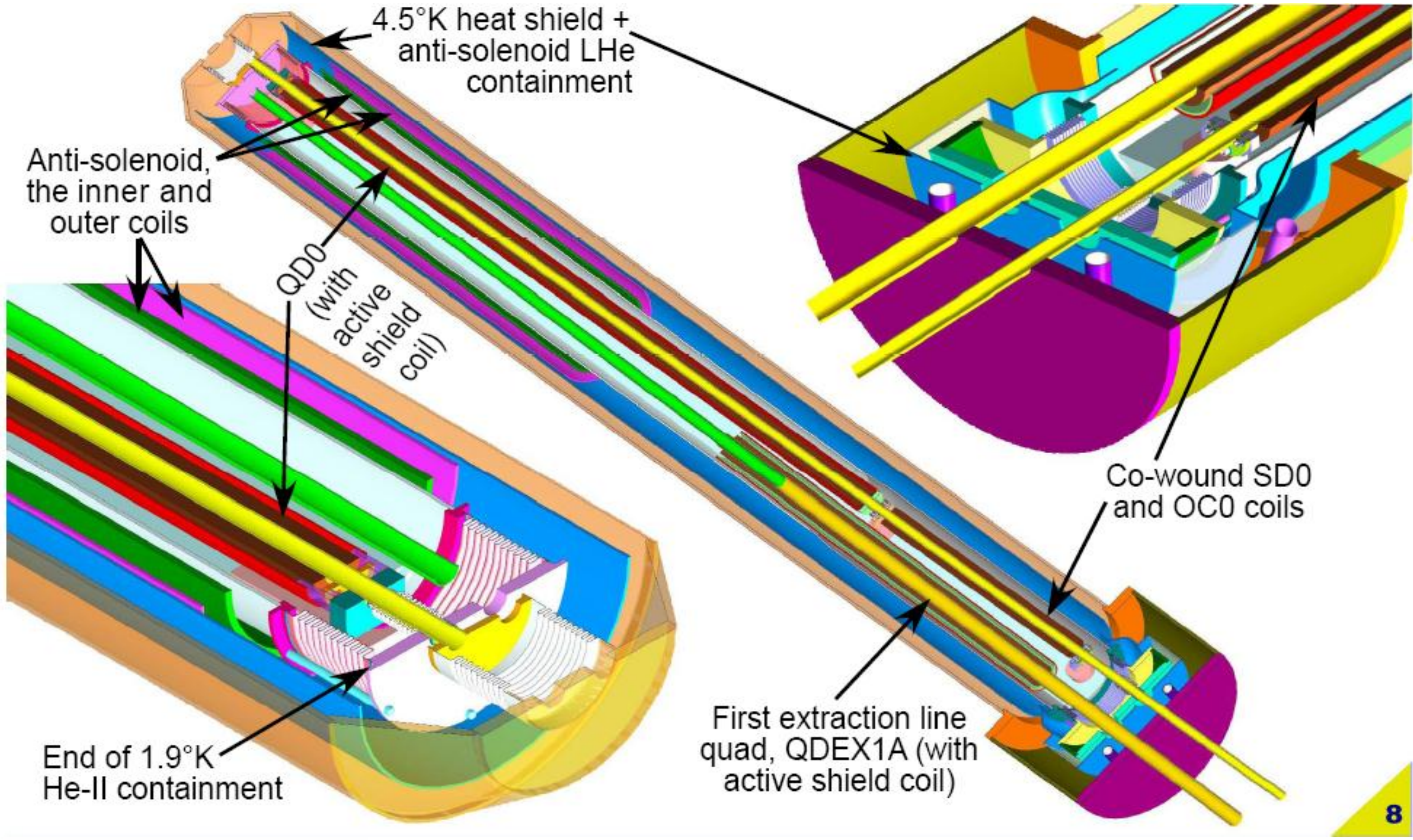


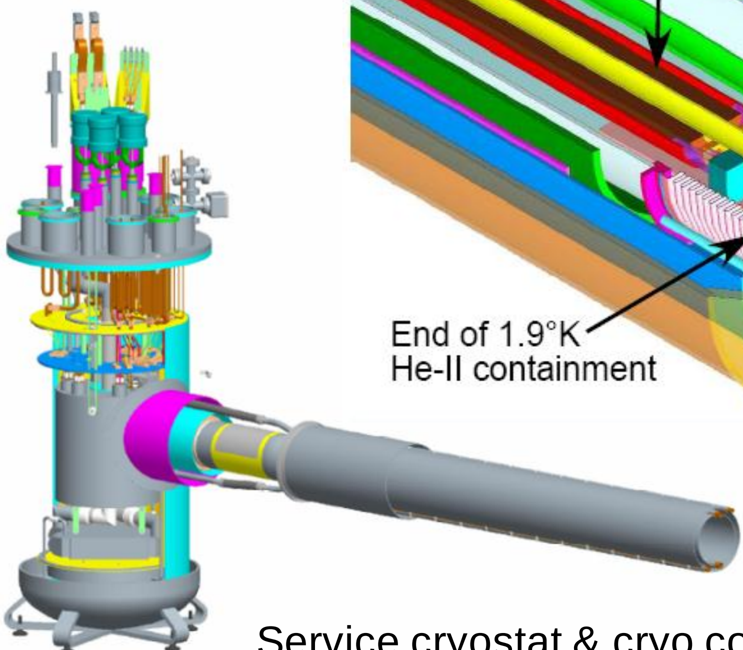
new force neutral antisolenoid

- Interaction region uses compact self-shielding SC magnets
- Independent adjustment of in- & out-going beamlines
- Force-neutral anti-solenoid for local coupling correction

IR Magnets

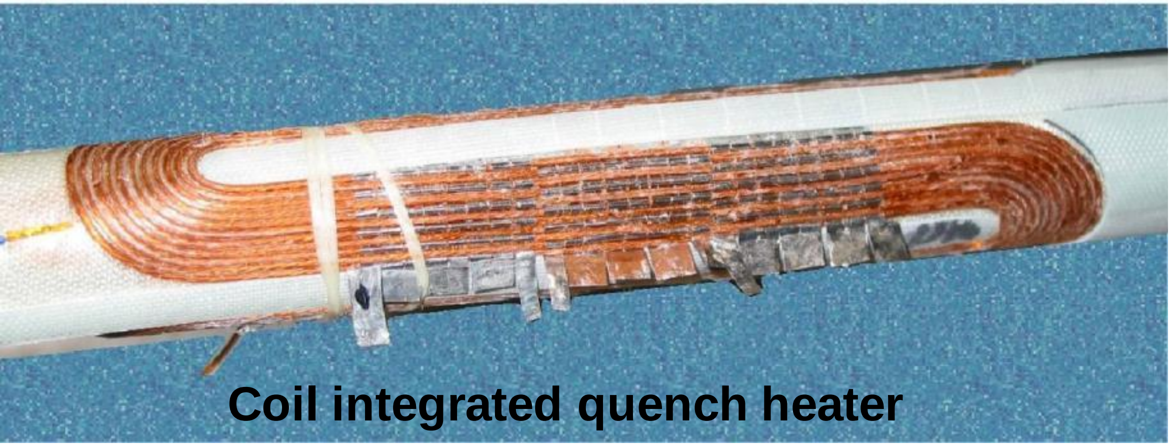
BNL



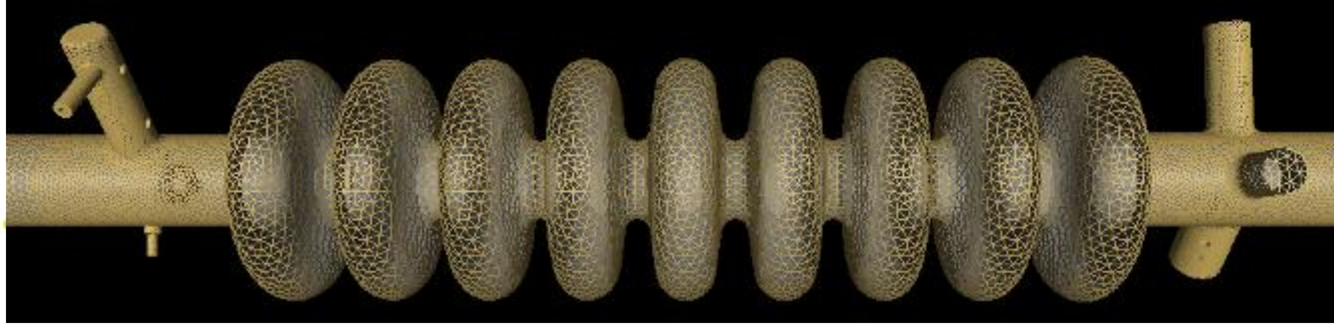


Service cryostat & cryo connections

IR magnets prototypes at BNL



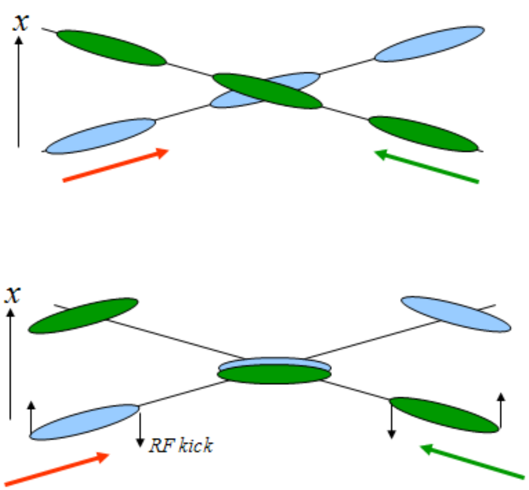
Crab cavity design

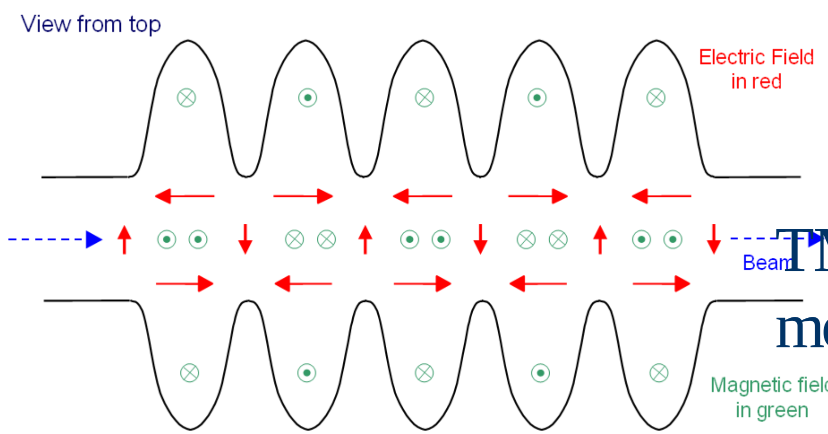


FNAL 3.9GHz 9-cell cavity in Opega3p. *K.Ko, et al*

- Prototypes of crab cavity built at FNAL and 3d RF models
- Design & prototypes been done by UK-FNAL-SLAC collaboration

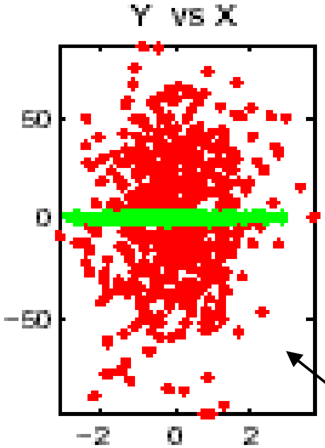
3.9GHz cavity achieved 7.5 MV/m (FNAL)





TM110 Dipole mode cavity

IR coupling compensation

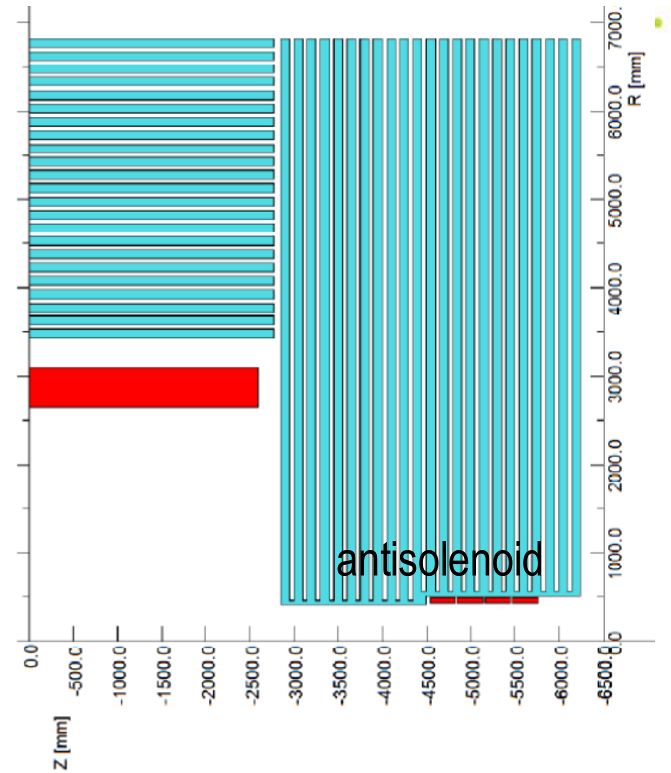


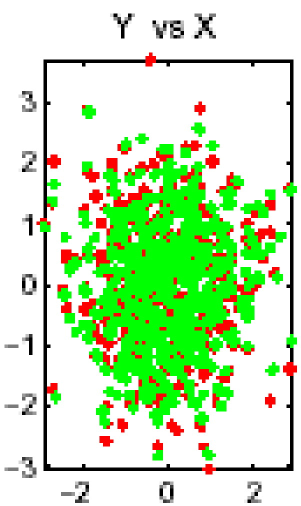
without compensation

$\sigma_y / \sigma_y(0)=32$

When detector solenoid overlaps QD0, coupling between y & x' and y & E causes large (30 – 190 times) increase of IP size (green=detector solenoid OFF, red=ON)

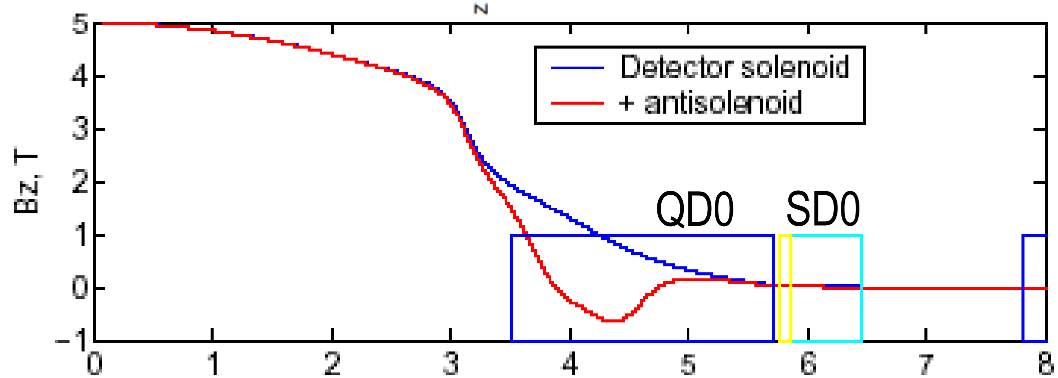
Even though traditional use of skew quads could reduce the effect, the local compensation of the fringe field (with a little skew tuning) is the most efficient way to ensure correction over wide range of beam energies





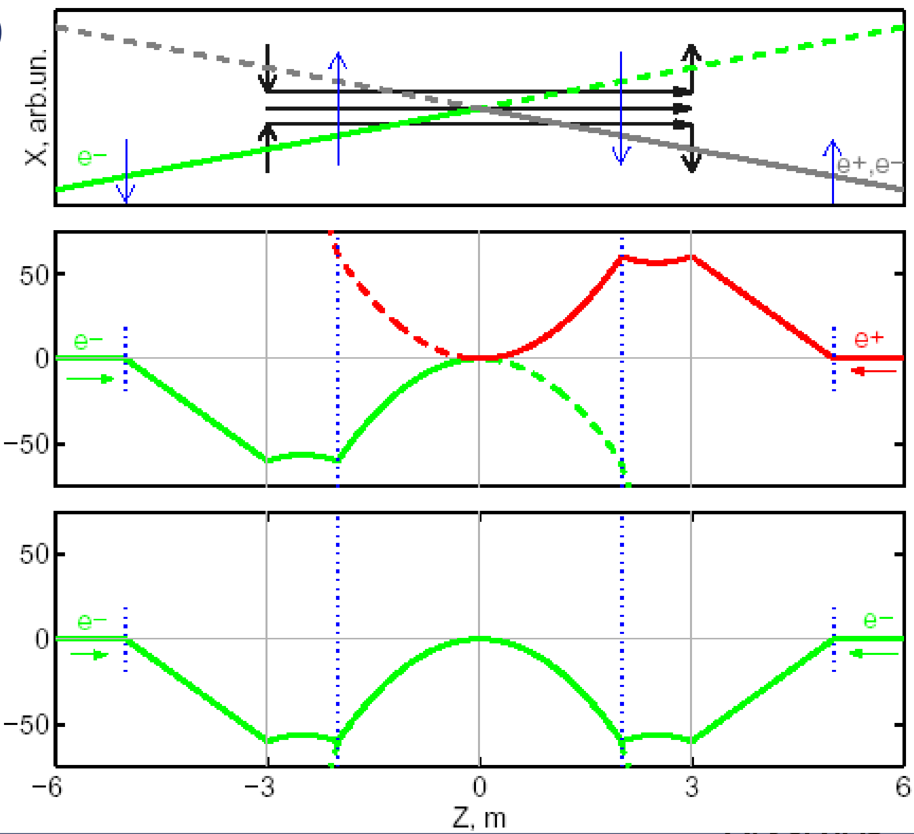
with compensation by antisolenoid

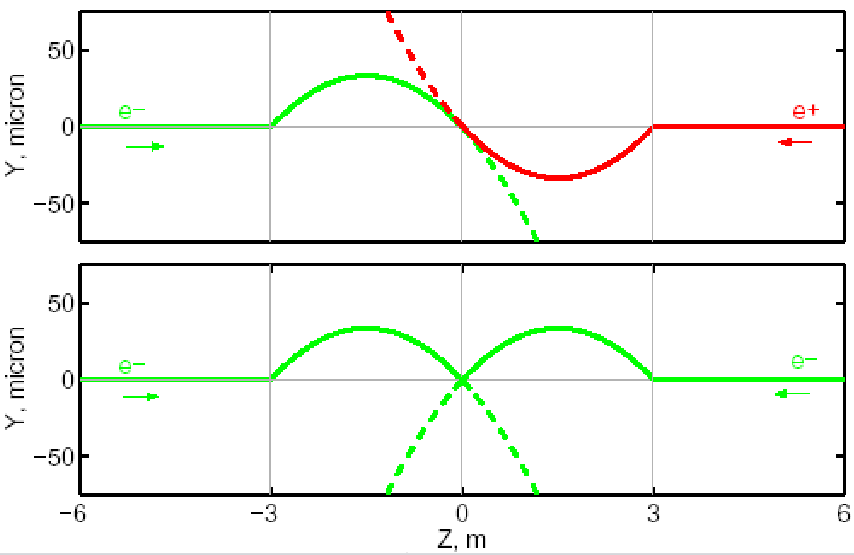
$\sigma_y / \sigma_y(0)<1.01$



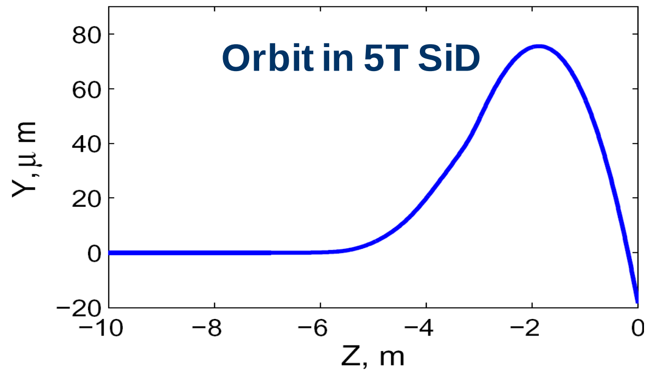
Detector Integrated Dipole

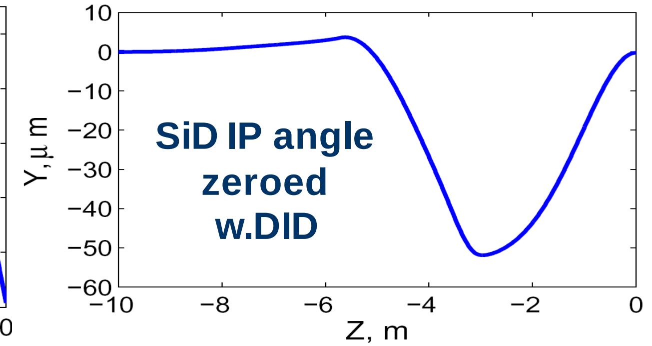
- With a crossing angle, when beams cross solenoid field, vertical orbit arise
- For e+e- the orbit is anti-symmetrical and beams still collide head-on
- If the vertical angle is undesirable (to preserve spin orientation or the e-e- luminosity), it can be compensated locally with DID
- Alternatively, negative polarity of DID may be useful to reduce angular spread of beam-beam pairs (anti-DID)





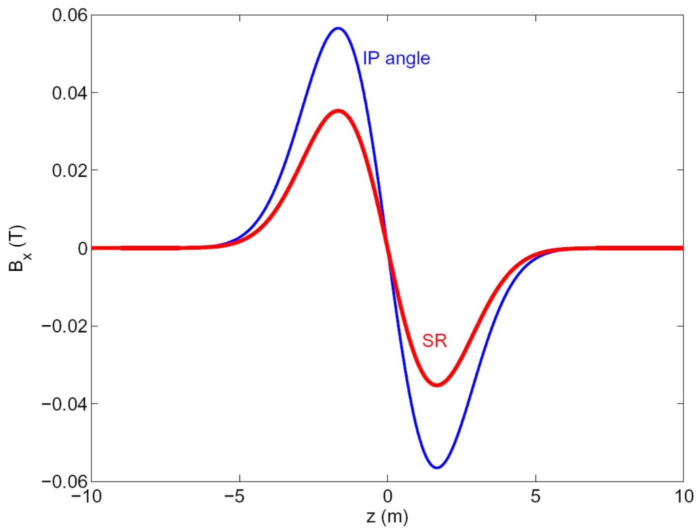
Use of DID or anti-DID

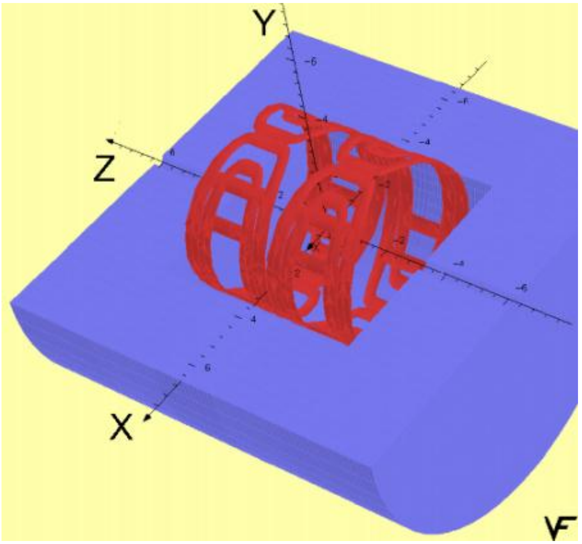




DID case

DID field shape and scheme



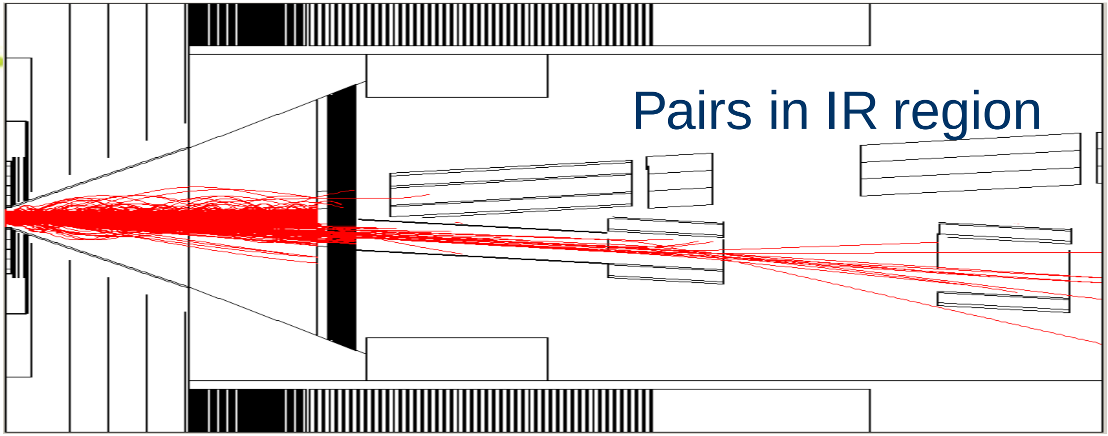


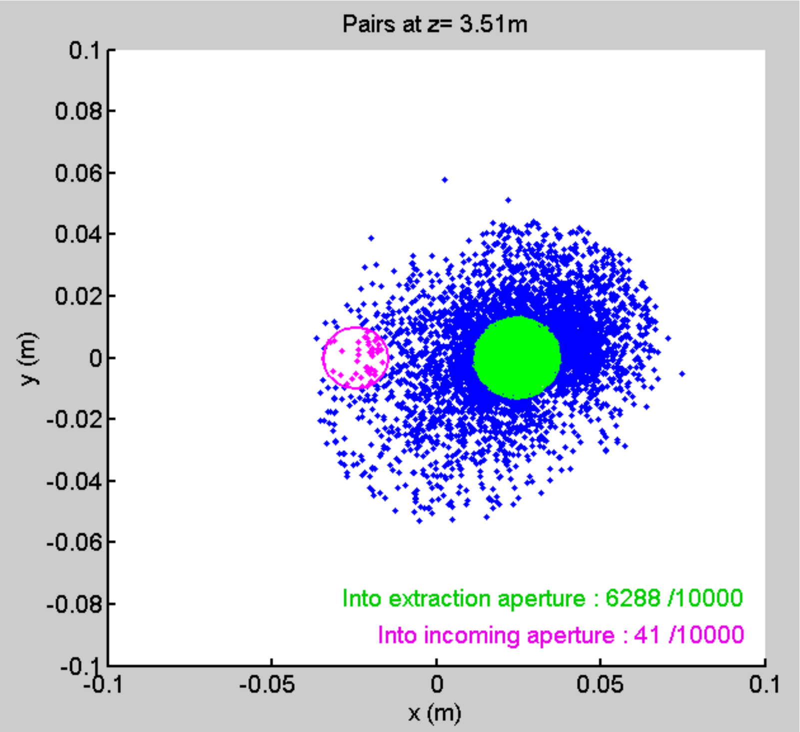
- The negative polarity of DID is also possible (called anti-DID)

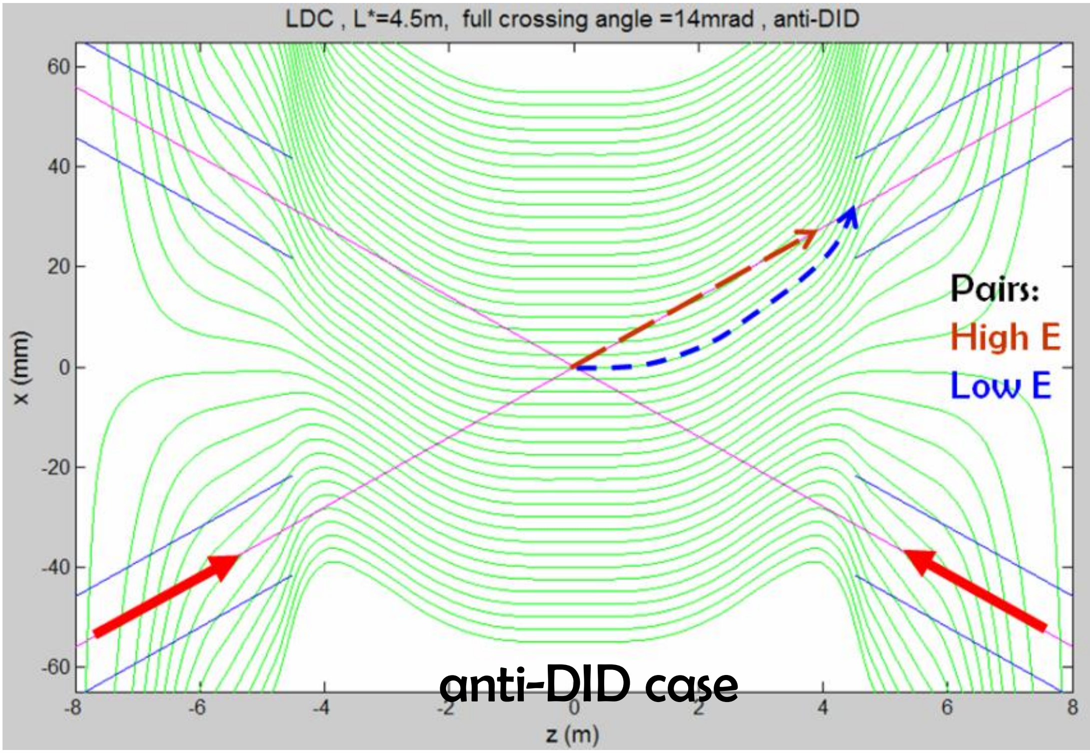
- In this case the vertical angle at the IP is somewhat increased, but the background conditions due to low energy pairs (see below) and are improved

Use of anti-DID to direct pairs

Anti-DID field can be used to direct most of pairs into extraction hole and thus improve somewhat the background conditions



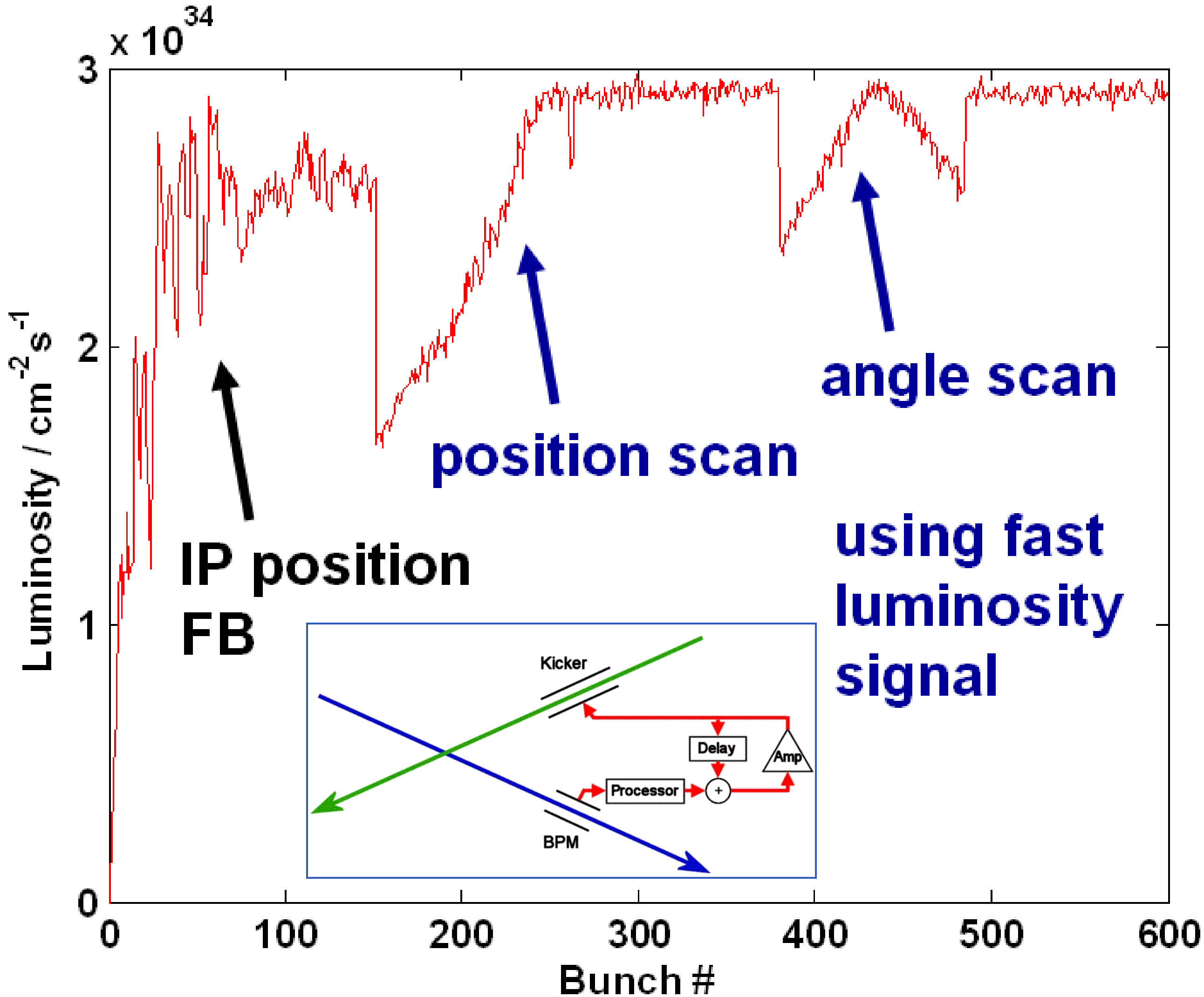




ILC intratrain simulation

ILC intratrain feedback (IP position and angle optimization), simulated with realistic errors in the linac and “banana” bunches.

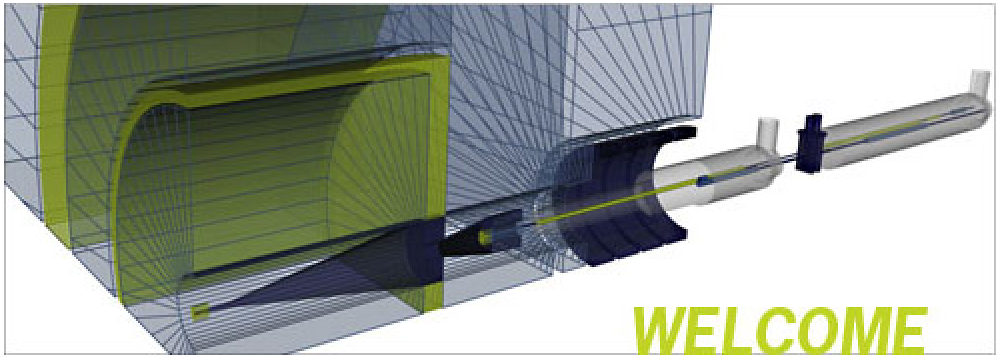
[Glen White]



IRENG07 Workshop

ILC INTERACTION REGION ENGINEERING DESIGN WORKSHOP SLAC

- Home
- Goals
- Registration
- Payment Information
- Agenda
- Organizing Committees
- The Charge to the IPAC
- Accommodations
- Travel and Directions
- Visa Information
- Social Events
- Contact



ILC Interaction Region Engineering Design Workshop

September 17-21, 2007

Stanford Linear Accelerator Center

Menlo Park, California

Please join us to review and advance the design of the subsystem of the Interaction Region of ILC, focusing in particular on their integration, engineering design and arrangements for push-pull operation.

RECENT NEWS

- Agenda has been updated.

REGISTRATION

Registration is necessary to participate in the workshop.
Registration fee is $30 and reception fee is $20.

→ Register

ACCOMMODATIONS

A block of 40 rooms is reserved until July 15, 2007 at the **Stanford Guest House**. Please reserve your room early and mention that you are attending this workshop.

→ More Information

http://www-conf.slac.stanford.edu/ireng07/

Work in preparation for IRENG07

- **WG-A: Overall detector design, assembly, detector moving, shielding.**
  - Including detector design for on-surface assembly and underground assembly procedures. Beamline pacman & detector shielding…
    - Conveners: Alain Herve (CERN), Tom Markiewicz (SLAC), Tomoyuki Sanuki (Tohoku Univ.), Yasuhiro Sugimoto (KEK)
- **WG-B: IR magnets design and cryogenics system design.**
  - Including cryo system, IR magnet engineering design, support, integration with IR, masks, Lumi & Beamcals, IR vacuum chamber...
    - Conveners: Brett Parker (BNL), John Weisend (SLAC/NSF), Kiyosumi Tsuchiya (KEK)
- **WG-C: Conventional construction of IR hall and external systems.**
  - Including lifting equipment, electronics hut, cabling plant, services, shafts, caverns, movable shielding; solutions to meet alignment tolerances...
    - Conveners: Vic Kuchler (FNAL), Atsushi Enomoto (KEK), John Osborne (CERN)
- **WG-D: Accelerator and particle physics requirements.**
  - Including collimation, shielding, RF, background, vibration and stability and other accelerator & detector physics requirements…
    - Conveners: Deepa Angal-Kalinin (STFC), Nikolai Mokhov (FNAL), Mike Sullivan (SLAC), Hitoshi Yamamoto (Tohoku Univ.)

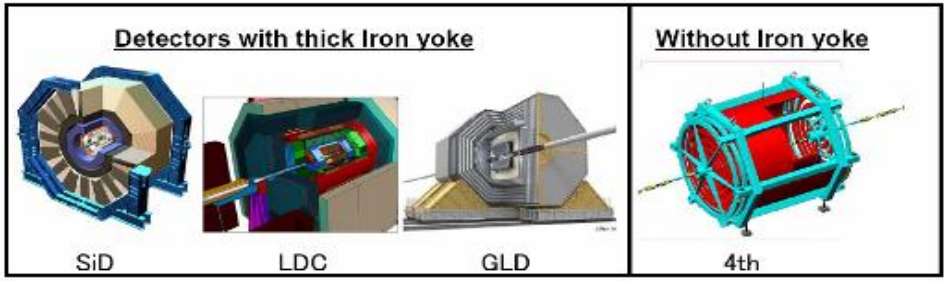
- WG-A, conveners meeting, July 5
- WG-D, conveners meeting, July 11
- WG-A, group meeting, July 12
- WG-B, conveners meeting, July 13
- WG-C, group meeting, July 17
- WG-B, group meeting, July 23
- WG-C, group meeting, July 24
- WG-A, group meeting, July 30
- WG-C, group meeting, July 31
- WG-D, group meeting, August 1
- WG-B, group meeting, August 2
- WG-A, group meeting, August 6
- WG-C, group meeting, August 7
- WG-A, group meeting, August 13
- WG-D, group meeting, August 15
- WG-B, group meeting, August 16
- WG-A, group meeting, August 20
- WG-C, group meeting, August 21
- WG-A, group meeting, August 27
- WG-C, group meeting, August 28
- Conveners and IPAC mtg, August 29
- WG-B, group meeting, August 30
- WG-B, group meeting, September 13

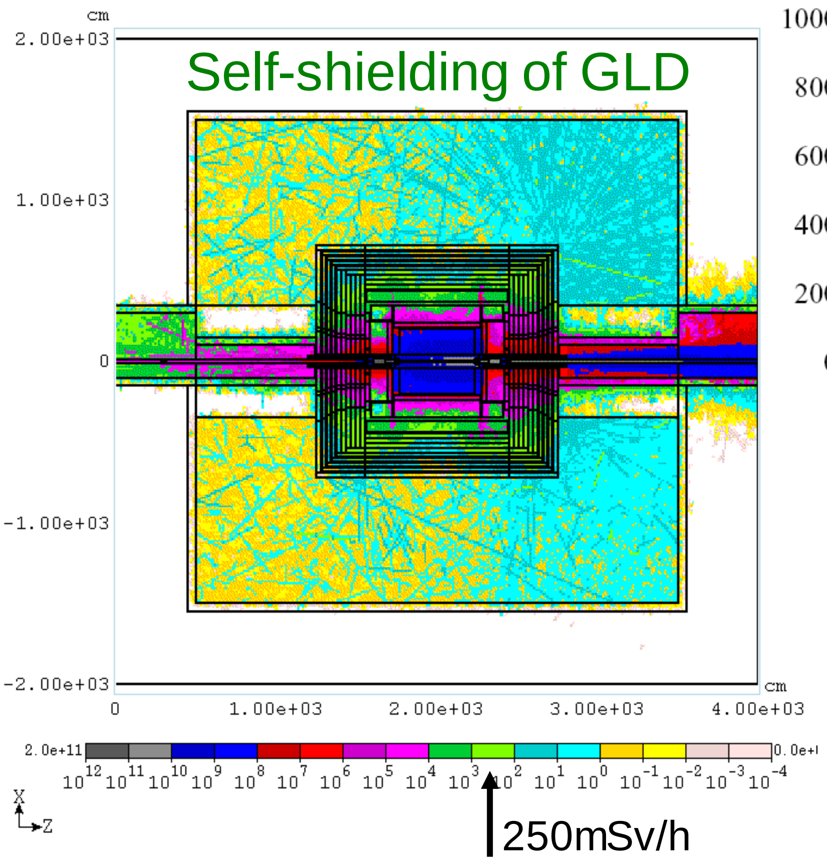
http://www-conf.slac.stanford.edu/ireng07/agenda.htm

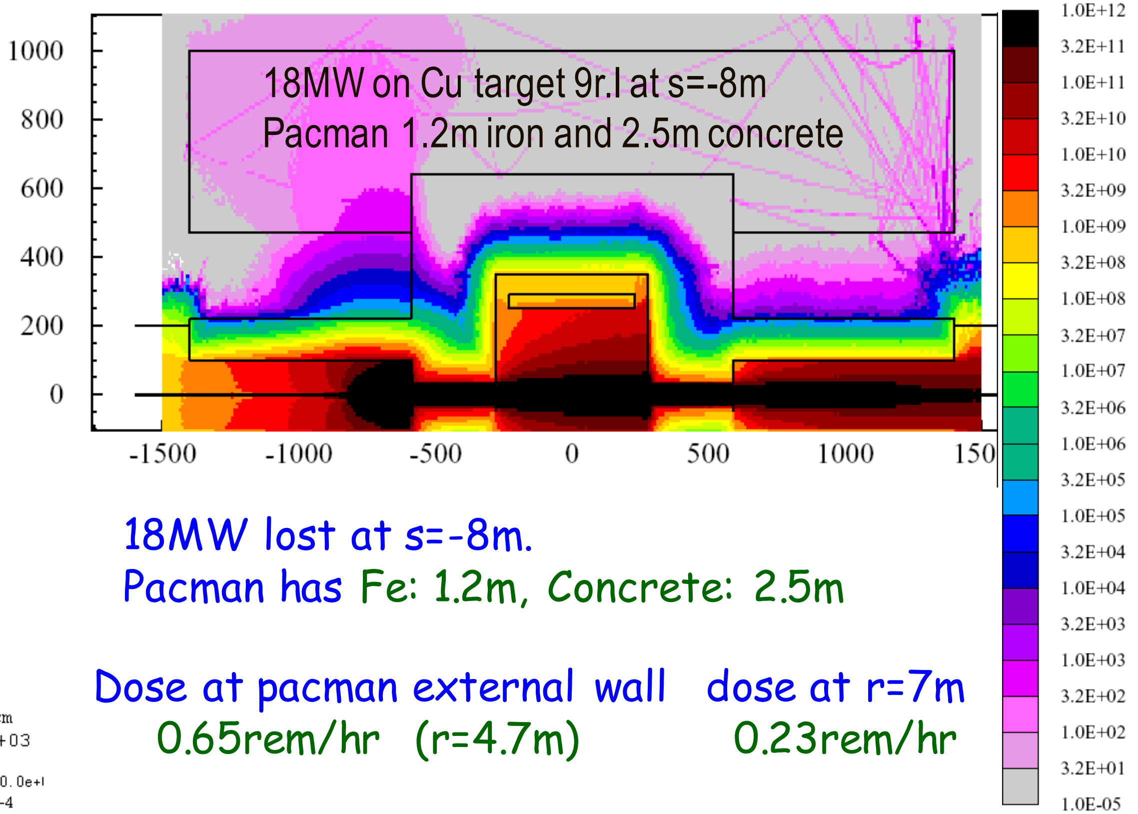
Shielding the IR hall

Detector itself is well shielded except for incoming beamlines.

A proper "pacman" can shield the incoming beamlines and remove the need for shielding wall.





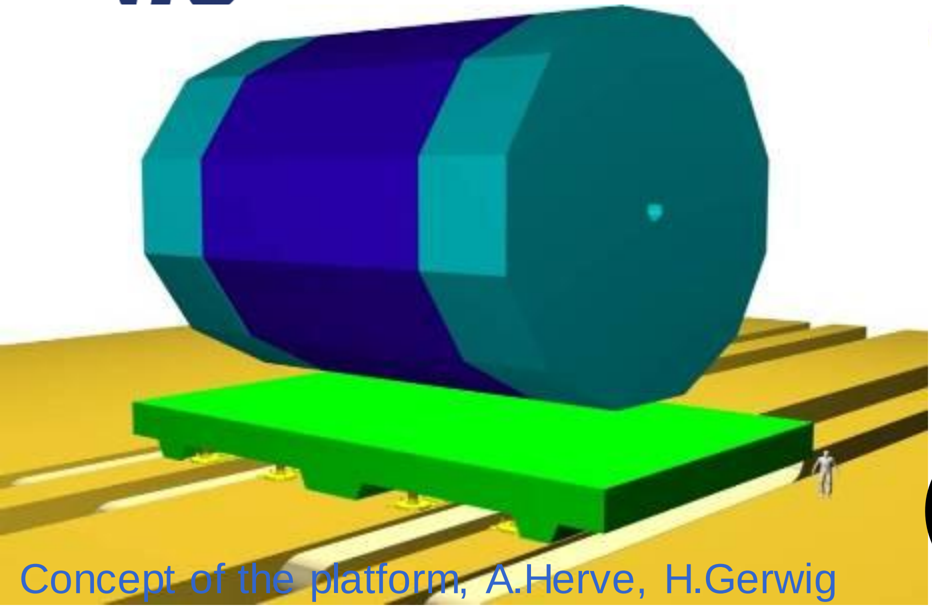


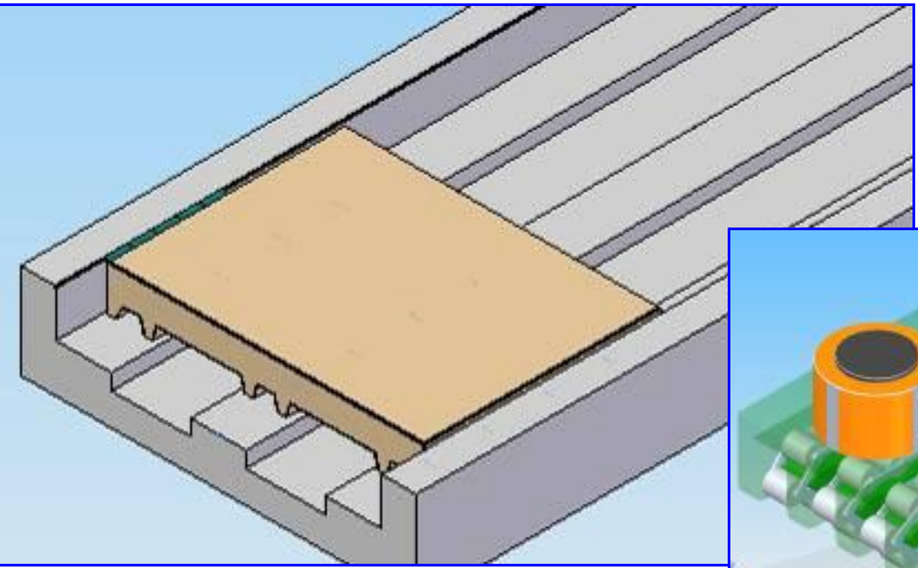
18MW lost at s=-8m.
Pacman has Fe: 1.2m, Concrete: 2.5m

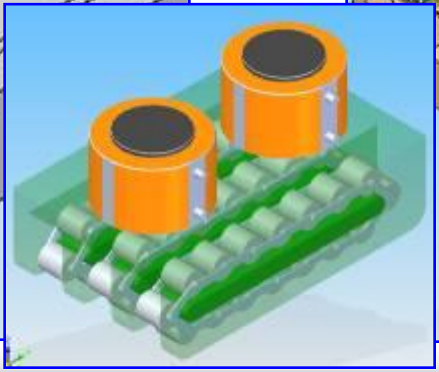
Dose at pacman external wall 0.65rem/hr (r=4.7m)

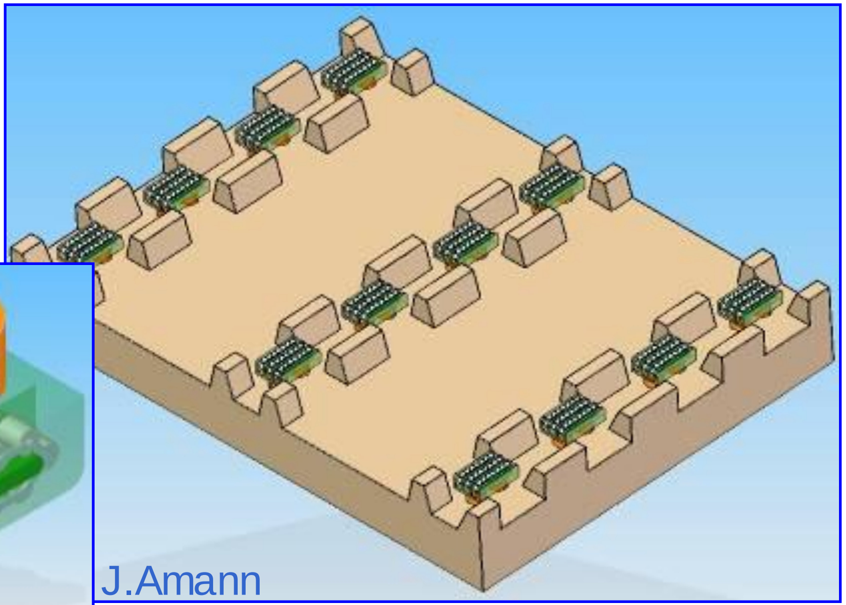
dose at r=7m 0.23rem/hr

Moving the detector



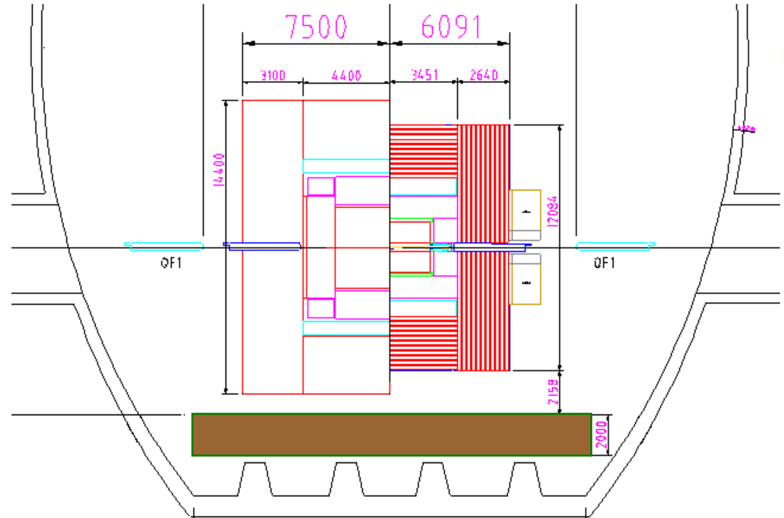


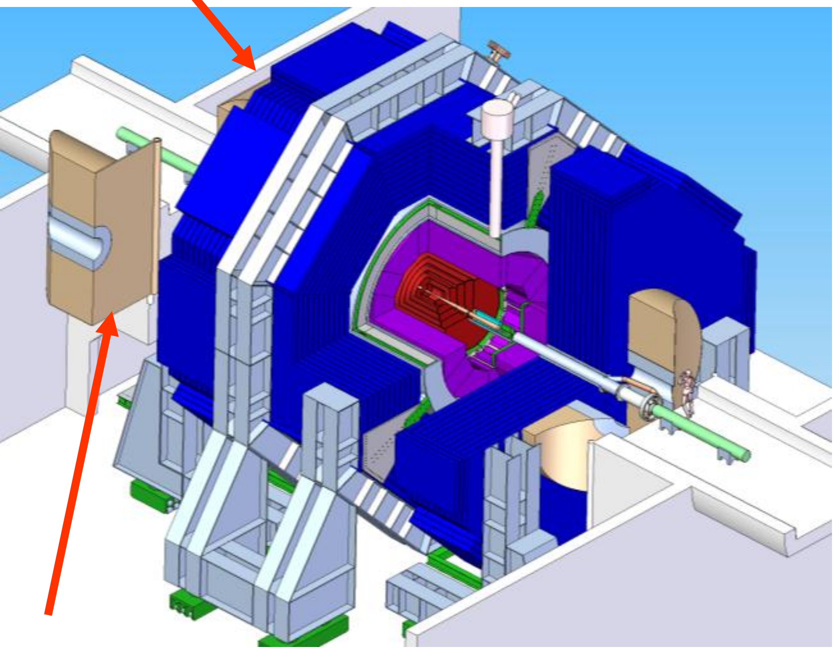




Example of MDI issues we are working on

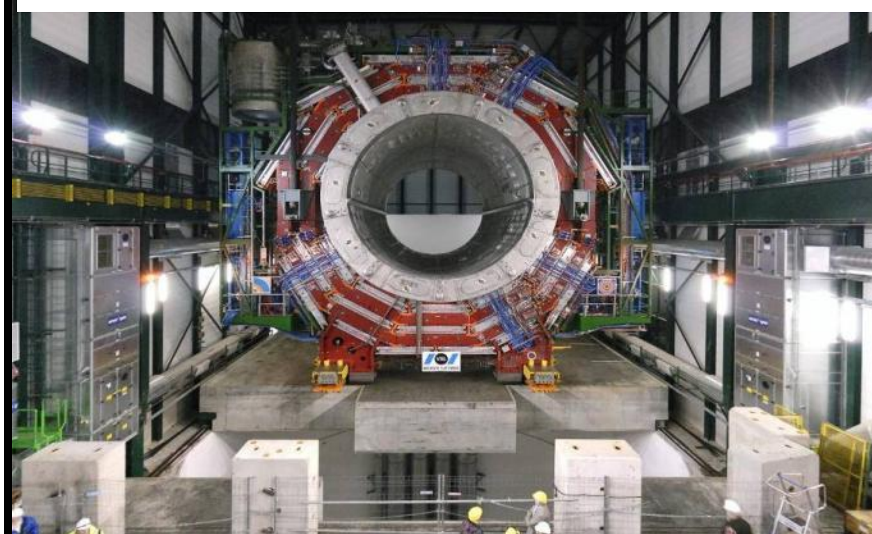
Detector motion system with
or without an intermediate platform



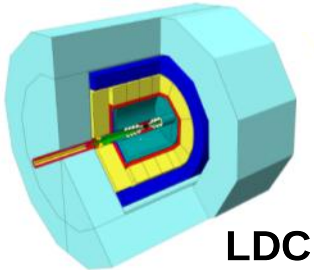


Detector and beamline shielding elements

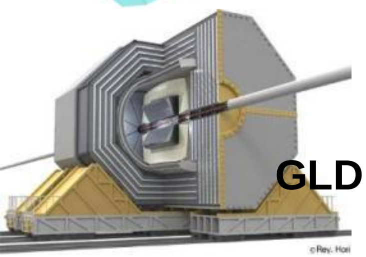
CMS platform – proof of principle for ILC



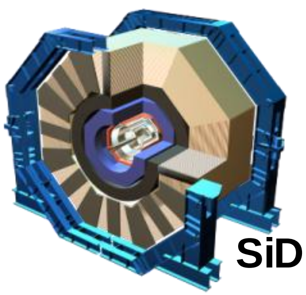
Evolution of ILC Detectors



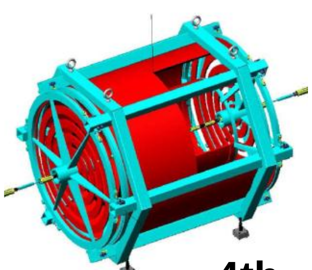
LDC



GLD



SiD



4th

LDC → GLD → Merged to ILD design → ILD

SiD

4th

Thorough evaluation of performance, validation of the concepts

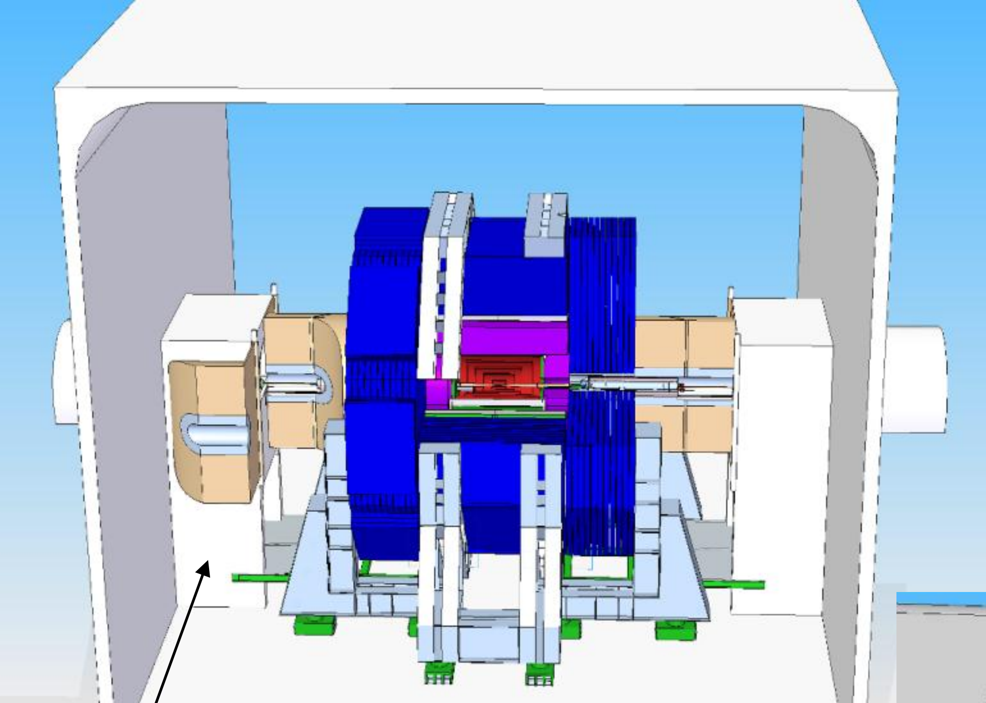
ILD validated

SiD validated

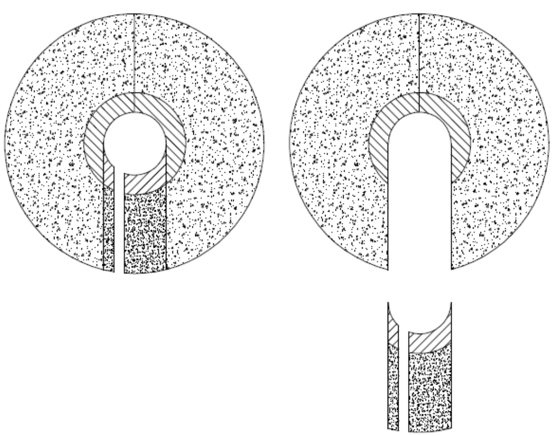
Technical design of detectors and R&D for critical sub-systems

- **Evolution, self-review and selection process are essential for meeting the challenging detector requirements motivated by physics**
  - Triggerless event collection (software event selection)
  - Extremely precise vertexing
  - Vertex, tracker, calorimeters integrated for optimal jet reconstruction

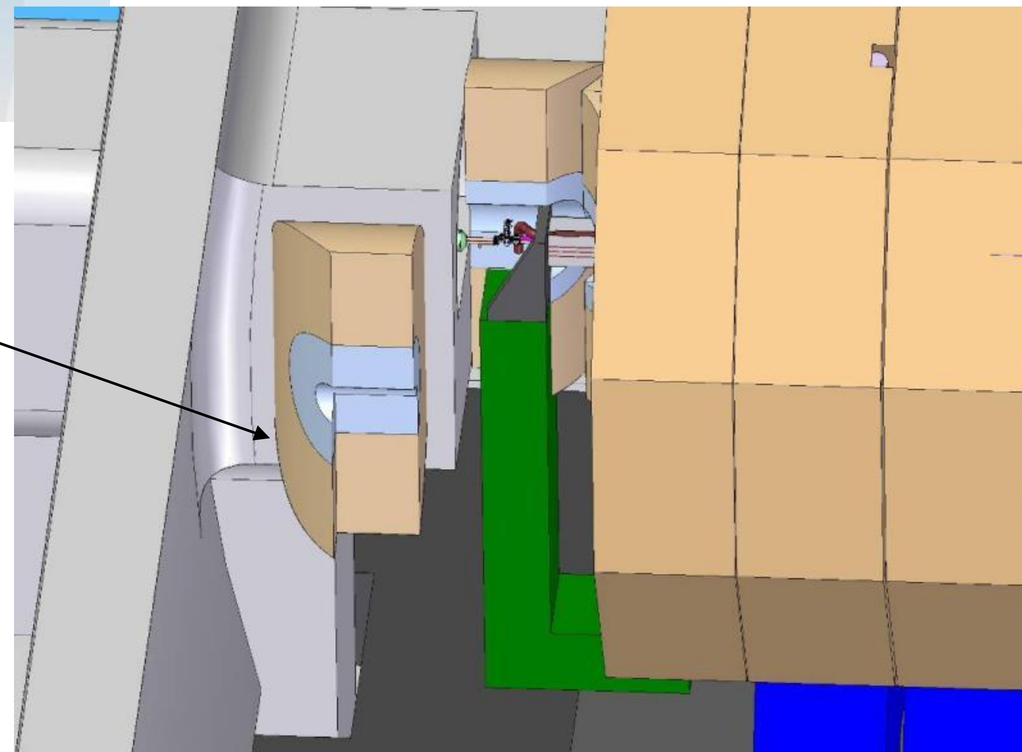
Example of system where initially different designs converged on a single compatible solution:
CMS-Inspired Hinged PacMan
w/ Cut-outs for ILD Pillar and Plugs



SiD ILD

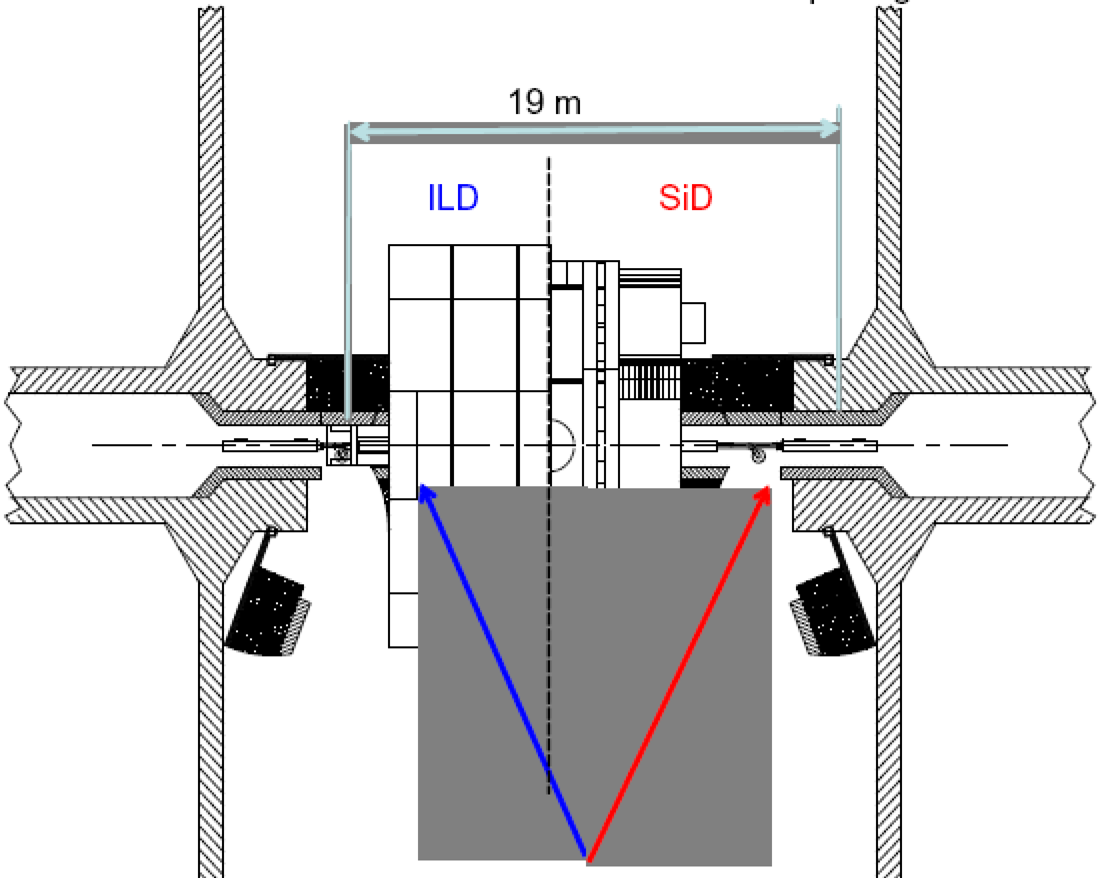


M.Oriunno, H.Yamaoka, A.Herve, et. al



Pacman compatible with SiD

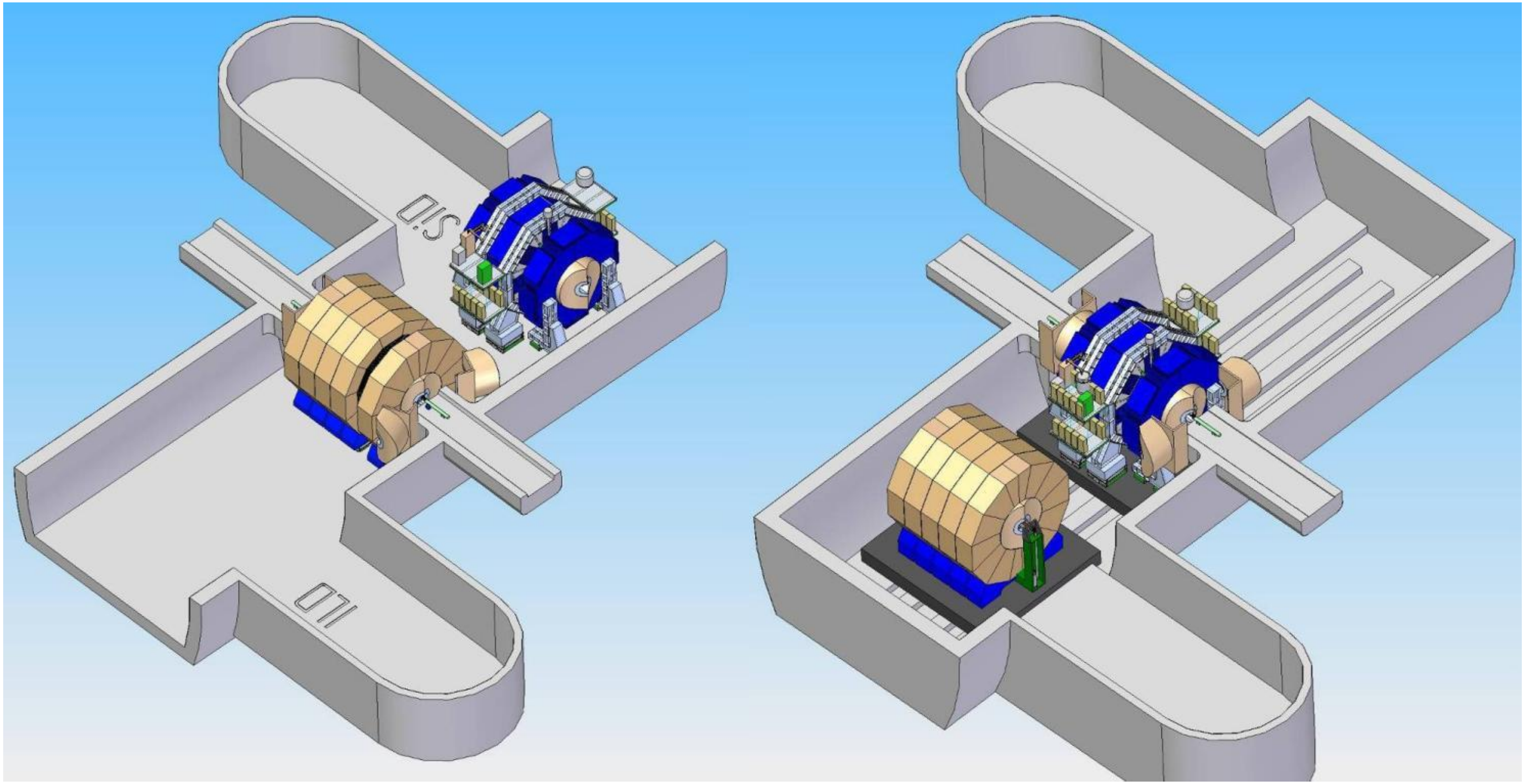
Pacmen closed: Modified to allow ILD opening



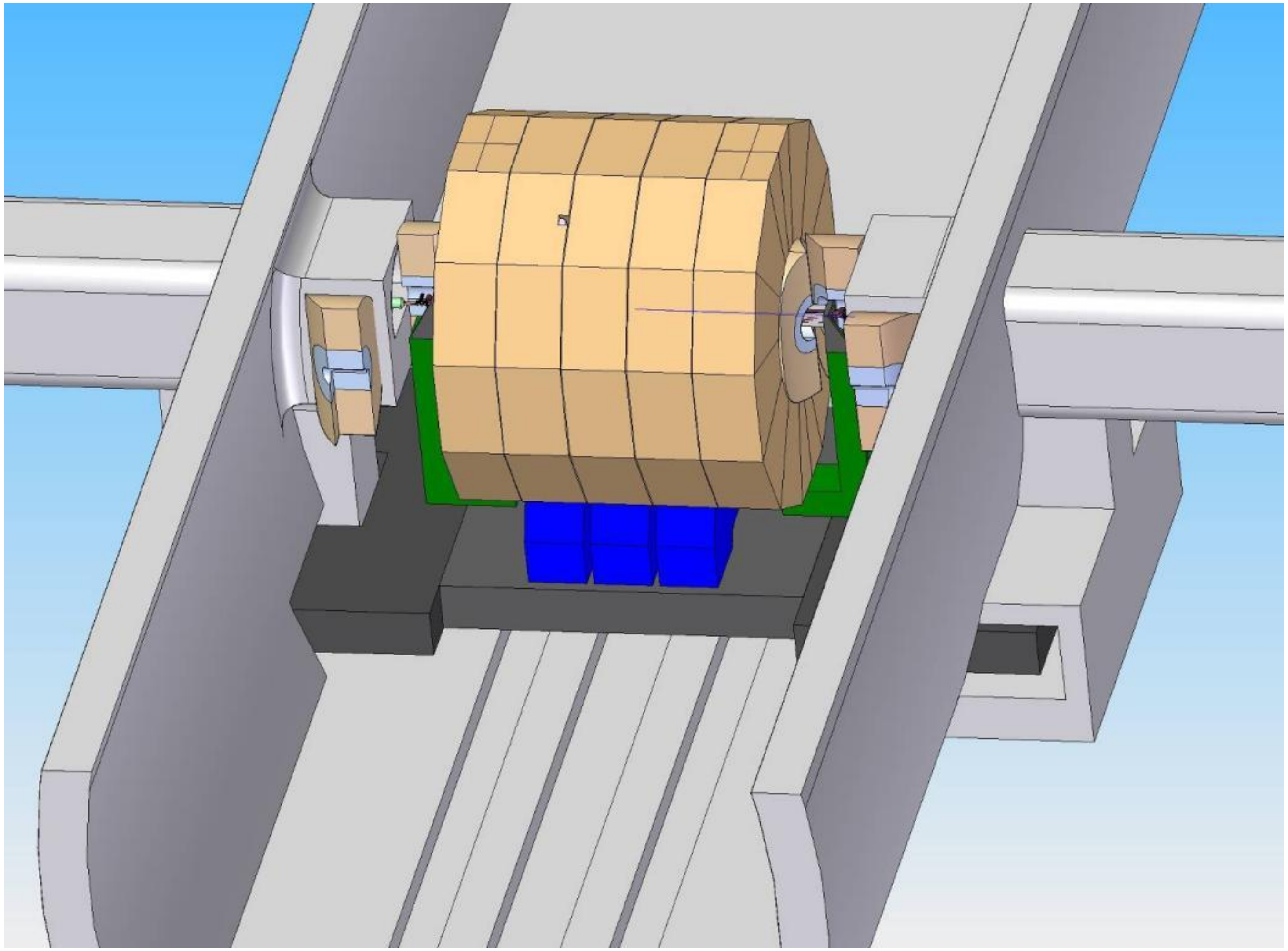
Interface pieces born by each experiment

From A. Hervé, K. Sinram, M. Oriunno

All detectors without / with platform

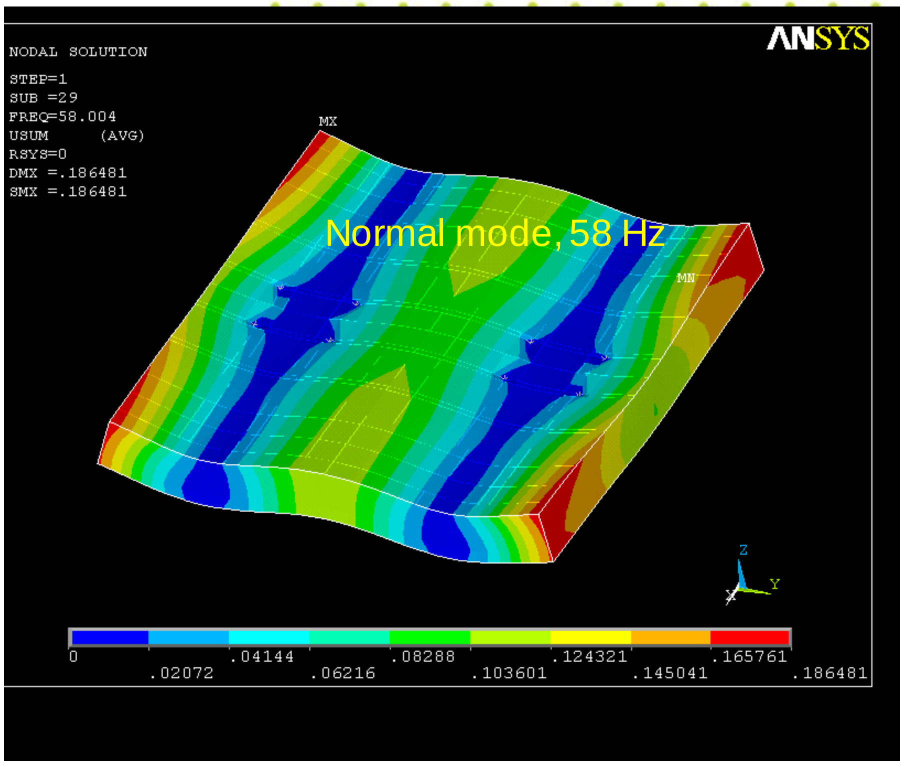


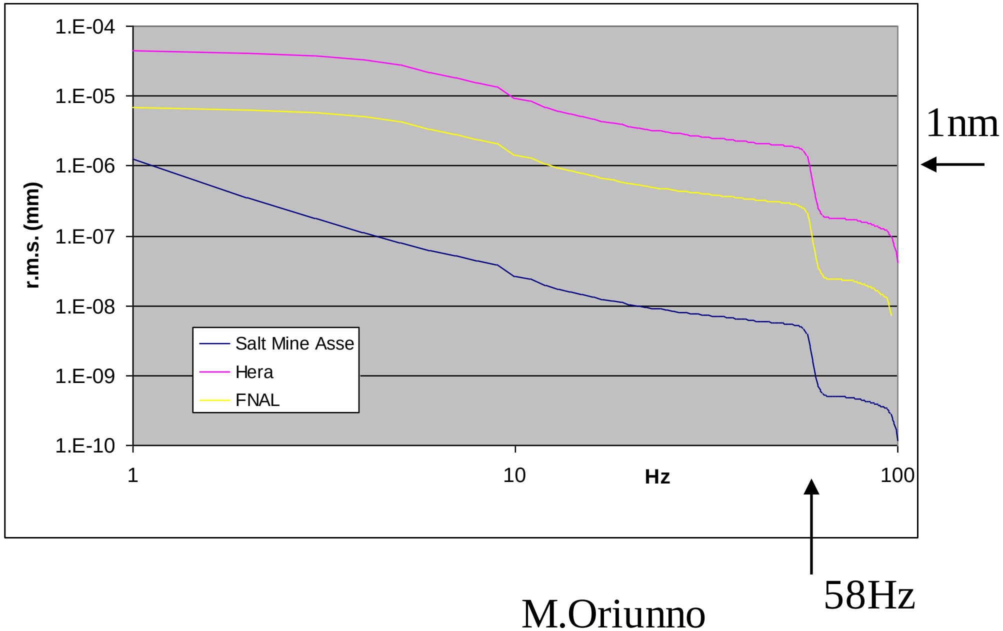
Half Platform w/ Pocket Storage



A.Herve, M.Oriunno, K,Sinram, T.Markiewicz, et al

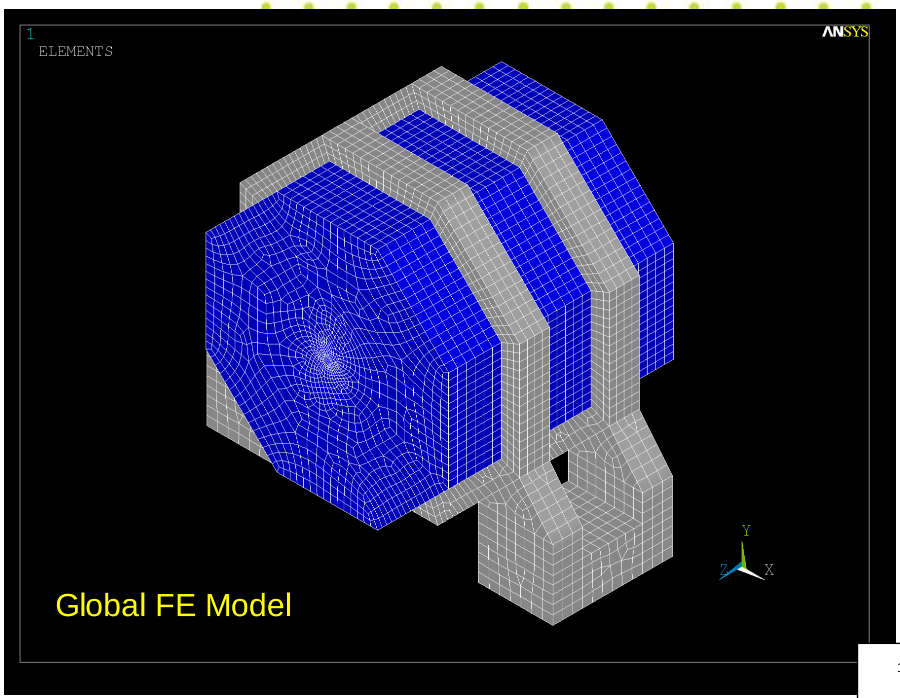
Preliminary
ANSYS analysis of Platform

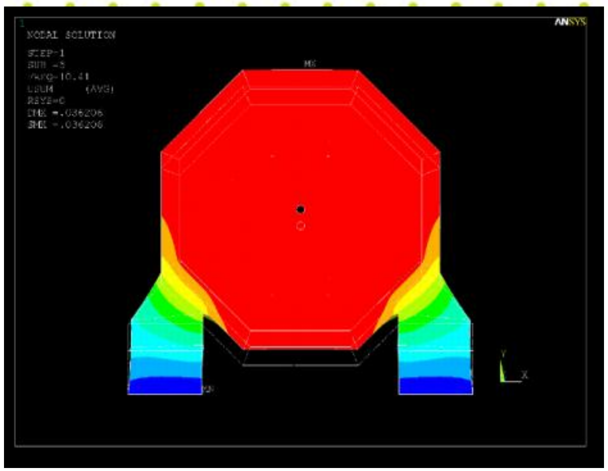




- First look of platform stability look rather promising: resonance frequencies are rather large (e.g. 58Hz) and additional vibration is only several nm

Detector stability analysis (SiD)

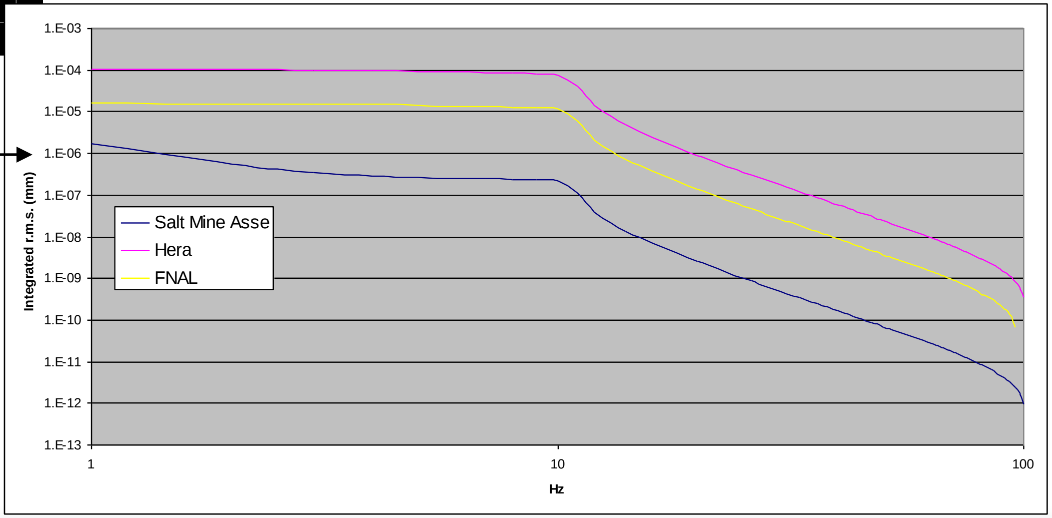




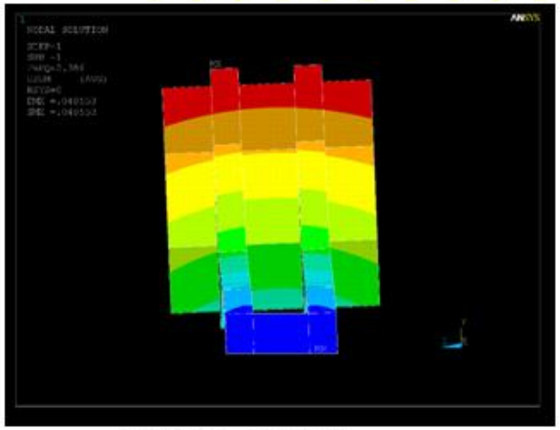
First vertical motion mode, 10.42 Hz

- First analysis shows possibilities for optimization
  - e.g. tolerance to fringe field => detector mass => resonance frequency

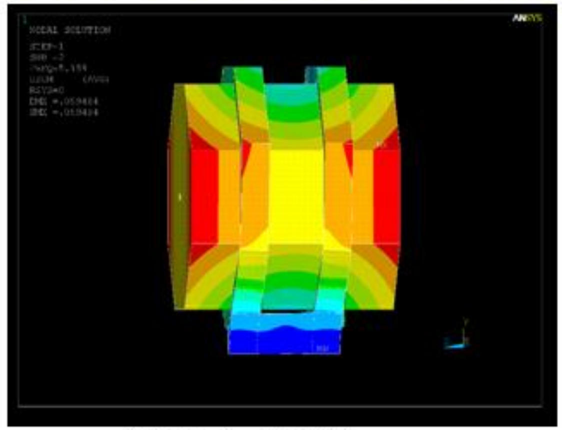
1nm



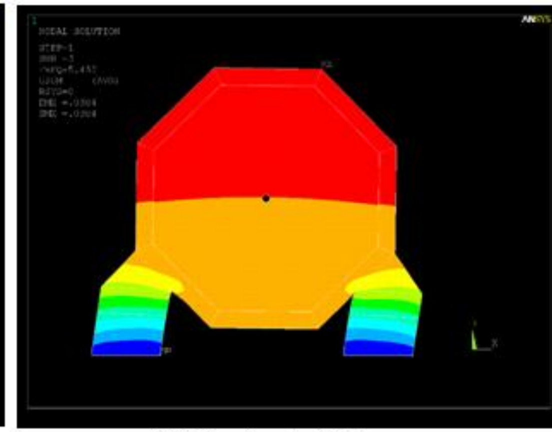
Free vibration modes of SiD



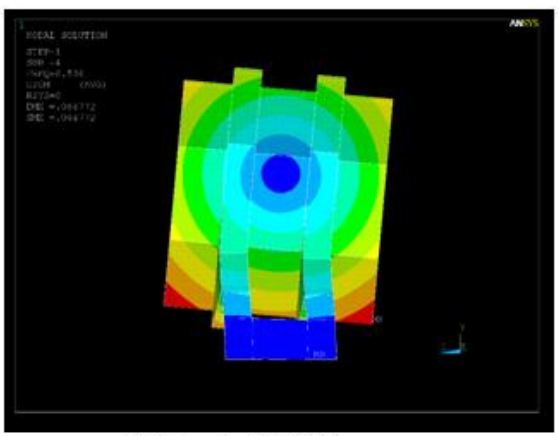
1st Mode, 2.38 Hz



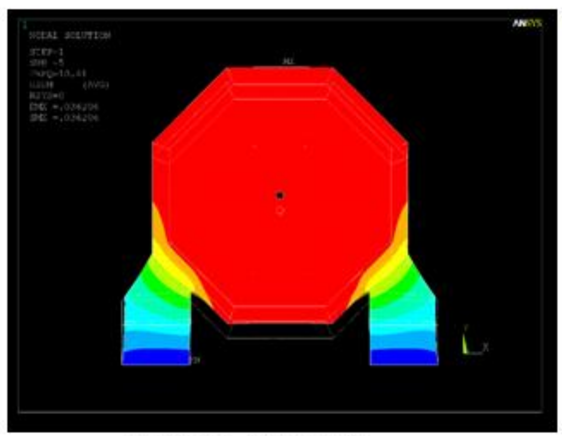
2nd Mode, 5.15 Hz



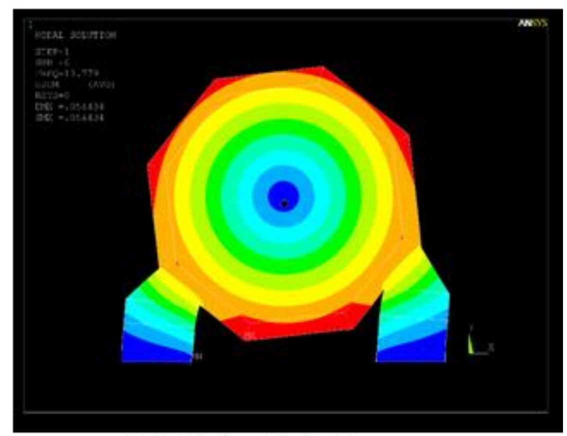
3rd Mode, 5.45 Hz



4th Mode, 6.53 Hz



5th Mode, 10.42 Hz

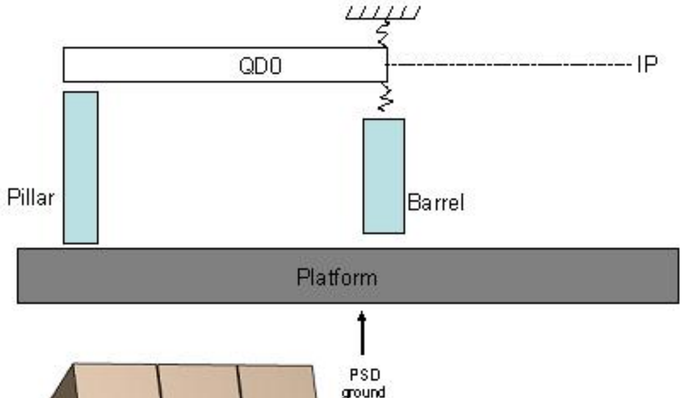


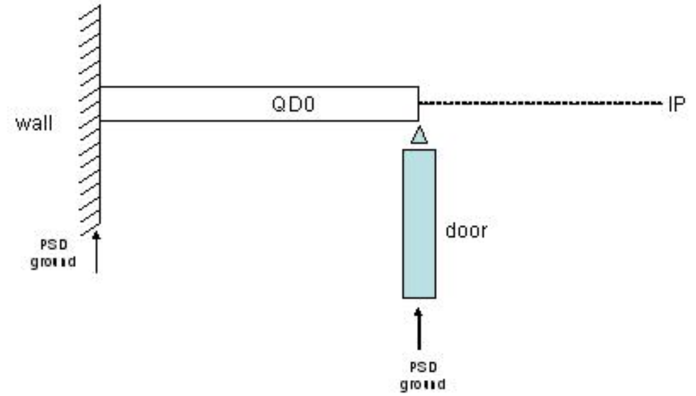
6th Mode, 13.7 Hz

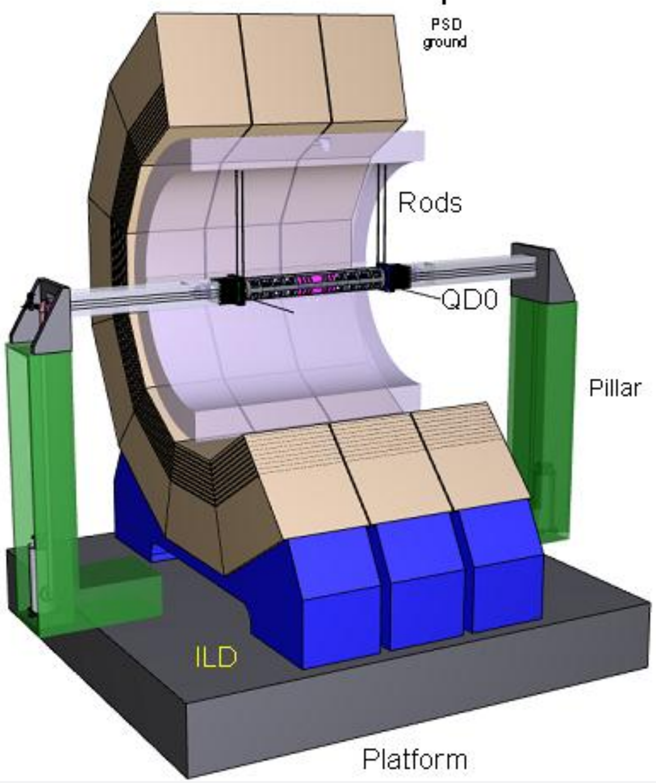
M.Oriunno

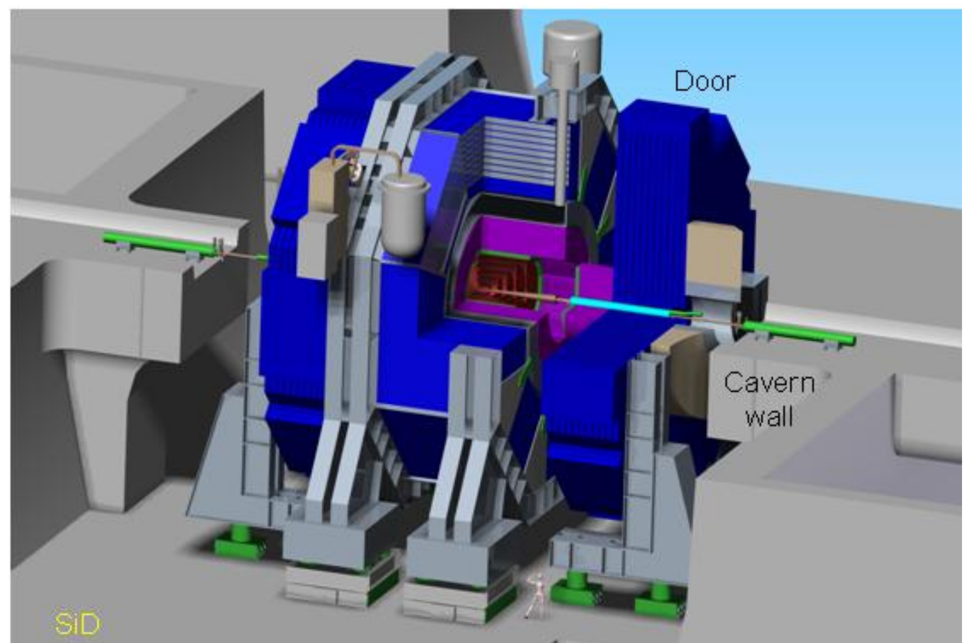
Vertical motion

QD0 supports in ILD and SiD

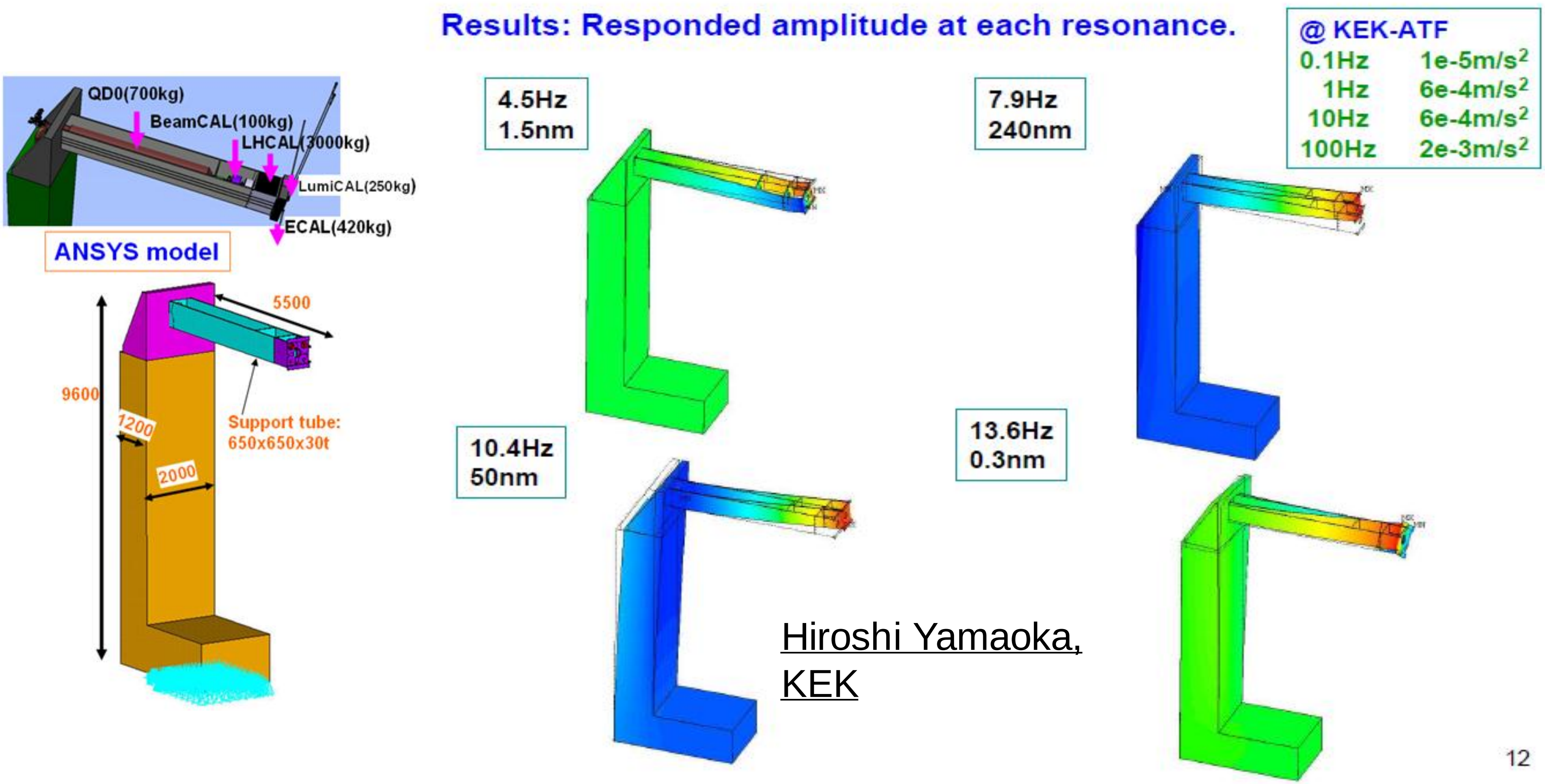








ILD FD stability analysis results

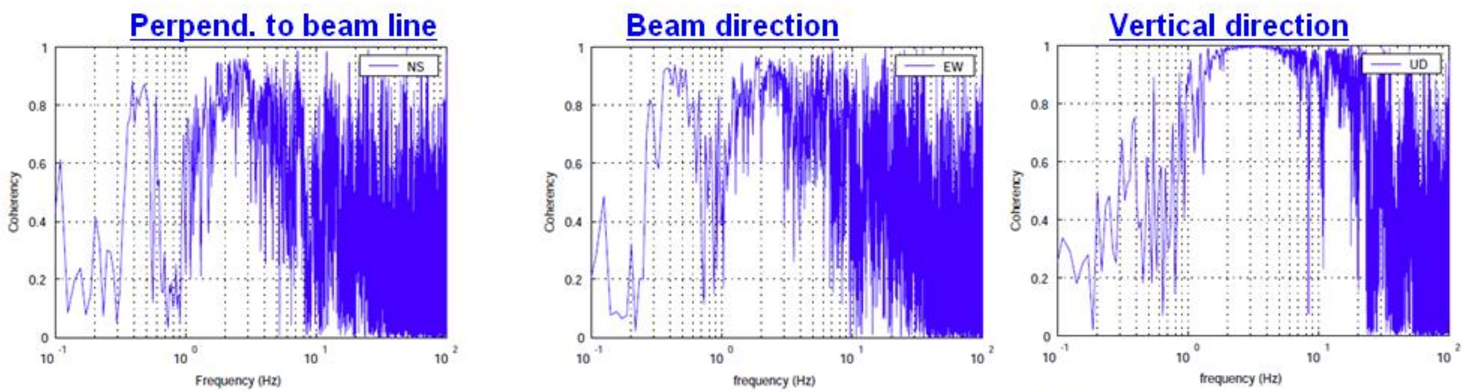


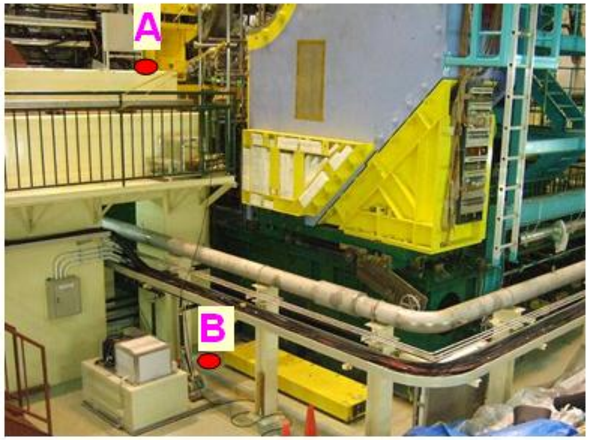
Hiroshi Yamaoka, KEK

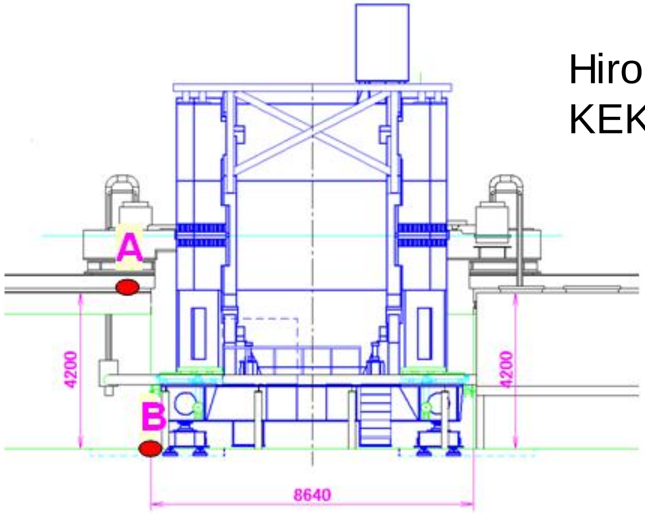
Stability studies at BELLE

Measurement: B

How is the coherency between the tunnel and floor?







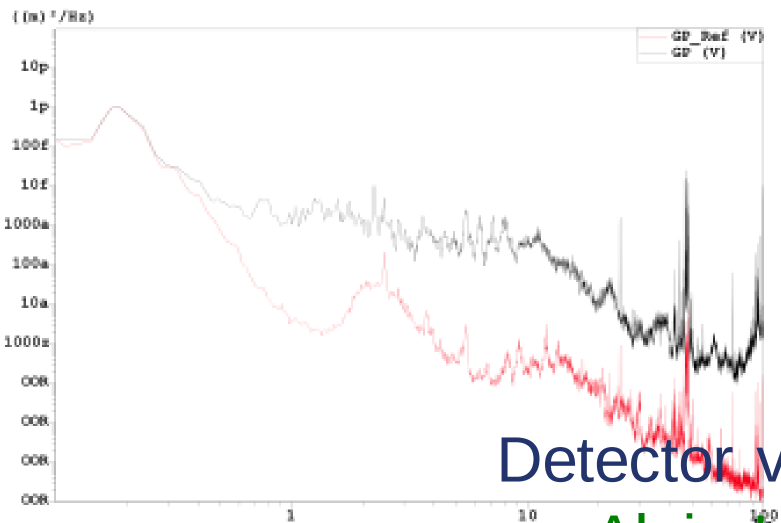
Hiroshi Yamaoka, KEK

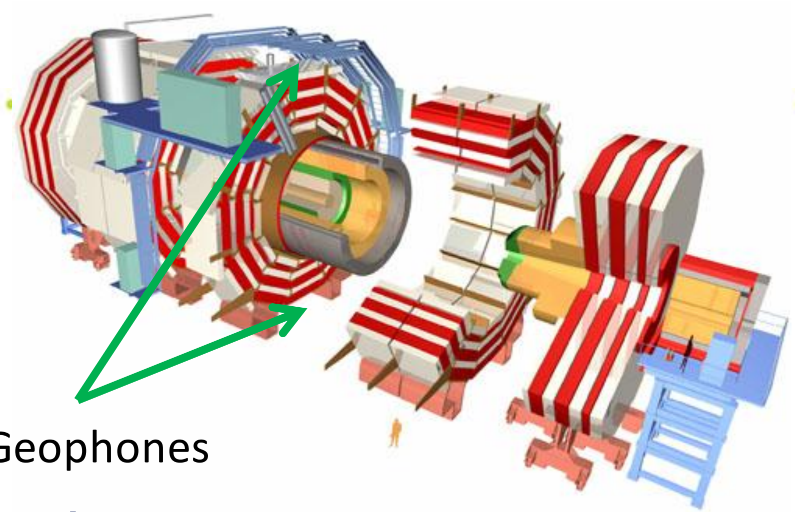
- Horizontal dir.: 0.~Hz, ~3Hz
- Vertical dir.: 1 ~ 20Hz

16

CMS top of Yoke measurement

PSD of the signals Vertical direction



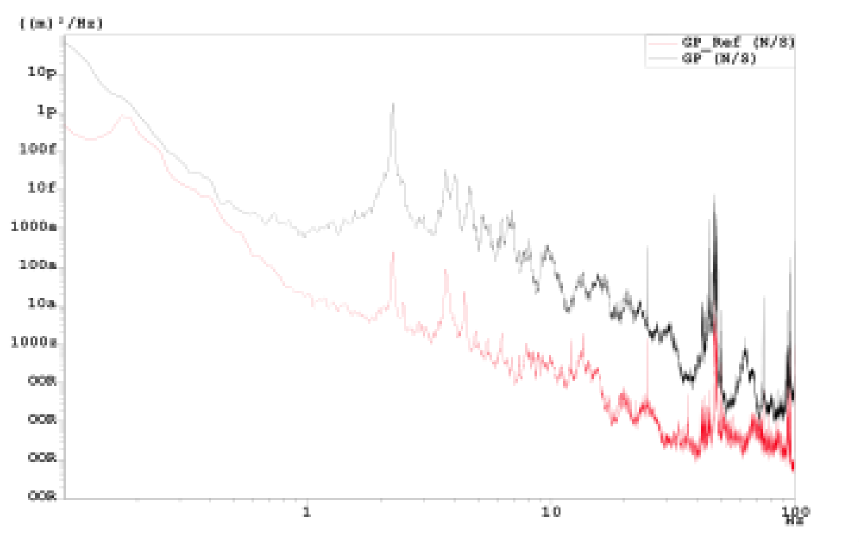


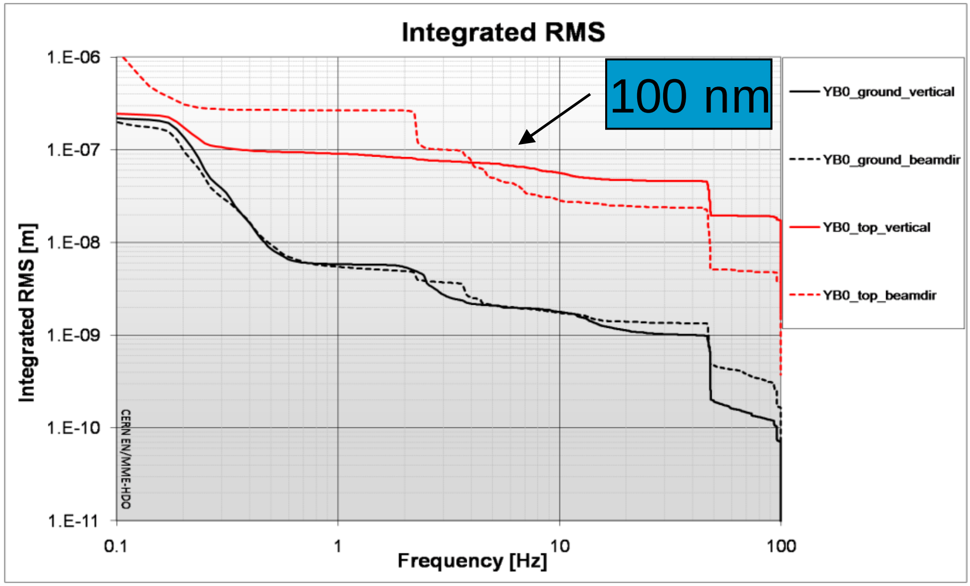
Detector vibrations and QD0 support

Alain Herve (ETH Zurich)

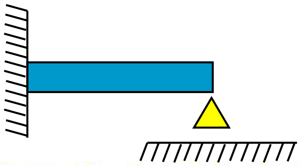
Cooling system OFF

PSD of the signals Beam direction

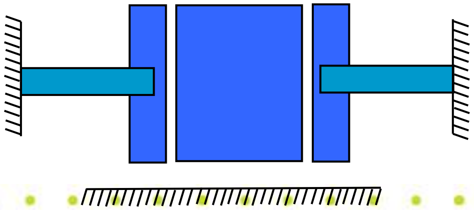


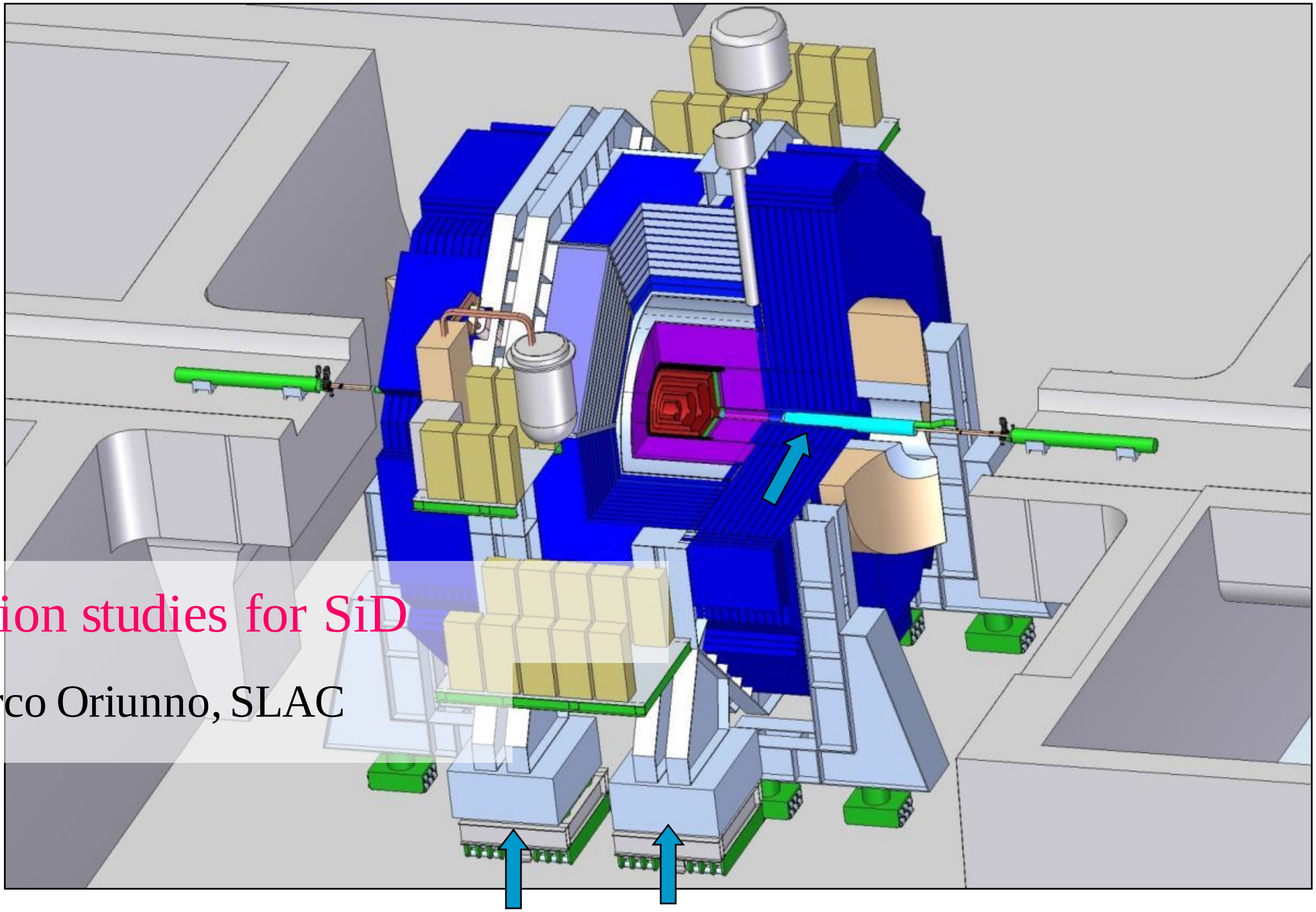


From this….

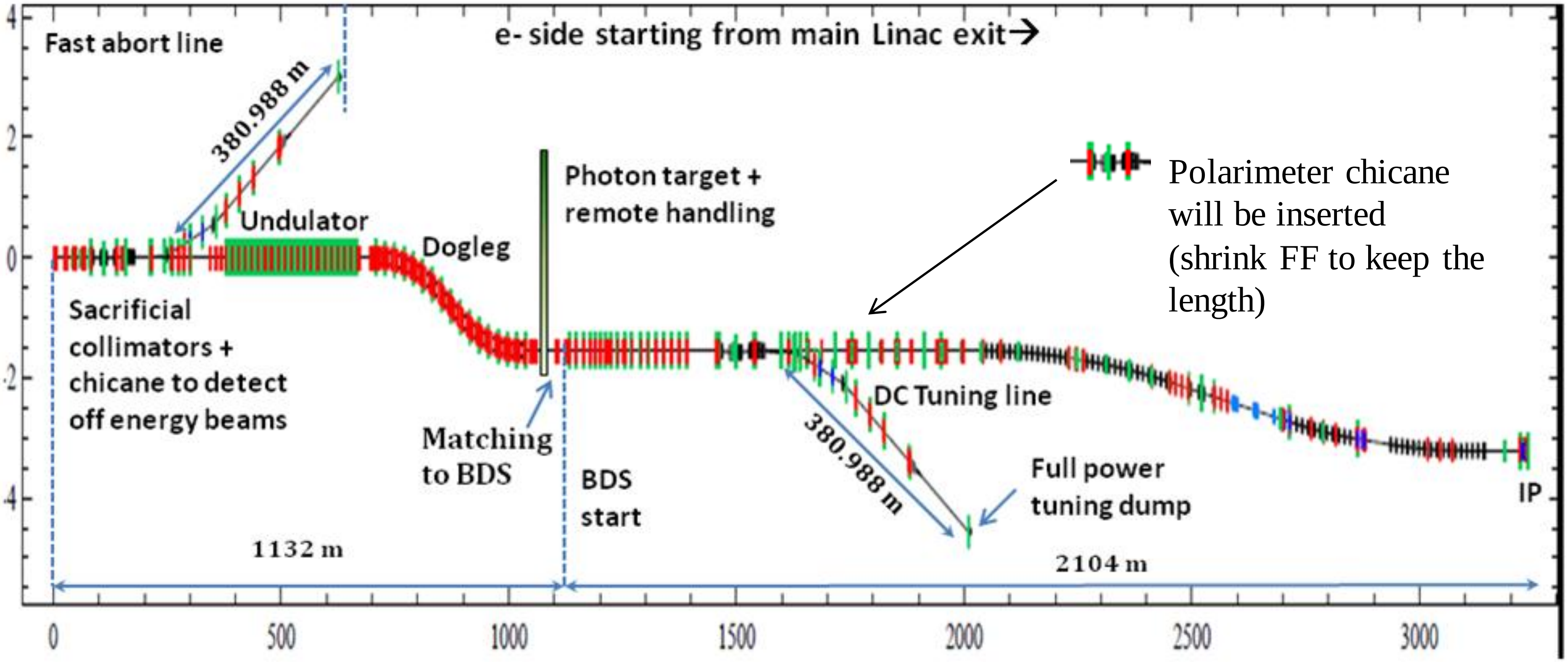


…….to this





Ground motion through the feet



- The central integration includes the sources in the same tunnel as the BDS. Relocation of the positron production system to the downstream end of the electron linac means placing it just before the beginning of the electron BDS. These changes need suitable design modifications to the layout of this area. Figure above shows the proposed new layout of the electron BDS

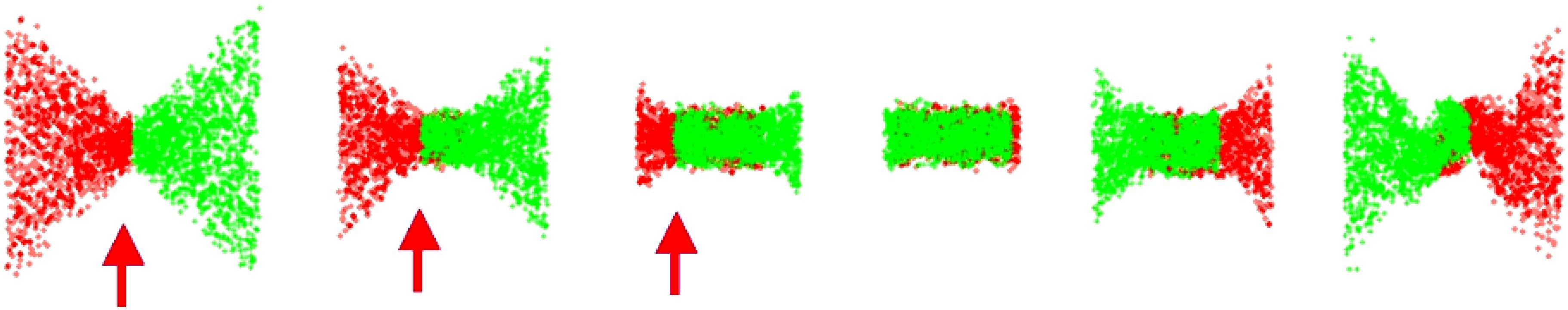
ILC Nominal and Low Power RDR

	Nom. RDR	Low P RDR
Case ID	**1**	**2**
E CM (GeV)	500	500
N	2.0E+10	2.0E+10
n_b	2625	1320
F (Hz)	5	5
P_b (MW)	**10.5**	**5.3**
$\gamma\varepsilon_X$ (m)	1.0E-05	1.0E-05
$\gamma\varepsilon_Y$ (m)	4.0E-08	3.6E-08
βx (m)	2.0E-02	1.1E-02
βy (m)	4.0E-04	2.0E-04

Z-distribution *	Gauss	Gauss
σ_x (m)	6.39E-07	4.74E-07
σ_y (m)	5.7E-09	3.8E-09
σ_z (m)	3.0E-04	2.0E-04
Guinea-Pig $\delta E/E$	**0.023**	**0.045**
Guinea-Pig L ($cm^{-2}s^{-1}$)	**2.02E+34**	**1.86E+34**
Guinea-Pig Lumi in 1%	1.50E+34	1.09E+34

* The RDR "low power" option has large "beamstrahlung energy spread" (beam-beam phenomena) and cause larger background in detectors

Beam-beam: Travelling focus



- Suggested by V.Balakin in ~1991 – idea is to use beam-beam forces for additional focusing of the beam – allows some gain of luminosity or overcome somewhat the hour-glass effect
- Figure shows simulation of traveling focus. The arrows show the position of the focus point during collision
- So far not yet used experimentally

New Low P parameter set

	Nom. RDR	Low P RDR	new Low P
Case ID	**1**	**2**	**3**
E CM (GeV)	500	500	500
N	2.0E+10	2.0E+10	2.0E+10
n_b	2625	1320	1320
F (Hz)	5	5	5
P_b (MW)	**10.5**	**5.3**	**5.3**
$\gamma\varepsilon_X$ (m)	1.0E-05	1.0E-05	1.0E-05
$\gamma\varepsilon_Y$ (m)	4.0E-08	3.6E-08	3.6E-08
βx (m)	2.0E-02	1.1E-02	1.1E-02
βy (m)	4.0E-04	2.0E-04	2.0E-04
Travelling focus	No	No	**Yes**
Z-distribution *	Gauss	Gauss	Gauss
σ_x (m)	6.39E-07	4.74E-07	4.74E-07
σ_y (m)	5.7E-09	3.8E-09	3.8E-09
σ_z (m)	3.0E-04	2.0E-04	**3.0E-04**
Guinea-Pig δE/E	**0.023**	**0.045**	**0.036**
Guinea-Pig L ($cm^{-2}s^{-1}$)	**2.02E+34**	**1.86E+34**	**1.92E+34**
Guinea-Pig Lumi in 1%	1.50E+34	1.09E+34	1.18E+34

*for flat z distribution the full bunch length is σ_z*2*$3^{1/2}$

Travelling focus allows to lengthen the bunch

Thus, beamstrahlung energy spread is reduced

Focusing during collision is aided by focusing of the opposite bunch

Focal point during collision moves to coincide with the head of the opposite bunch

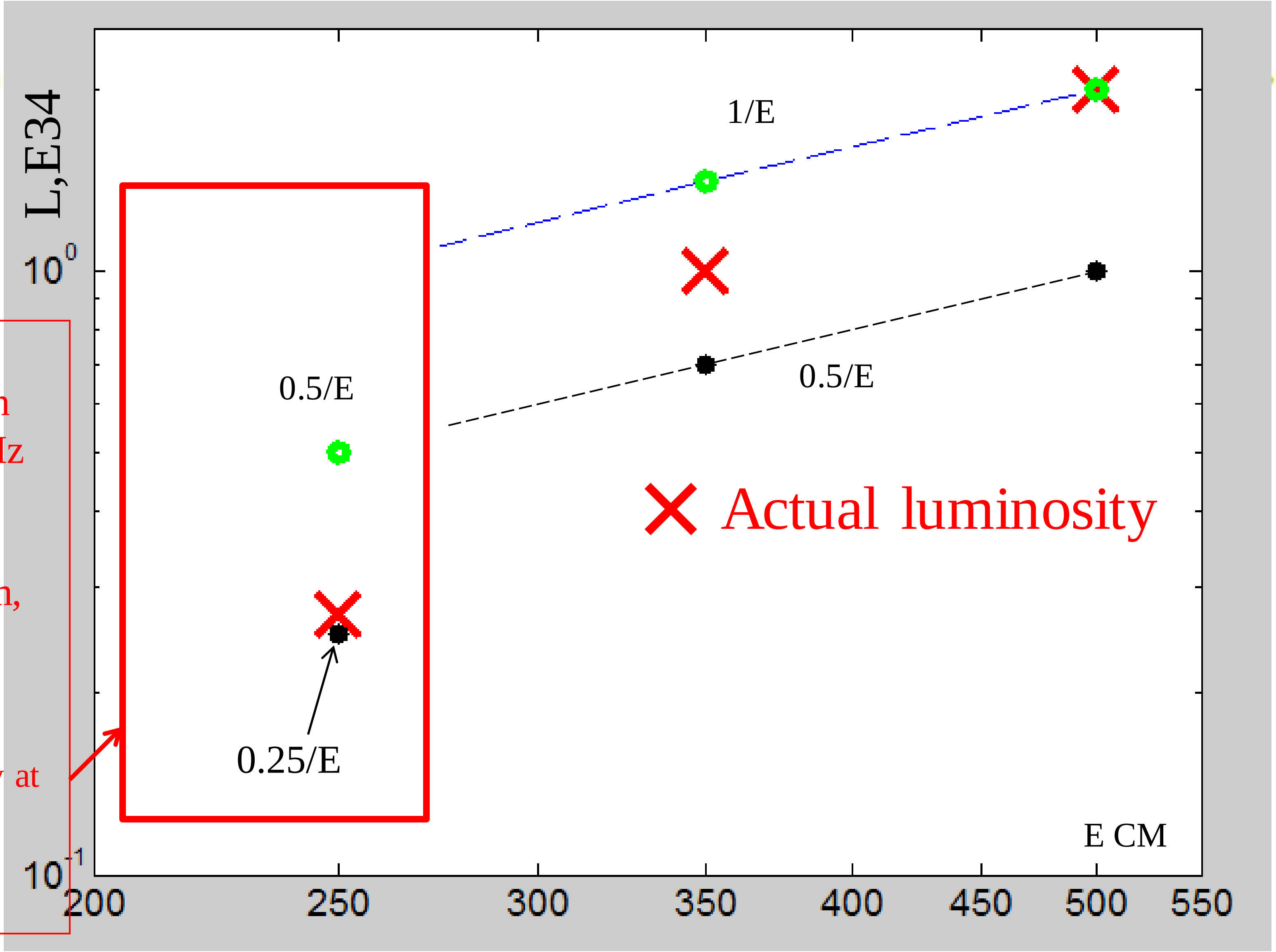
Beam Parameters

	RDR			SB2009 w/o TF				SB2009 w TF			
CM Energy (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Ne- (*10^{10})	2.05	2.05	2.05	2	2	2	2.05	2	2	2	2.05
Ne+ (*10^{10})	2.05	2.05	2.05	1	2	2	2.05	1	2	2	2.05
nb	2625	2625	2625	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	370	370	370	740	740	740	740	740	740	740	740
F (Hz)	5	5	5	5	2.5	5	5	5	2.5	5	5
γex (*10^{-6})	10	10	10	10	10	10	10	10	10	10	10
γey (*10^{-6})	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
βx	22	22	20	21	21	15	11	21	21	15	11
βy	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σx eff (*10^{-9} m)	948	802	639	927	927	662	474	927	927	662	474
σy eff (*10^{-9} m)	10	8.1	5.7	9.5	9.5	7.4	5.8	6.4	6.4	5.0	3.8
L (10^{34} cm^{-2}s^{-1})	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0

Rate at IP = 2.5Hz,
Rate in the linac = 5Hz (every other pulse is at 150GeV/beam, for e+ production)

Low luminosity at this energy reduces the physics reach

SB2009 Lumi



Rate at IP = 2.5Hz, Rate in the linac = 5Hz (every other pulse is at 150GeV/beam, for e+ production)

Low luminosity at this energy reduces the physics reach

Work on mitigations of L(E) with SB2009 during and after ILC2010

- Discussion of double rep rate was initiated ~month before the ILC2010

  this allowed achieving significant progress at LCWS10

- Doubling the rep rate (below ~125GeV/beam)
  - **BDS WG discussed implications with other Working Groups:**
    - DR => ~OK (new conceptual DR design; duty factor issue)
    - Sources => OK
    - Linac, HLRF, Cryogenics => OK
- FD optimized for ~250GeV CM
  - **Shorter FD reduce beam size in FD and increase collimation depth, reducing collimation related beam degradation**
  - **Will consider exchanging FD for low E operation or a more universal FD that can be retuned**

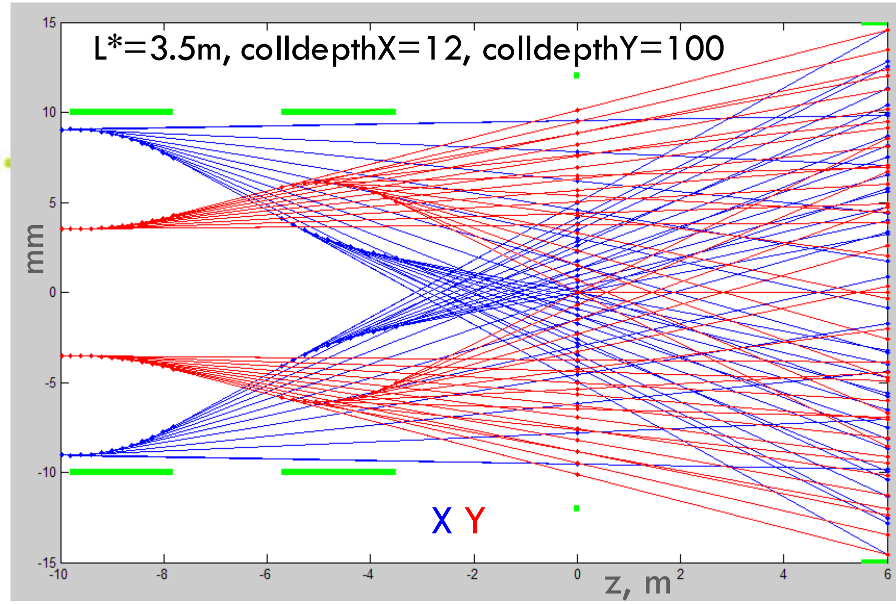
Lumi(E) dependence in SB2009

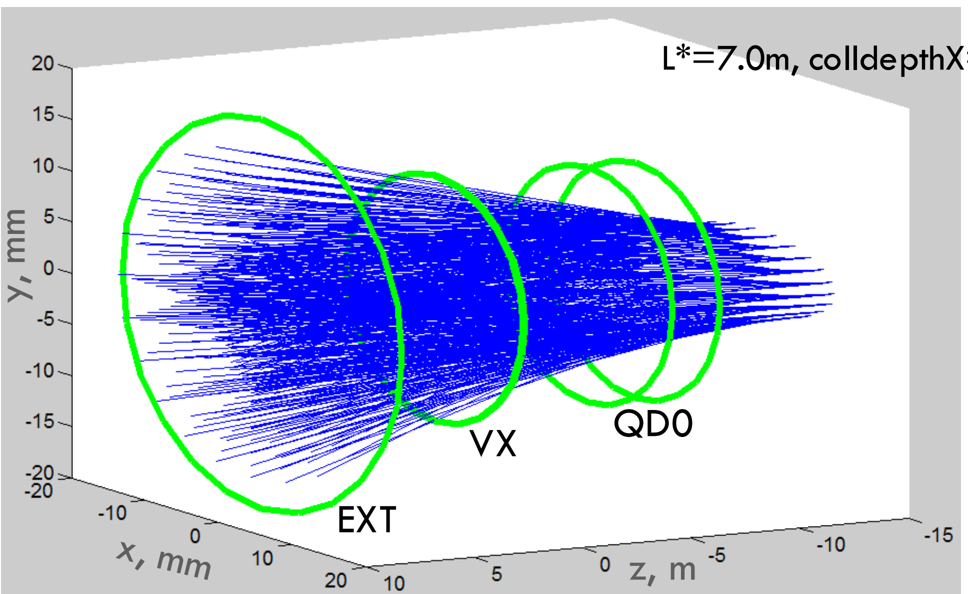
- Factor determine shape of L(E) in SB2009
  - Lower rep (/2) rate below ~125GeV/beam
  - Collimation effects: increased beam degradation at lower E due to collimation wakes and due to limit (in X) on collimation depth

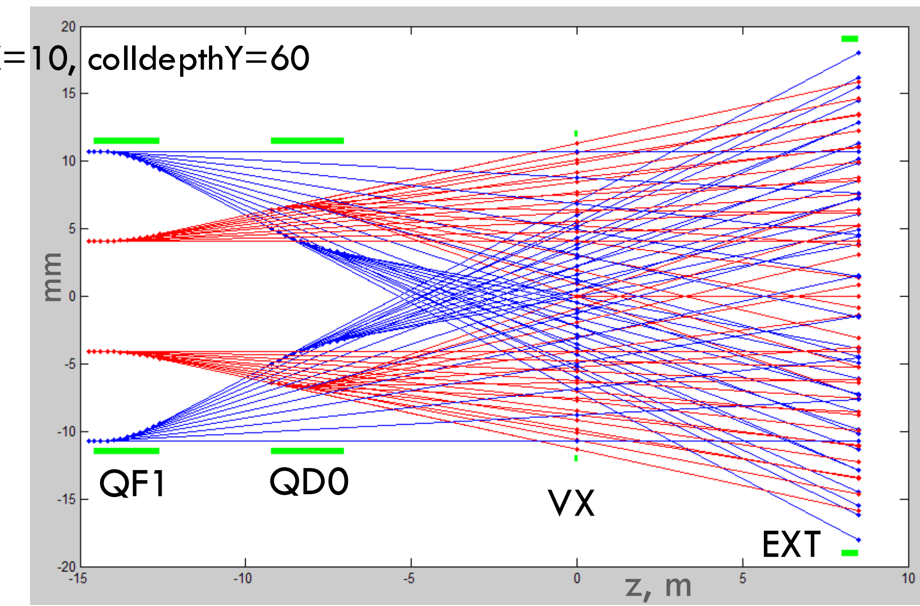
- Understanding the above limitations, one can suggest mitigation solutions:
  - 1) Consider doubling the rep rate at lower energy
  - 2) Consider Final Doublet optimized for 250GeV CM

FD & collimation

- Reduced Collimation depth at lower E is responsible for large fraction of reduction of luminosity (w.r.to 1/E ideal curve)
- Shorter, matched to lower E, final doublet, will give some reduction of beam size at FD, thus increase the collimation depth





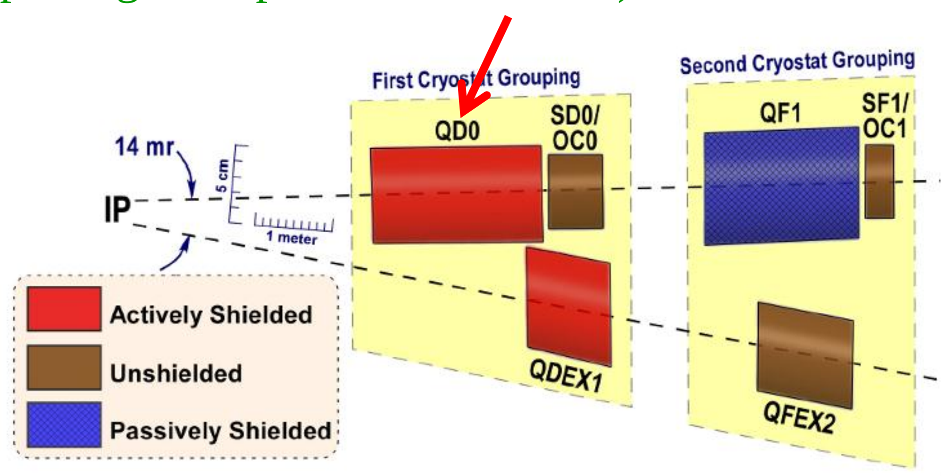


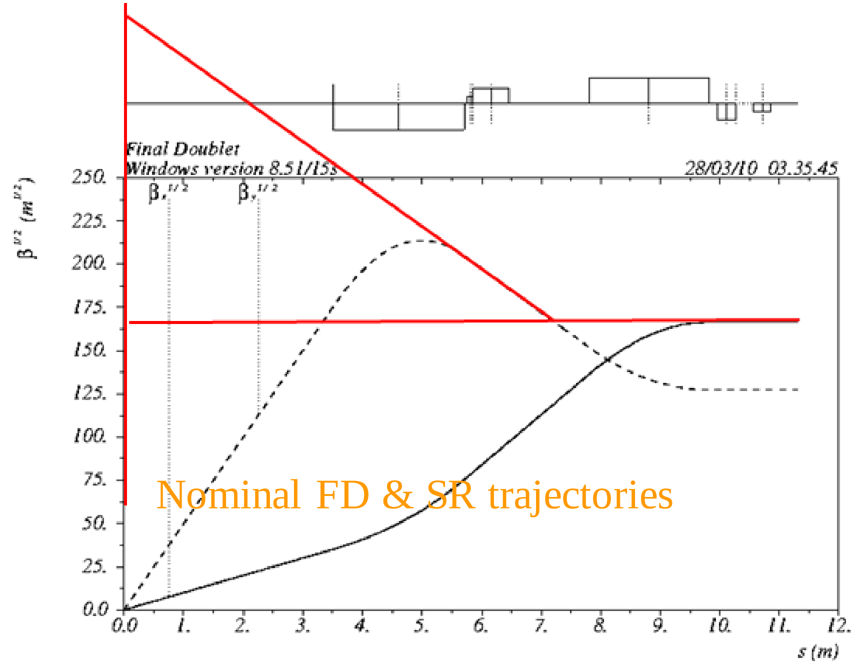
Rays show trajectories of possible SR photons. Amount of rays is not quantitative.

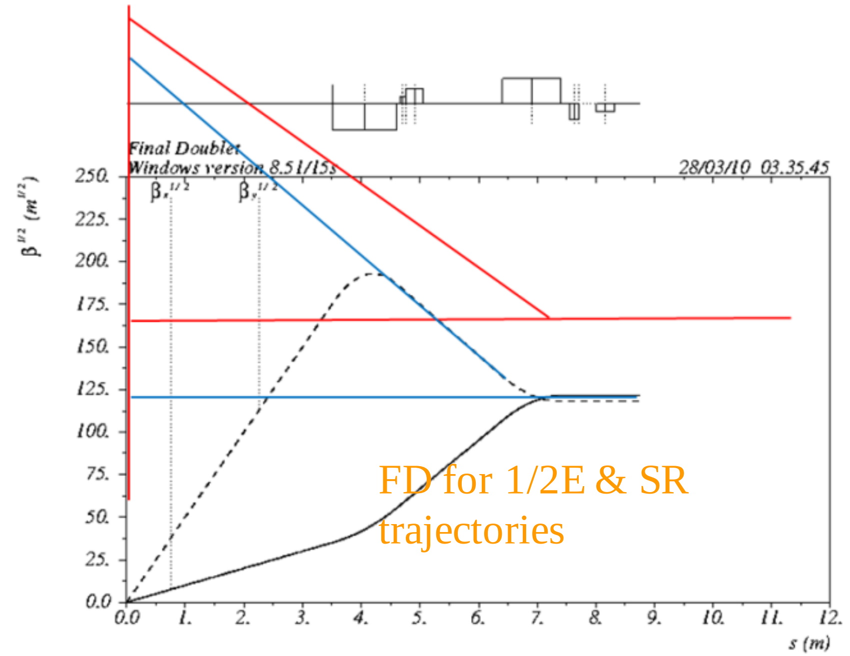
FD for low E

FD optimized for lower energy will allow increasing the collimation depth by ~10% in Y and by ~30% in X (Very tentative!)

- One option would be to have a separate FD optimized for lower E, and then exchange it before going to nominal E
- Other option to be studied is to build a universal FD, that can be reconfigured for lower E configuration (may require splitting QD0 coil and placing sextupoles in the middle)





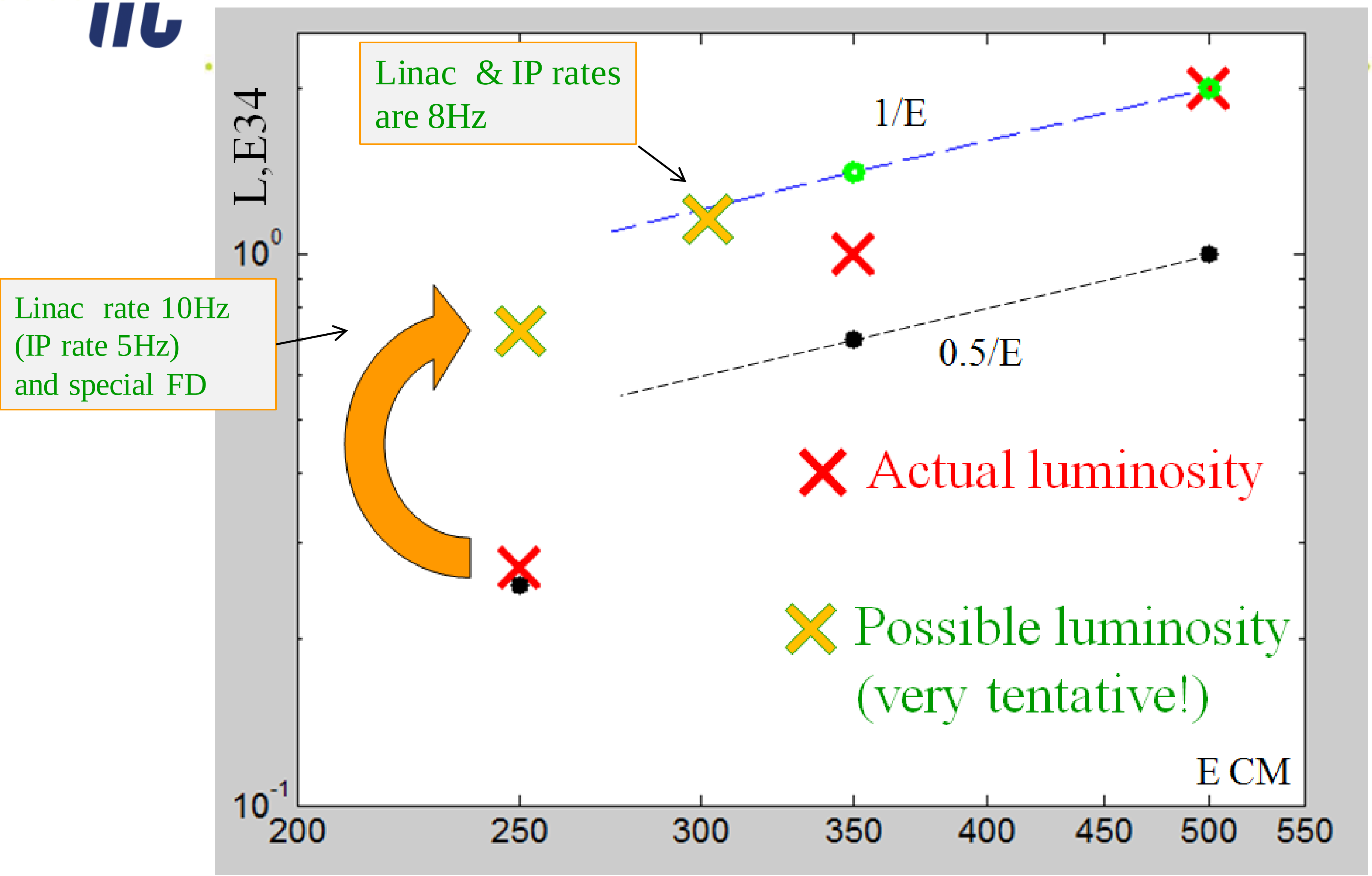


Beam Parameters & mitigation

	RDR			SB2009 w/o TF				SB2009 w TF			
CM Energy (GeV)	250	350	500	250.a	250.b	350	500	250.a	250.b	350	500
Ne- ($*10^{10}$)	2.05	2.05	2.05	2	2	2	2.05	2	2	2	2.05
Ne+ ($*10^{10}$)	2.05	2.05	2.05	1	2	2	2.05	1	2	2	2.05
nb	2625	2625	2625	1312	1312	1312	1312	1312	1312	1312	1312
Tsep (nsecs)	370	370	370	740	740	740	740	740	740	740	740
F (Hz)	5	5	5	5	2.5	5	5	5	2.5	5	5
γex ($*10^{-6}$)	10	10	10	10	10	10	10	10	10	10	10
γey ($*10^{-6}$)	4	4	4	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
βx	22	22	20	21	21	15	11	21	21	15	11
βy	0.5	0.5	0.4	0.48	0.48	0.48	0.48	0.2	0.2	0.2	0.2
σz (mm)	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
σx eff ($*10^{-9}$ m)	948	802	639	927	927	662	474	927	927	662	474
σy eff ($*10^{-9}$ m)	10	8.1	5.7	9.5	9.5	7.4	5.8	6.4	6.4	5.0	3.8
L (10^{34} cm^{-2}s^{-1})	0.75	1.2	2.0	0.2	0.22	0.7	1.5	0.25	0.27	1.0	2.0

- Tentative! At 250 GeV CM the mitigations may give
  - * 2 L due to double rep rate
  - * about 1.4 L due to FD optimized for low E

SB2009 Lumi



Linac & IP rates are 8Hz
Linac rate 10Hz (IP rate 5Hz) and special FD
1/E
0.5/E
L, E34
10^0
10^{-1}
Actual luminosity
Possible luminosity (very tentative!)
E CM
200
250
300
350
400
450
500
550

New parameters based on the following assumptions

- Starting point: parameters developed by the Physics Questions Committee (B. Foster, A. Seryi, J. Clarke, M. Harrison, D. Schulte, T. Tauchi) in December 2009.
- Take into account progress on 10Hz rep rate for low E achieved after LCWS10
  - There are issues with DR duty cycle that are being studied, however assume that they will be solved
- Assume that we will develop and use new universal FD that gives additional luminosity improvement (only) for 200 and 250 GeV energies
- Consider the following energies: 200, 250, 350, 500 GeV CM
- Assume single stage bunch compressor (min sigma_z=230um – will use 300um and consider 230 as an overhead or safety margin)
- Assume 10Hz and 1300 bunches
- Consider separately the cases with and without Travelling Focus
- Energy and rep rate:

E=	200	250	350	500	GeV CM
IP rep rate	5	5	5	5	Hz
Linac rate	10	10	5	5	Hz
	(double pulsing)				

BAW-2 Themes

								upgrade
Centre-of-mass energy	E_{cm}	**GeV**	**200**	**230**	**250**	**350**	**500**	**1000**
Luminosity	L	$\times 10^{34}$ cm^{-2}s^{-2}	**0.5**	**0.5**	**0.7**	**0.8**	**1.5**	**2.8**
Luminosity (Travelling Focus)	L_{TF}	$\times 10^{34}$ cm^{-2}s^{-2}	**0.5**		**0.8**	**1.0**	**2.0**	
Number of bunches	n_b		1312	1312	1312	1312	1312	2625
Collision rate	f_{rep}	Hz	5	5	5	5	5	4
Electron linac rate	f_{linac}	Hz	10	10	10	5	5	4
Positron bunch population	N_+	$\times 10^{10}$	2	2	2	2	2	2

Formally agreed parameter sets across energy range
ILC-EDMS document ID 925325

http://ilc-edmsdirect.desy.de/ilc-edmsdirect/document.jsp?edmsid=*925325

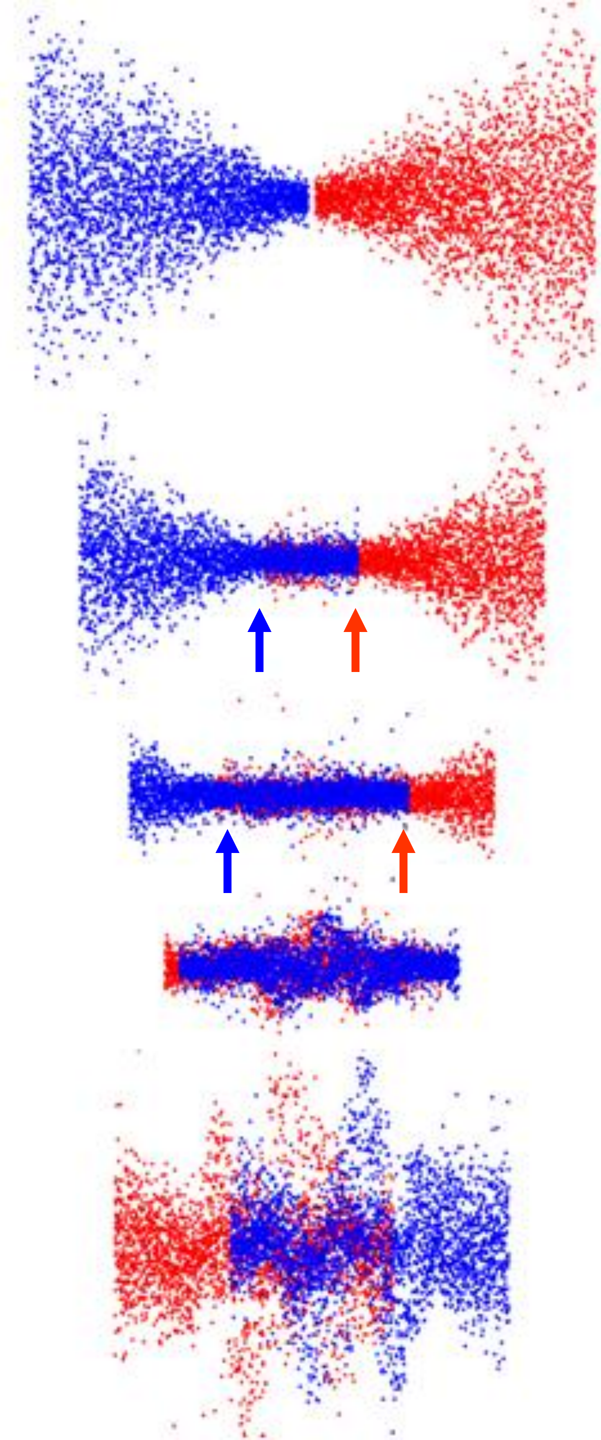
BAW-2 Issues

Travelling Focus	• More detailed simulations required • Stability issues → impact on feedback and tolerances • considered higher-risk option • Inclusion not a cost issue
10Hz Operation (Low E_{cm})	• Positron damping ring 50% duty cycle • RF solution still required (this workshop) • Understanding cost impact (1.9% TPC) • Other emerging options (high-field undulator)
Upgrade / Risk-Mitigation	• Understand scenarios for re-establishing RDR bunch number • Cost impact (mostly CFS) • Considered either as possible luminosity upgrade or risk-mitigation (GDE PAC)
Physics impact	↔ Working with Physics & Detector groups as part of the TLCC process

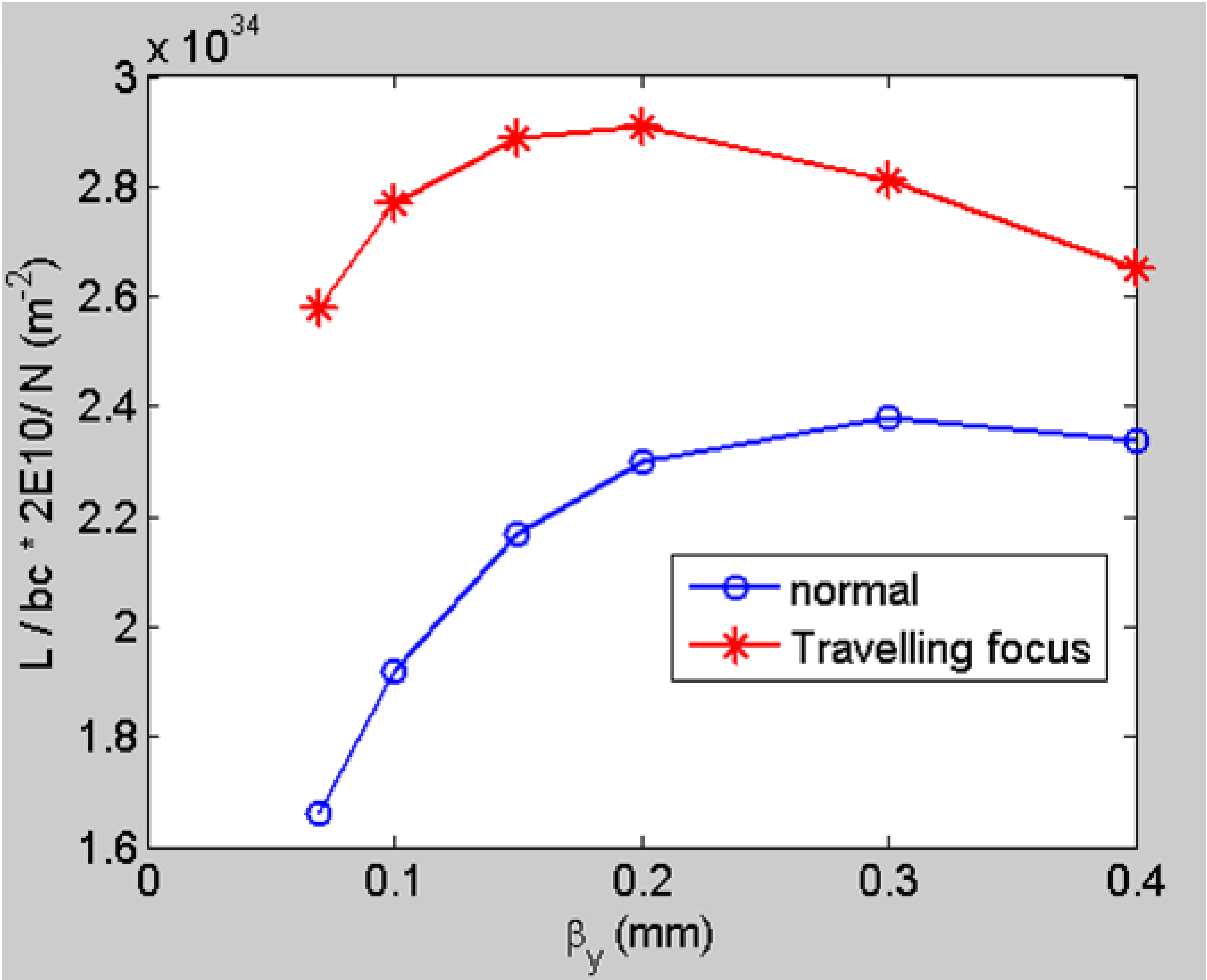
18.11.10

N. Walker et al

25

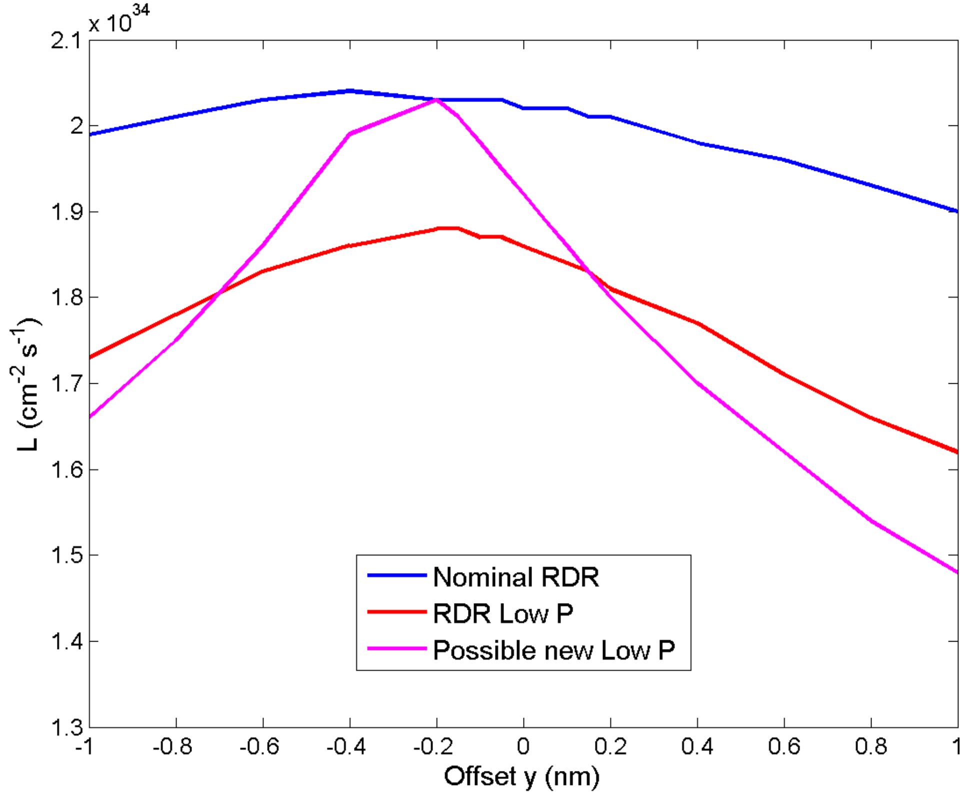


Arrows show location of focal point for each bunch at a particular moment


x 10^34
3
2.8
2.6
2.4
2.2
2
1.8
1.6
0
0.1
0.2
0.3
0.4
L / bc * 2E10/ N (m^-2)
β_y (mm)
normal
Travelling focus

SB2009 beam offset sensitivity

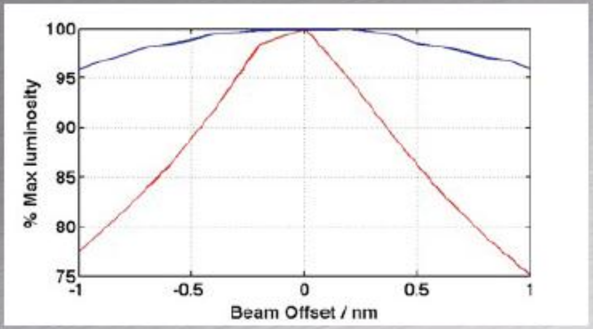
- Higher Disruption
  - **Higher sensitivity to Δy**
  - **Intratrain Feedback more challenging**
  - **Vertical bunch-bunch jitter to be <200pm for <5% lumi loss**
  - **However, twice longer bunch separation will help to improve bunch-bunch uniformity & jitter**



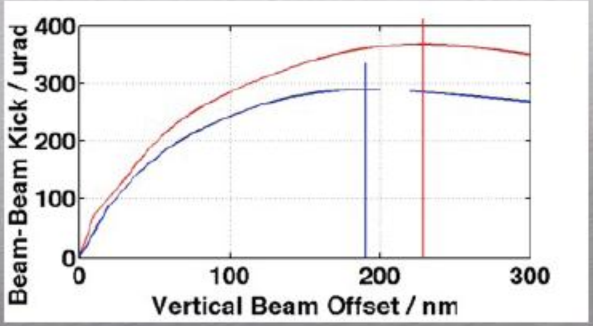
Fast Feedback Performance Studies for ILC

Glen White (SLAC)
Javier Resta-Lopez (JAI)
GDE/ALCPG Workshop Sept. 2009

IP Beam-Beam Dynamics



SB2009 (lowP with trav focus)
Nominal Parameter Set



GUINEA-PIG Simulations

- IP vertical position feedback based on beam-beam kick
- "turn over" point of kick sets desired dynamic range
- SB2009 more sensitive
- Vertical beam offset must be kept <200pm for <5% lumi loss
- SB2009 parameter set gives slightly larger dynamic range for FFB system

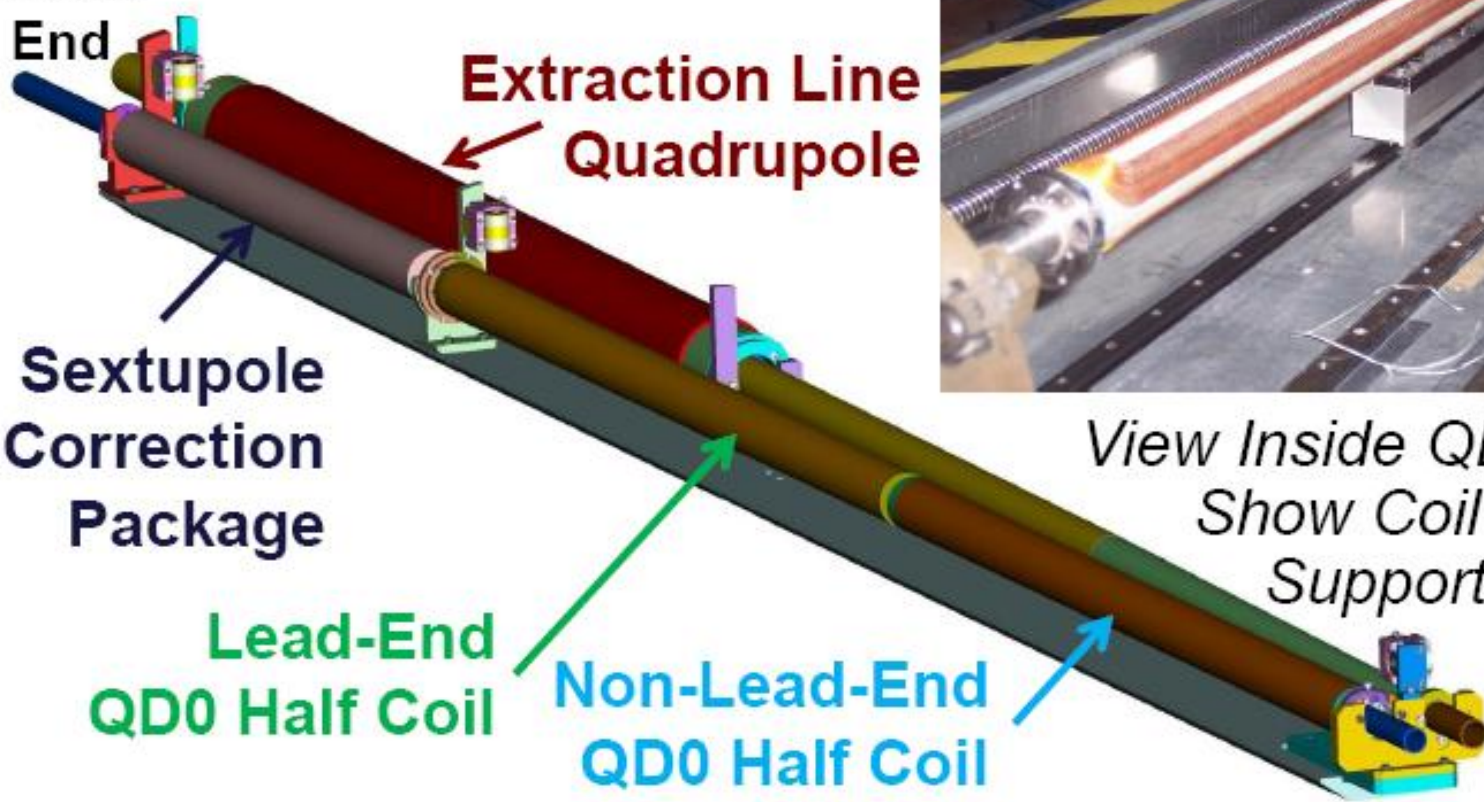
Thursday, October 1, 2009

- The travelling focus can be created in two ways.
- The first way is to have small uncompensated chromaticity and coherent E-z energy shift $\delta E/\delta z$ along the bunch. One has to satisfy $\delta E\ k\ L^{*}_{eff} = \sigma_z$ where k is the relative uncompensated chromaticity. The δE needs to be 2-3 times the incoherent spread in the bunch. Thus, the following set may be used: δE=0.3%, k=1.5%, L^{*}_{eff} =6m.
- It is clear that additional energy spread affect the physics. Therefore, second method is considered:

- The second way to create a travelling focus is to use a transverse deflecting cavity giving a z-x correlation in one of the FF sextupoles and thus a z-correlated focusing
- The cavity would be located about 100m upstream of the final doublet, at the $\pi/2$ betatron phase from the FD
- The needed strength of the travelling focus cavity can be compared to the strength of the normal crab cavity (which is located just upstream of the FD):
  - $U_{trav.cav.}/U_{crab.cav.} = \eta_{FD} R_{12}^{cc} / (L^{*}_{eff}\, \theta_c\, R_{12}^{trav})$.
  - Here η_{FD} is dispersion in the FD, θ_c full crossing angle, R_{12}^{trav} and R_{12}^{cc} are transfer matrix elements from travelling focus transverse cavity to FD, and from the crab cavity to IP correspondingly.
- For typical parameters η_{FD} =0.15m, θ_c =14mrad. R_{12}^{cc} =10m, R_{12}^{trav} =100m, L^{*}_{eff} =6m one can conclude that the needed strength of the travelling focus transverse cavity is about 20% of the nominal crab cavity.

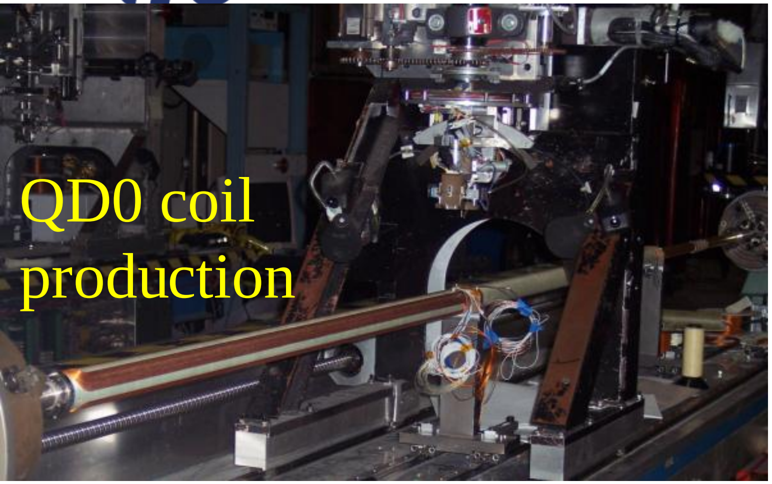
QD0 Split Coil Winding Implementation

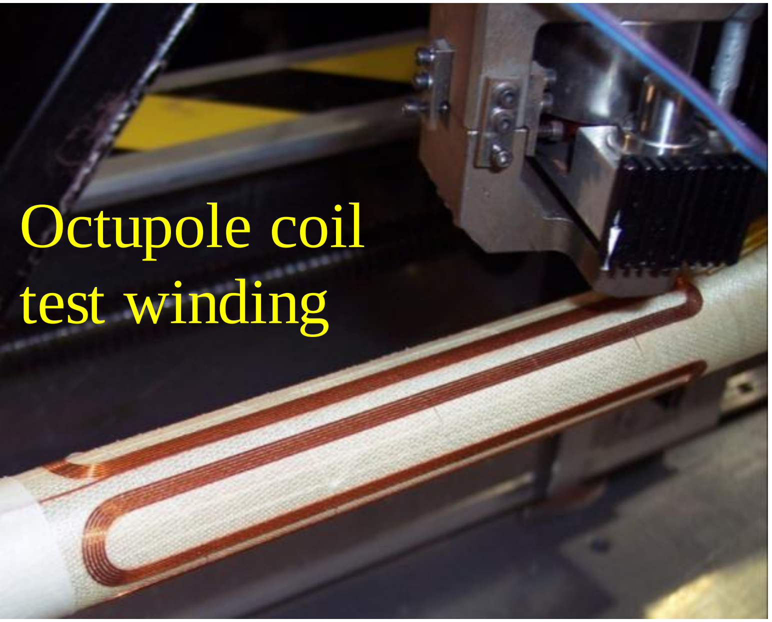
QD0 split coil variant may be useful for low-energy running as a Universal Final Focus.



View Inside QD0 Cryostat to Show Coil Positions and Support Infrastructure

QD0 R&D Prototype Coil Winding Status



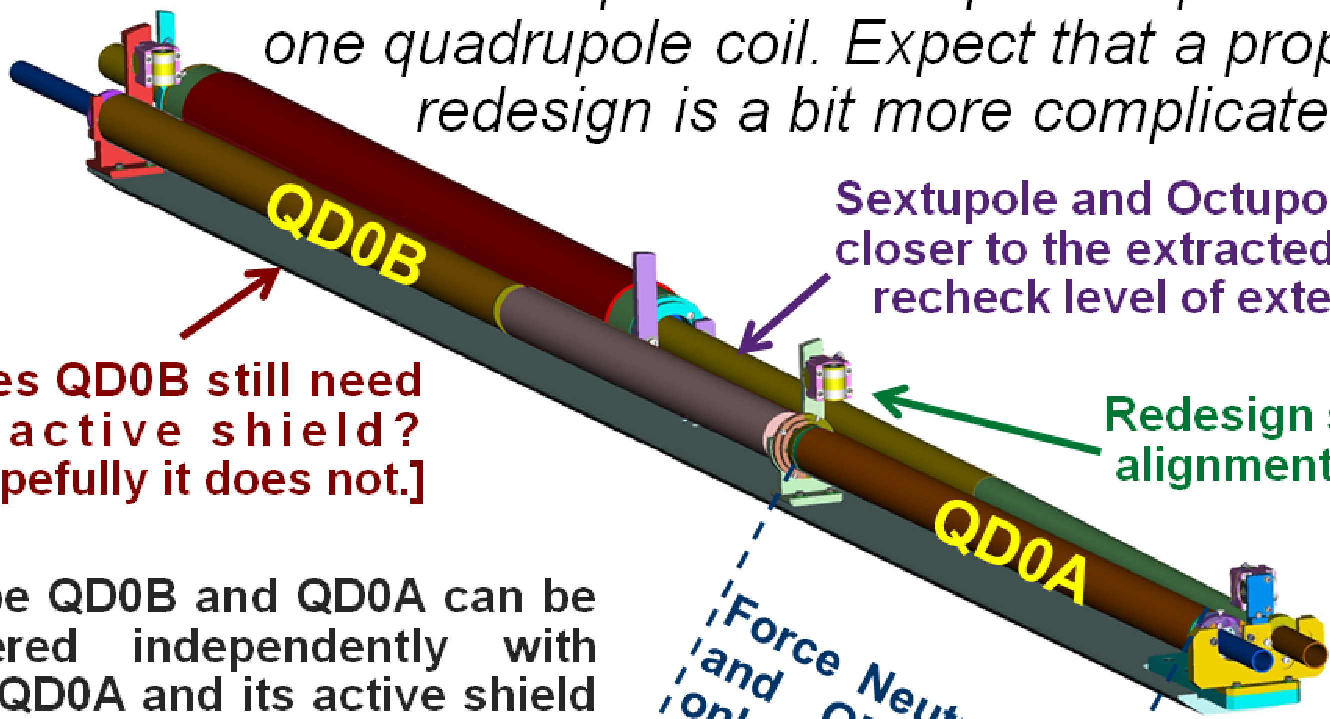


- To control coil support tube position during winding, we split QD0 coil in order to have a fixed support.
- Coil winding of all the quadrupole layers is complete and the measured harmonic agree with expectations.
- Vertical cold test has been done; tested to 10% above operating current without quenching; forced quenches with spot heater, saw no degradation.
- Have started winding octupole coil correction windings; next we will start winding the main sextupole coil sets.

"Report to ATF2 Technical Board,"
Brett Parker, BNL-SMD

Universal Final Focus (Cartoon) Issues

Here I took the CAD layout from slide #7 and did cut/paste to swap sextupole and one quadrupole coil. Expect that a proper redesign is a bit more complicated.



Sextupole and Octupole coils are now closer to the extracted beam; so must recheck level of external B-field.

Does QD0B still need an active shield? [Hopefully it does not.]

Redesign support & alignment scheme.

Force Neutral Anti-Solenoid and QD0A Active Shield only need to extend over this region?

Maybe QD0B and QD0A can be powered independently with only QD0A and its active shield run in series?

Do QD0A and QD0B have to have the same coil structure and magnetic length?

Adopted Low-P parameters

Parameter	unit	RDR (nom.)	Proposed
E_{cm}	GeV	500	500
Rep. rate	Hz	5	5
Q_{bunch}	nC	3.2	3.2
Bunches/pulse		2625	1312
Main Linac			
RF pulse length	ms	1.6	KCS: 1.6 DRFS: 2.2
Beam current	mA	9	KCS: 6 DRFS: 4.5
Average beam power	MW	10.5	5.3
Damping Ring[1]			
Circumference	m	6476	3238
Avg. Current	mA	388	390
Damping time	ms	21	24
RF power	MW	3.97	1.76

	Centre-of-mass energy	E_{cm}	**GeV**	**200**	**230**	**250**	**350**	**500**	**upgrade 1,000**
	Collision rate	f_{rep}	Hz	5	5	5	5	5	4
	Electron linac rate	f_{linac}	Hz	10	10	10	5	5	4
	Number of bunches	n_b		1,312	1,312	1,312	1,312	1,312	2,625
	Electron bunch population	N_-	$x10^{10}$	2	2	2	2	2	2
	Positron bunch population	N_+	$x10^{10}$	2	2	2	2	2	2
	Main linac average gradient	G_{av}	MV/m	12.6	14.5	15.8	22.1	31.5	>31.5
	RMS bunch length	σ_z	Mm	0.3	0.3	0.3	0.3	0.3	0.3
	Electron RMS energy spread	$\Delta p/p$	%	0.22	0.22	0.22	0.22	0.21	0.11
	Positron RMS energy spread	$\Delta p/p$	%	0.17	0.15	0.14	0.1	0.07	0.04
	Electron polarisation	P_-	%	80	80	80	80	80	80
	Positron polarisation	P_+	%	31	31	31	29	22	22
	IP RMS horizontal beam size	σ_x^*	nm	904	843	700	662	474	554
	IP RMS vertical beam size	σ_y^*	nm	9.3	8.6	8.3	7	5.9	3.3
	Luminosity	**L**	$\times 10^{34}$ cm^{-2}s^{-2}	**0.47**	**0.54**	**0.71**	**0.86**	**1.49**	**2.7**
	Fraction of luminosity in top 1%	$L_{0.01}/L$		92.20%	89.80%	84.10%	79.30%	62.50%	63.50%
	Average energy loss	δE_{BS}		0.61%	0.78%	1.23%	1.75%	4.30%	4.86%
Using	IP RMS vertical beam size	σ_y^*	nm	6	5.6	5.3	4.5	3.8	2.7
Travelling	**Luminosity**	**L**	$\times 10^{34}$ cm^{-2}s^{-2}	**0.64**	**0.73**	**0.97**	**1.17**	**2.05**	**3.39**
Focus	Fraction of luminosity in top 1%	$L_{0.01}/L$		91.60%	89.00%	83.00%	77.90%	60.80%	62.30%
	Average energy loss	δE_{BS}		0.61%	0.79%	1.26%	1.78%	4.33%	4.85%

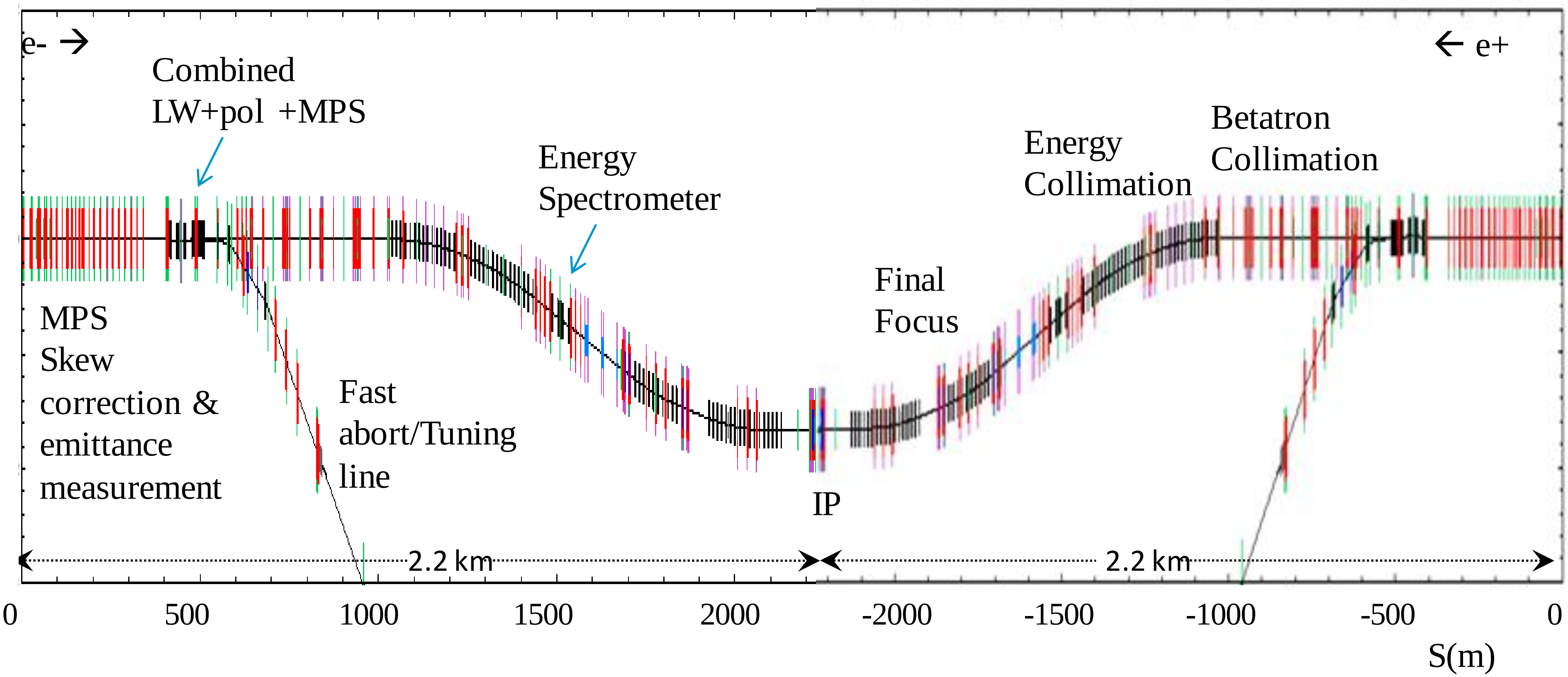
Outline

- RDR Design
- Changes to BDS Design in SB2009
- Few modifications in the design
- Possible future changes

Optics updates
By Deepa Angal-Kalinin

RDR Beam Delivery System

ILC2006e (M. Woodley, A. Seryi et al) : Layout compatible for 1 TeV CM. http://www-project.slac.stanford.edu/ilc/acceldev/beamdelivery/rdr/



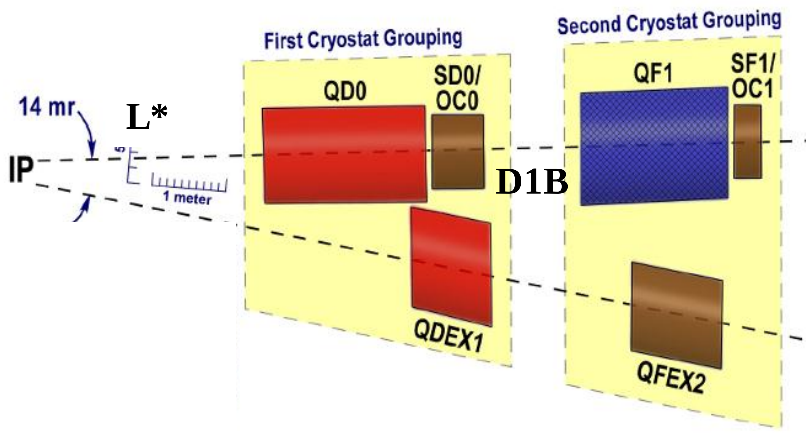
One interaction region @crossing angle of 14 mrad with push-pull arrangements for two detectors. R. Versteegen's talk on IR simulations (WG5).

RDR Beam Delivery System

1. Concerns about combined functionality of MPS collimator, laser wire detector and upstream polarimeter measurements.

   It was planned to separate these functionalities for precise polarisation measurements.

2. Possible shortening of 1 TeV CM BDS to allow more emittance growth due to synchrotron radiation.

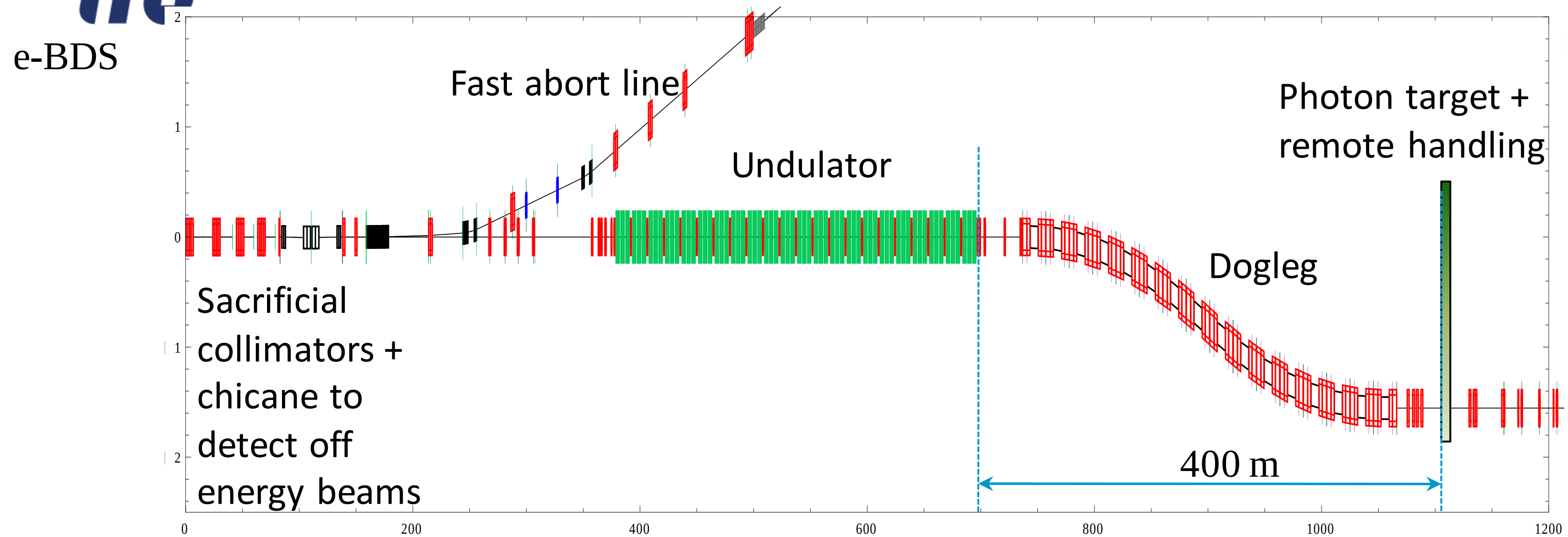


3. Push-pull requirement : location of QF1 unchanged. D1B adjusted according to L*.

   Different L* decks were prepared (A. Seryi) to study collimation depths and muons. Optics was not tuned for beam size and band width etc.

Recent attempt to address all these points alongwith required changes for SB2009.

SB2009 : Changes to BDS Design

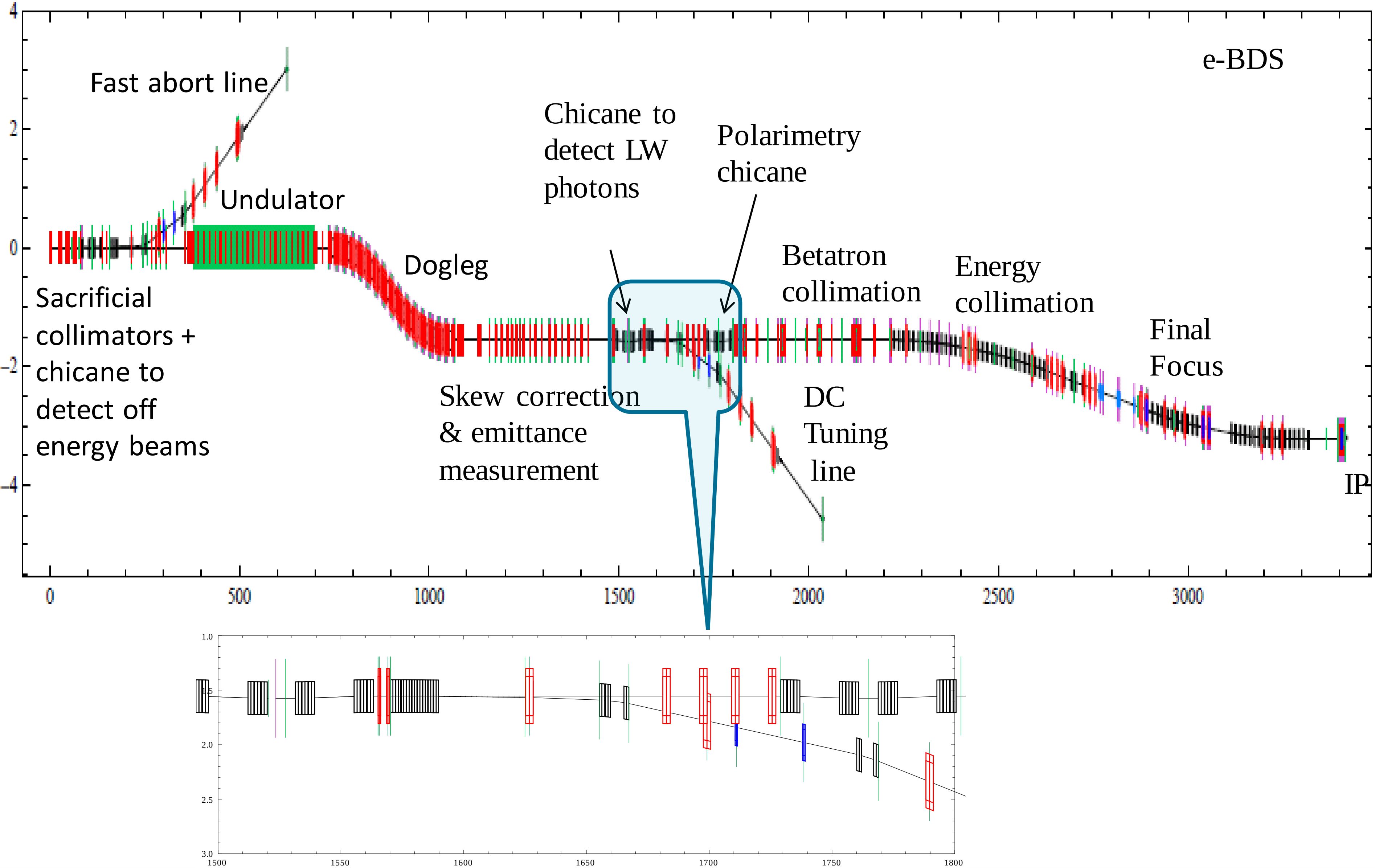


- Undulator based positron source moves to the end of the e- main Linac as part of central integration

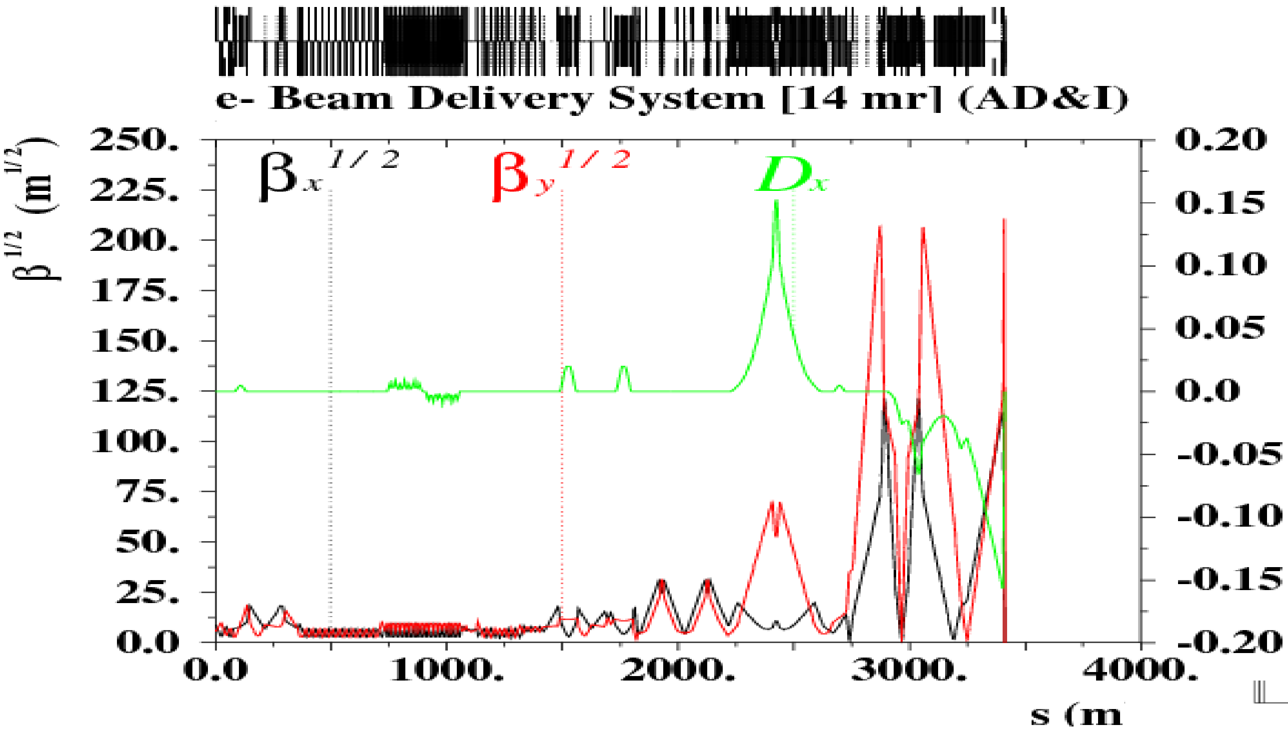
- Dogleg needs to provide 1.5m transverse offset at the target location at ~400m from the end of the undulator and ~40m drift near target area for remote handling.

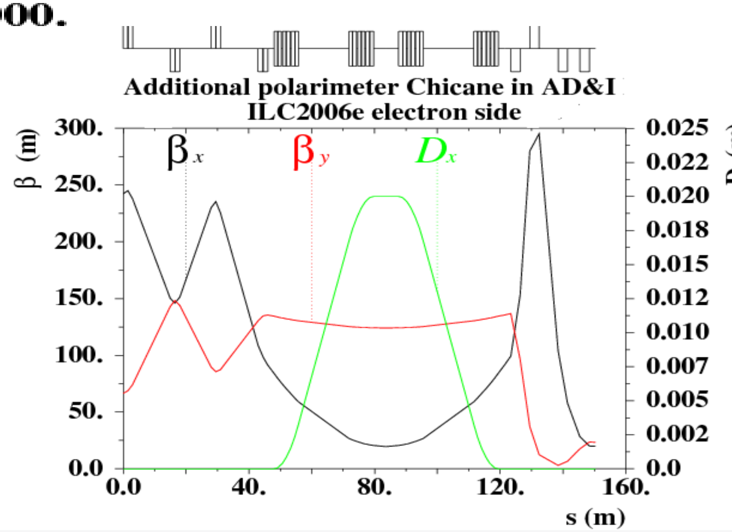
- Fast abort line in the beginning of the RDR BDS lattice before the undulator.

SB2009 e- BDS


e-BDS
Fast abort line
Undulator
Sacrificial collimators + chicane to detect off energy beams
Dogleg
Skew correction & emittance measurement
Chicane to detect LW photons
Polarimetry chicane
Betatron collimation
DC Tuning line
Energy collimation
Final Focus
IP
4
2
0
-2
-4
0
500
1000
1500
2000
2500
3000
1.0
1.5
2.0
2.5
3.0
1500
1550
1600
1650
1700
1750
1800

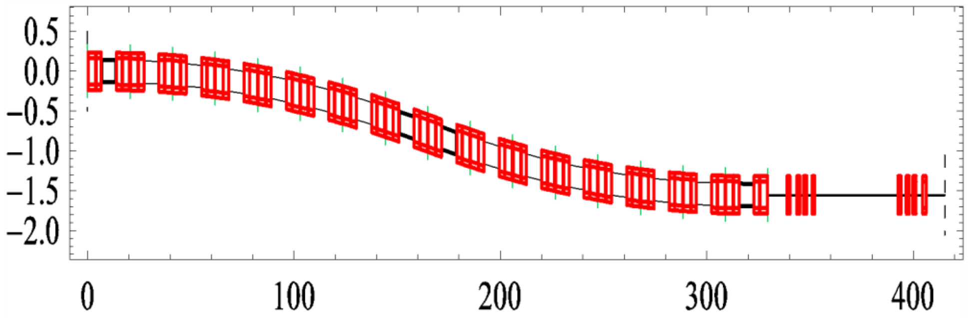
SB2009 e- BDS Optics

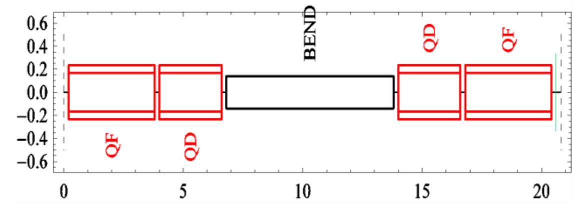




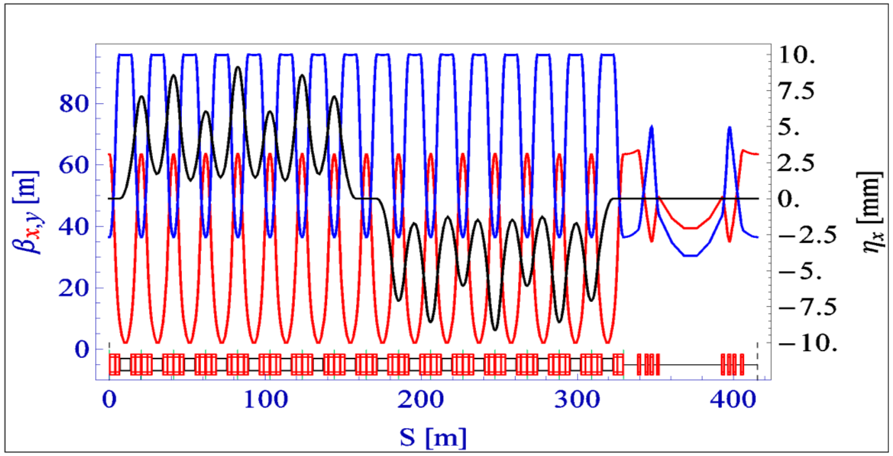
The Dogleg Design

- Theoretical Minimum Emittance (TME) lattice.





- Provides ***1.5m*** offset in ***~400m***
- Emittance growth is ***~3.8%*** (1TeV CM)
- Decimation of dipoles is possible



- The first and last dipoles in each of the two bending sections have lower bend angles to match the dispersion into, and out of, the dogleg.

- These dipoles can be used to match and correct incoming errors to minimise the emittance growth seen in the dogleg sections.

The Dogleg Tolerances

- Due to the ***space constraints*** and ***strong focusing*** in the dogleg design, the tolerances are tight.

- The results of uncorrected mismatch entering the lattice, for a 10% emittance growth in the lattice at 1TeV CM (cf. 3.8% nominal).

Parameter	Tolerance	With Correction
Initial α_x	-1.7 – 1.71	N/A
Initial β_x *(m)*	10 $\rightarrow$200	N/A
Initial η_x *(mm)*	-9.5 – 11	-21 – 27
Initial η_x' *(mrad)*	-0.13 – 0.2	-0.32 – 0.4
Initial x (mm) (centroid)	-0.13 – 0.21	-0.6 – 0.75
Initial x′ (μ*rad) (centroid)*	-2 – 3.2	-11.5 – 12.9

WEPE031, IPAC10

The Dogleg Tolerances

- Important to understand the implications to tuning and tolerances due to the strong focussing dogleg lattice.

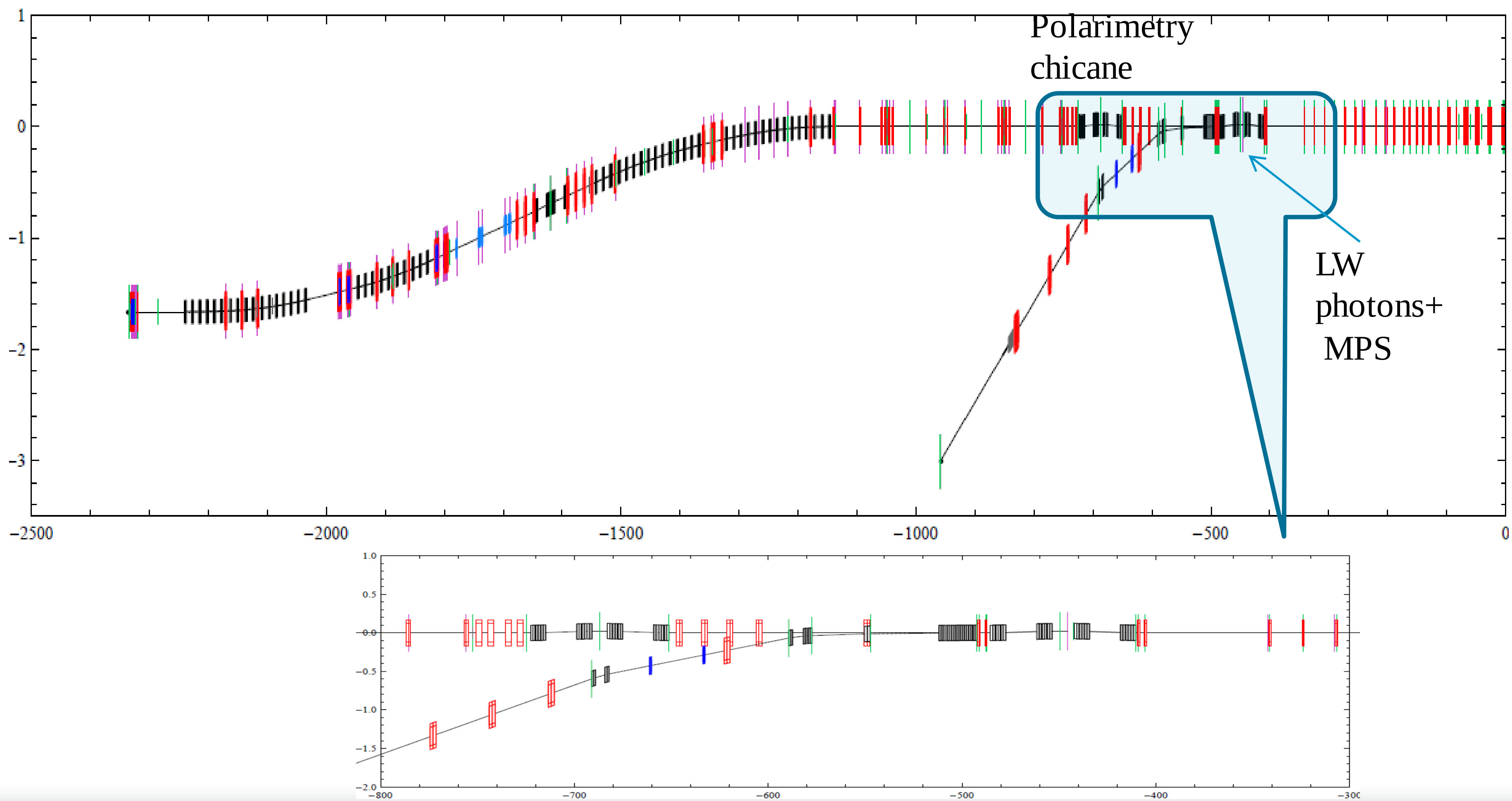
- Preliminary studies indicate that very tight tolerances on the incoming dispersion, as well as the required trajectory correction.

- Correction of these errors using the 4 “end” dipoles in the design has shown that it is possible to widen the tolerance levels significantly.

- Additional correction for the trajectory within the dogleg needs to be looked at further and to understand if decimation of dipoles will be useful to relax the tolerances at 500 GeV CM.

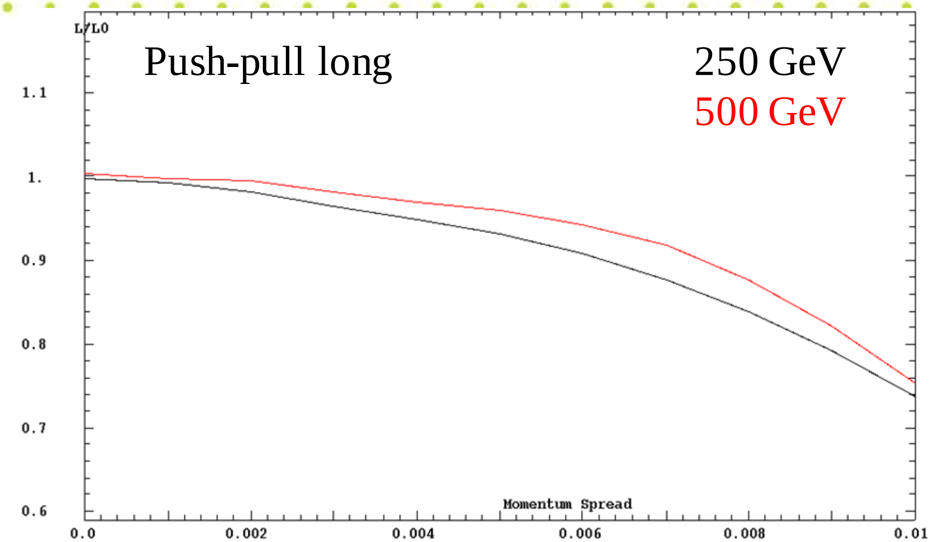
Positron BDS

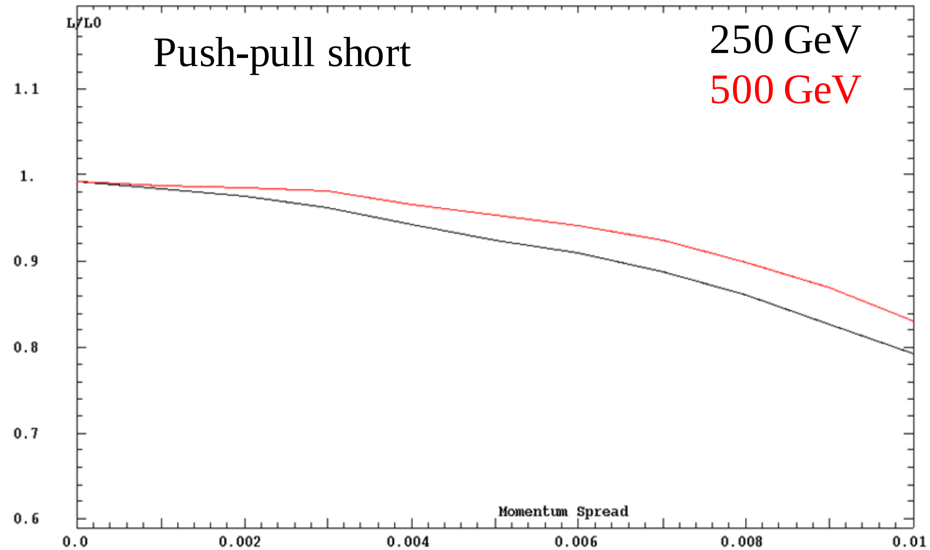
Separated polarimetry chicane, combined functionality of laser wire and MPS still in the same chicane. Need laser wire simulations to see if this is okay.



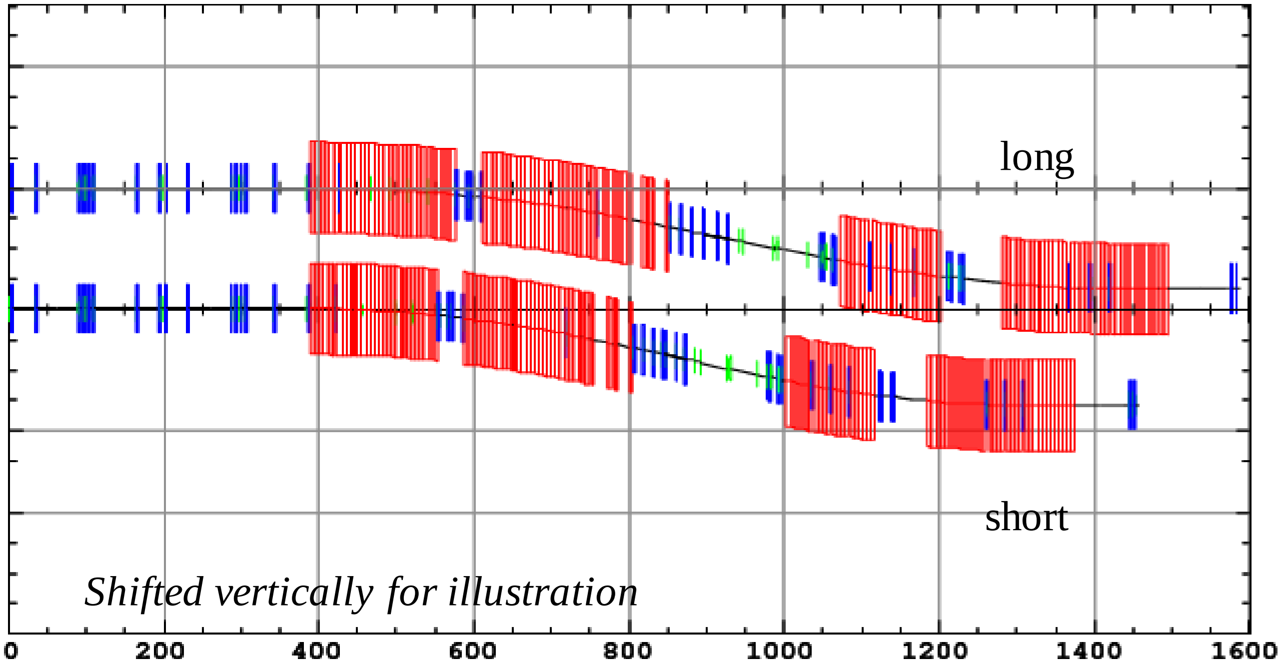
Shortening of Energy Collimation and Final Focus

- Emittance growth <1% @500 GeV beam for RDR.
- First attempt to reduce the FFS length of push-pull deck by R. Versteegen (CEA).
- Multiplied all the dipole lengths and drifts by 0.87 in the energy collimator and the FFS in order to approximately double emittance growth in these sections.
- Re-tuned linear optics and sextupoles to optimise the luminosity and the bandwidth.



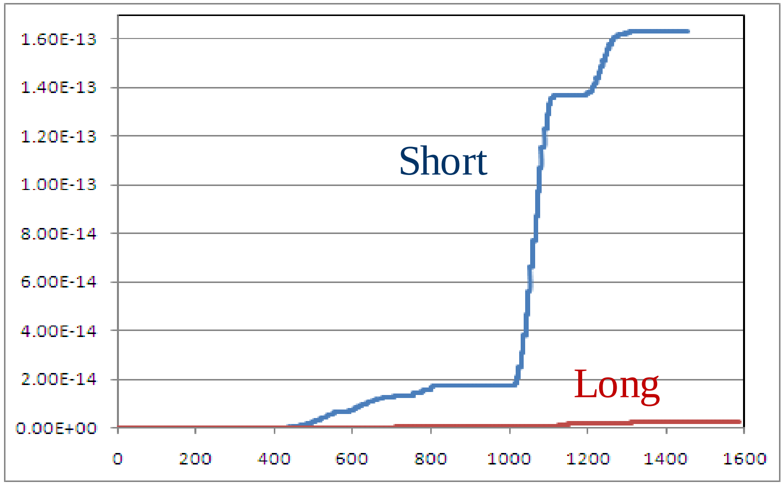


Shortening of Energy Collimation and FF



Reduced the total length by ~130 m and horizontal emittance increased to ~1.6%.

This length reduction is not yet implemented in SB2009.



Support for Travelling Focus in SB2009

A.Seryi, WE6PFP082, PAC09

- Create Travelling focus using a transverse deflecting cavity giving a z-x correlation in one of the FF sextupoles and thus provide z-correlated focusing.
  - The cavity will be located about 100m upstream of the final doublet, at the $\pi/2$ betatron phase from the FD.
  - The strength required will be ~20% of the nominal crab cavity.

- Such a cavity is not yet included in the lattice.

- Tracking studies and possibly mitigation of higher order aberrations will be needed.

Optics updates

By Deepa Angal-Kalinin

Possible Future Changes

On e- BDS side:

- Needs re-designing of shorter fast abort line before the undulator.
- Needs design of DC tuning line on electron side. Replace kickers with DC dipoles→ will affect the region between LW chicane and polarimetry chicane.
- Details of power deposition in the tunnel and radiation effects will need to be evaluated.
- Start-to-end simulations including the dogleg design.
- Possible decimation of dogleg dipoles may be necessary if start-to-end simulations indicate.

on e+ BDS side:

- LW simulations for combined functionality of LW photon detection and MPS for fast abort.

Possible Future Changes

On both BDSs:

- Implementing shorter Final focus in final decks.
- Support for travelling focus and low power beam dynamics simulations including collimation depth changes.
- Study the possibility of merging full power tuning (tuning + fast abort on e+ side)dump with the main beam dump.

SB2009 BDS Decks

- No decks available publicly after RDR ILC2006e decks . The changes after the RDR need to be made available at some central place.
- We will keep all these decks in present condition on EDMS soon with detailed comments for any future developments by interested colleagues.

http://projects.astec.ac.uk/ilcdecks/

ILC Beam Delivery System lattice design changes since the RDR

D. Angal-Kalinin

ASTeC, STFC, Daresbury Laboratory

This note summarises the status of changes made to ILC BDS decks after ILC RDR was published and comments on the remaining lattice design work which needs to be done in the future.

Summary of changes required/requested/studied after the RDR is listed below. These changes were made separately and were not released as a final BDS version, which was foreseen to be done during the EDR phase. The decks for the corresponding changes are available at (http://projects.astec.ac.uk/ilcdecks/), with the corresponding directories highlighted below in ***red***. Archives of these directories (in .zip format) are available at http://projects.astec.ac.uk/ilcdecks/Archives.

1. In the RDR design ***(ILC2006e_RDR_decks)***, the functionalities of machine protection, detection of laser wire photons were combined in the upstream polarimeter chicane in both e+ and e- BDS. The implications of these combined functionalities were discussed in the "Workshop on polarization and Energy measurements at ILC" held in Zeuthen in April 2008 :
   http://indico.desy.de/contributionDisplay.py?sessionId=1&contribId=10&confId=585
   The BDS team has agreed to separate these functionalities by adding another chicane for upstream polarimetry. This change was implemented in October 2010 and is mentioned in point 5 below.

2. RDR BDS decks ***(ILC2006e_RDR_decks)*** were not modified for the push-pull operation; i.e. the inner length (D1B in the decks) between final doublet (QD0 and QF1 in the decks) was not increased which will allow operation with different L*(D0 in the decks) whilst maintaining the location of QF1

DESIGN OF AN 18 MW VORTEX FLOW WATER BEAM DUMP FOR 500 GeV ELECTRONS/POSITRONS OF AN INTERNATIONAL LINEAR COLLIDER

Polepalle Satyamurthy, Pravin Rai, Vikas Tiwari, Kiran Kulkarni
ADS Target Development Section, Beam Technology Development Group, Bhabha Atomic Research Centre, Mumbai, India-400085

John Amann, Ray Arnold, Dieter Walz
SLAC National Accelerator Laboratory, Stanford, Menlo Park, CA, USA

Andrei Seryi, John Adams Institute for Accelerator Science, UK

Tristan Davenne, Ottone Caretta, Chris Densham *Rutherford Appleton Laboratory, UK*

Robert B Appleby
The University of Manchester and the Cockcroft Institute, UK

A 56 page report (paper for NIM) has been finalised and submitted

- **Abstract**

- Beam dumps are essential components of any accelerator system. They are usually located at the end of beam delivery systems and are designed to safely absorb and dissipate the particle energy. In the second stage of the proposed International Linear Collider (ILC), the electron and positron beams are accelerated to 500 GeV each (1TeV total). Each bunch will have $2x10^{10}$ electrons/positrons, and 2820 bunches form one beam bunch train with time duration of 0.95ms and 4 Hz frequency. The average beam power will be 18 MW with a peak power of 4.5 GW. The FLUKA code was used to determine the power deposited by the beam at all critical locations. This data forms the input into the thermal hydraulic analysis CFD code for detailed flow and thermal evaluation. Both 2D and 3D flow analysis was carried out at all the critical regions to arrive at optimum geometry and flow parameters of the beam dump. Analysis of generation and propagation of pressure waves due to rapid deposition of heat has also been analysed.

26 May 2011, Polepalle Satyamurthy, Pravin Rai, Vikas Tiwari, Kiran Kulkarni (BARC), John Amann, Ray Arnold, Dieter Walz (SLAC), Andrei Seryi (JAI), Tristan Davenne, Ottone Caretta, Chris Densham (RAL), Robert Appleby (Univ. of Manchester)

Results that were already reported earlier (examples)

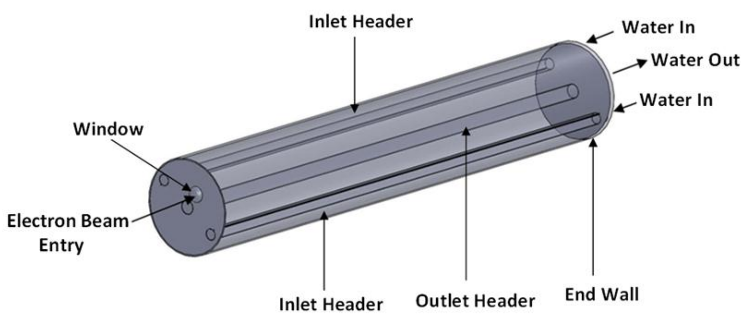


Fig. 1.Schematic of the water beam dump of vortex-type flow

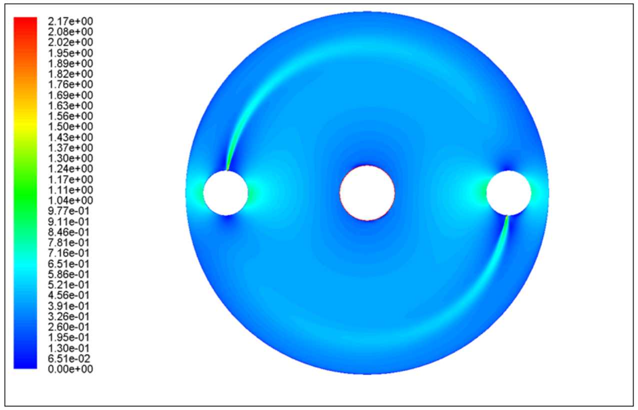
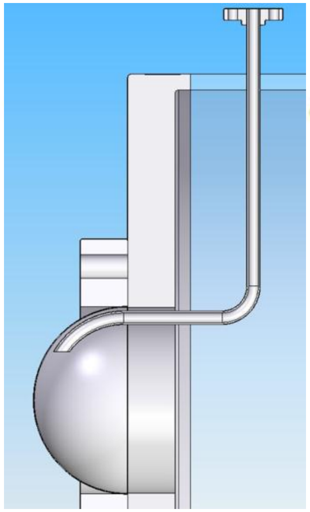


Fig. 10. Velocity Contours (inlet velocity: 2.17m/s; mass flux: 19kg/m/s)



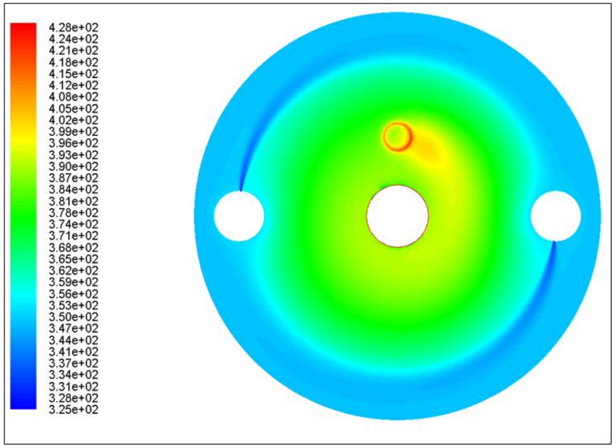


Fig. 11.Temperature distribution at the time when the beam train completes energy deposition at z = 2.9 m ≡8.1 X_o (Maximum temperature : 155°C)

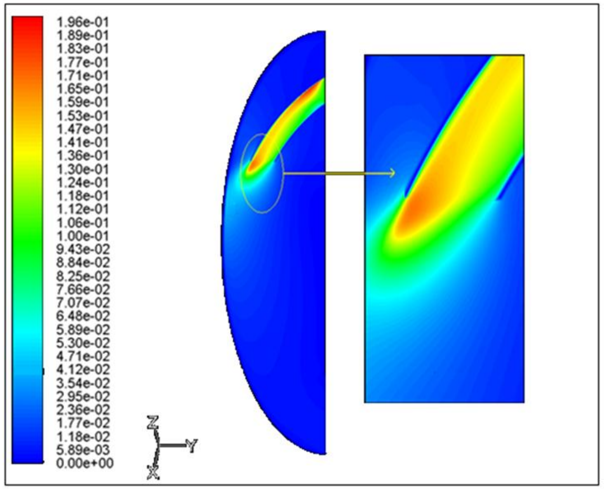


Fig. 17. Jet velocity near the window ~0.045m/s (contours taken on a plane which slices the central jet pipe)

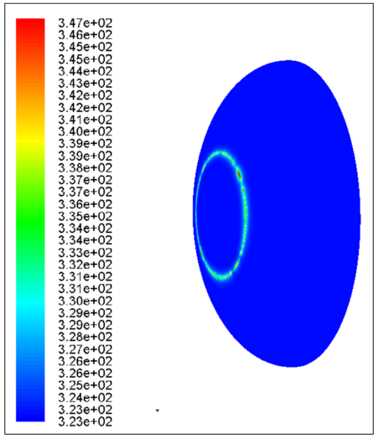


Fig. 18. Window temperature distribution just when the bunch train completes power deposition (Max temp : 74°C)

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New results – pressure wave analysis (example)

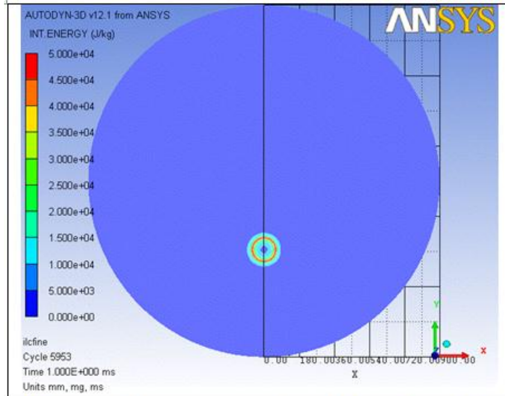

Figure 33.a Contour plot of energy deposition at a section through the beam dump

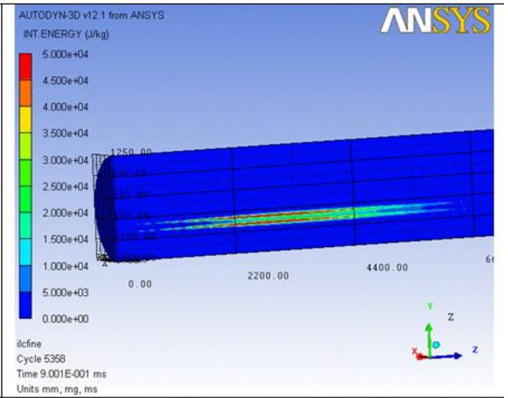

Figure33.b Contour plot of energy deposition at a section through the beam dump

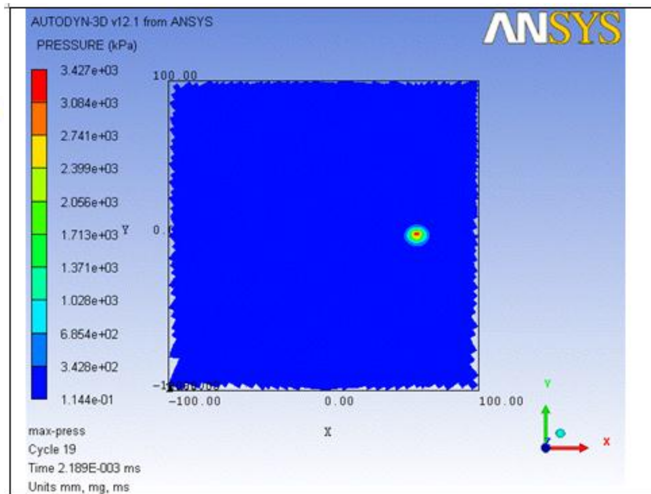

Figure 34.a Peak predicted pressure occurring after twelve bunches

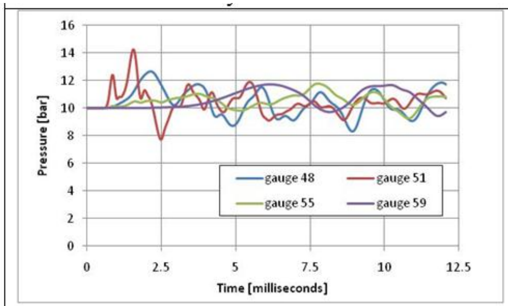

Figure 35.c Pressure on the internal surface of the beam dump at selected gauge points (gauge 51 sees the maximum recorded pressure)

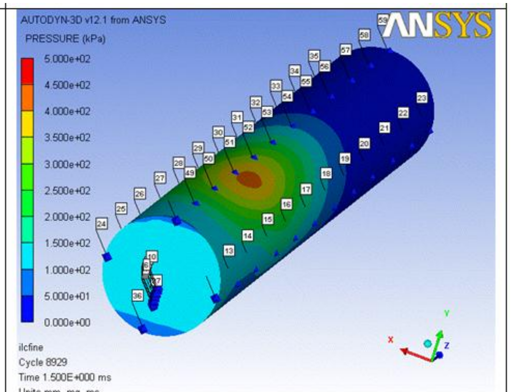

Figure 35.dPressure contours on the internal surfaces of the beam dump after 1.5ms, showing peak calculated pressure on beam dump wall relative to 10bar operating pressure.

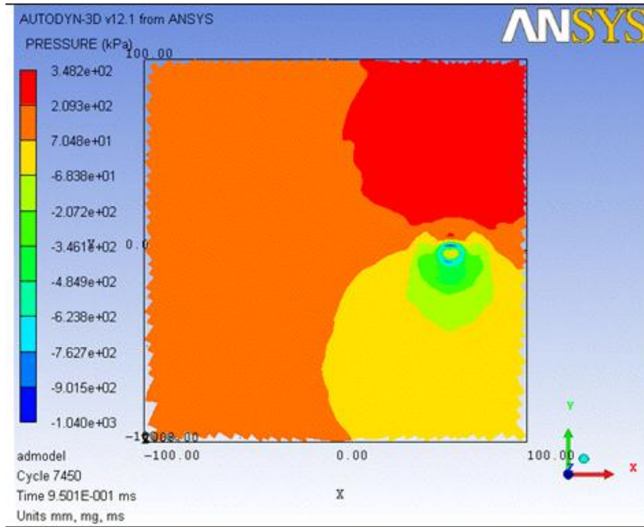

Figure 34.c Pressure at the end of the bunch train reaching -10.4bar relative to the 10.bar operating pressure

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Recent updates:

- 1.1 The window can experiences a maximum pressure of 12.5 bar
- 1.2 The maximum pressure experienced by Beam dump (other than window) is 15 bar
- 1.3 The maximum of local transient pressure water sees is 44 bar
- 1.4 The minimum local transient pressure water sees ***during the train*** is 4 bar
- 1.5 The minimum local transient pressure water sees ***just after the train*** is -0.4 bar which is likely to cause cavitation

- The dump and windows have sufficient strength safety margin, so 1.1 and 1.2 are OK.
- The 1.3 by itself is not a problem.
-
- Most of the concern is perhaps due to 1.4 and especially 1.5.
- However, the calculations are for max beam power and also for the worst case scenario, when there are no bubbles in the water -- while they may reduce the pressure effects. Also, maybe there are other ways to mitigate this problem. Maybe we can also think about gradual reduction of the charge of the last ~100 bunches in the train (however the damping ring or the linac dynamics will likely preclude this – need to be discussed with DR and Linac colleagues).

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PM's notes

Optics:

- Final doublet / IR configuration for push-pull
- Split final doublet for low-energy running scenario
- General optics solution for SB2009 IP parameters (focusing)
- Impact of above on collimation/collimation depth
- What will we be able to do for TDR?
- Physics instrumentation – MDI Requirements
    - (chicanes for spectrometer,
    - upstream polarimeter and
    - laser wires,…)
    - Beamline space needed
- 6. Dumps (also RTML): rating/spec for all the BDS dumps fores**een.**
    - New results from dump studies

(relevant for TeV parameter set)

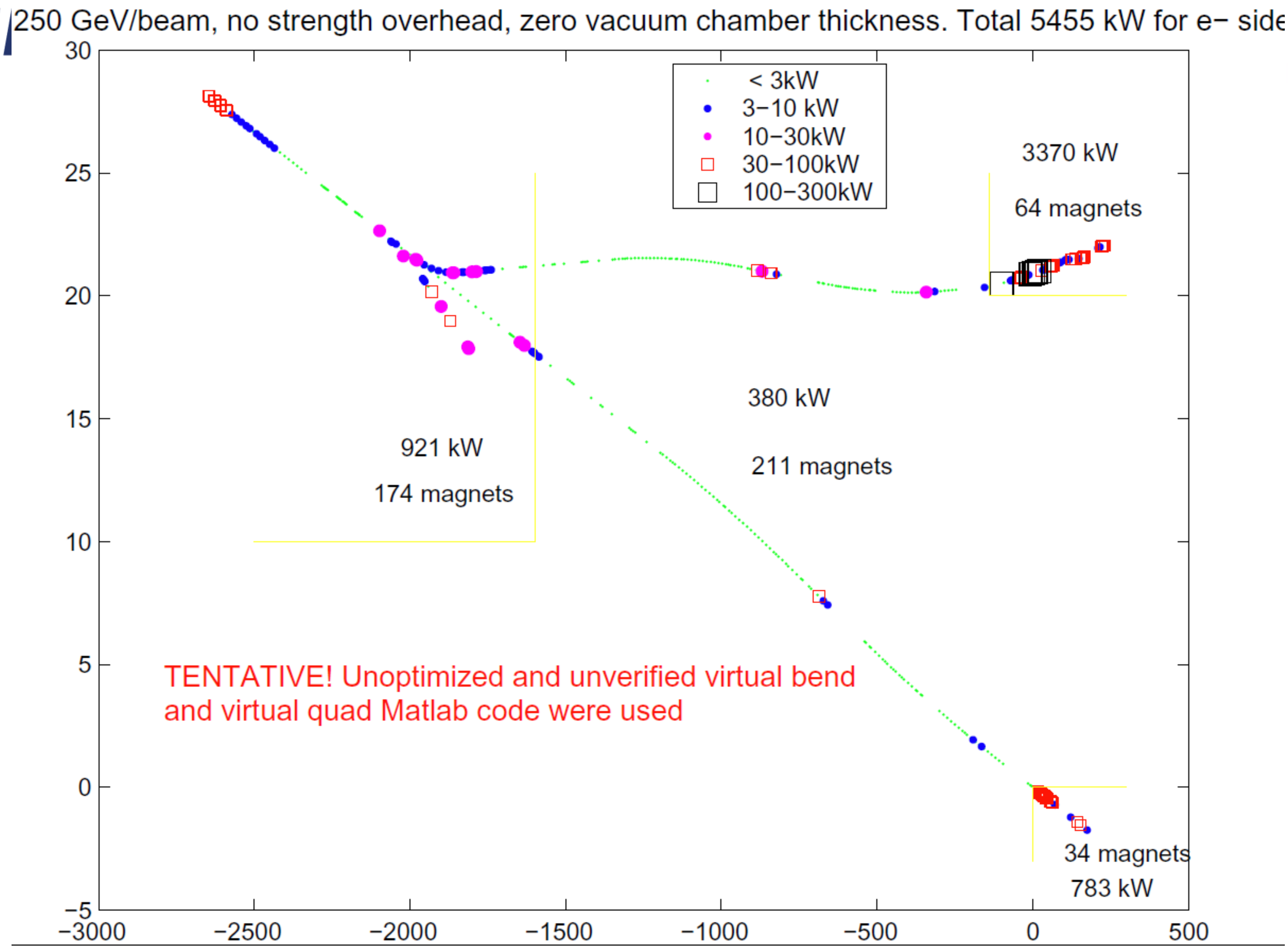
PM's notes

	Proposed Baseline Change or update	PM Comment or Recommendation
1	Final doublet / IR configuration for push-pull	Needs integration into BDS optics
2	Split final doublet for low-energy running scenario	Needs integration into BDS optics
3	SB2009 optics	Needs to be completed
4	Collimation depth	Needs integration into BDS optics
5	chicanes for spectrometer,	Space to be allocated; needs specification
6	polarimetry	Space to be allocated; needs specification
7	laser wires	Space to be allocated; needs specification
8	Dumps	Needs specification; analysis plan
9	Crab cavities for travelling focus	Needs integration into BDS optics

To summarise:

- After Oct 2011 (baseline review in DESY)
- Substantial progress, since then, is in
  - MDI/CFS design (reviewed separately)
  - ATF2 progress (special sessions)
  - Beam dump system
    - NIM review paper published (linked to the agenda)
    - BARC is ready to build the beam dump system if needed
- We have created a plan to finish the remaining optics and cost estimation work this summer, to fit in the timescale of the TDR

Extra slides


250 GeV/beam, no strength overhead, zero vacuum chamber thickness. Total 5455 kW for e− side
< 3kW
3−10 kW
10−30kW
30−100kW
100−300kW
3370 kW
64 magnets
921 kW
174 magnets
380 kW
211 magnets
34 magnets
783 kW
TENTATIVE! Unoptimized and unverified virtual bend and virtual quad Matlab code were used
30
25
20
15
10
5
0
−5
−3000
−2500
−2000
−1500
−1000
−500
0
500

Power & cooling in BDS

Table as of Valencia, 1TeV CM, two IR.

Table is as of 11/26/2006

Area	Section	Sum of Magnet Quantity	Sum of Total Magnet Power (kW)	Sum of Total Cable Loss (kW)	Sum of Power Supply Quantity	Sum of Total PS Loss to Air (kW)	Sum of Total PS Loss to Water (kW)	Sum of Required Water Flow (gpm)	Sum of Total of All Losses (kW)	Sum of Expected Running kVA
BDS	e- Common	63	1,439	60	31	73	152	57	1,724	2,028
	e+ Common	63	1,439	60	31	73	152	57	1,724	2,028
	e- 14mr1	286	2,969	229	191	200	279	106	3,676	4,325
	e+ 14mr1	286	2,969	229	191	200	279	106	3,676	4,325
	e- 14mr2	173	476	74	146	82	0	0	632	744
	e+ 14mr2	173	476	74	146	82	0	0	632	744
BDS Total		1,044	9,768	726	736	712	862	327	12,064	14,193

9.768 + 0.862 + 2*18 MW => Power from Magnets, PS & Dumps to LCW

0.726 MW => Cables to Air=> approximately 60W/m in average

0.712 MW => PS to Air => taken out by Chilled water

Valencia 14/14 baseline. Conceptual CFS layout