BDS & MDI

Andrei Seryi, SLAC
for the Beam Delivery team

to be presented to ILC Accelerator Advisory Panel

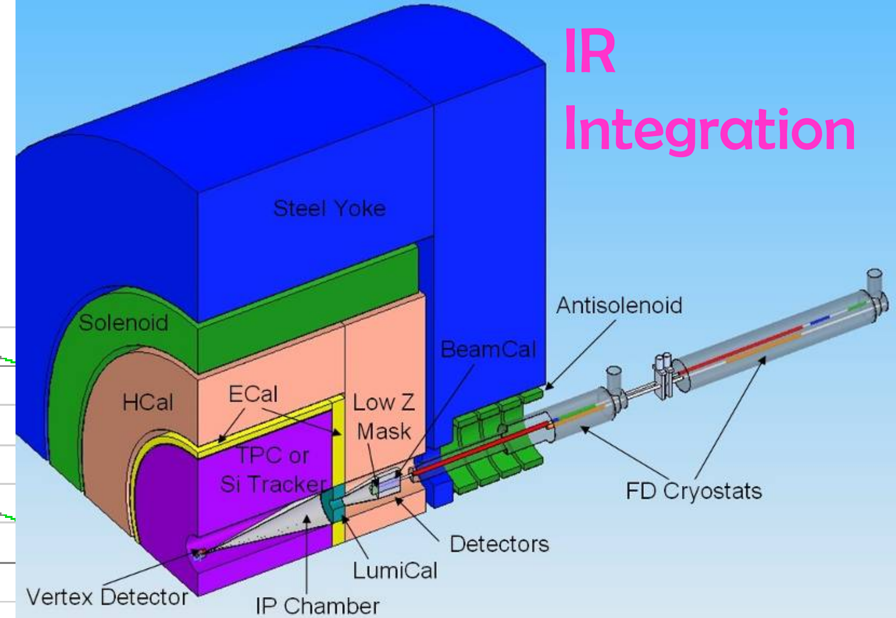
April 20, 2009

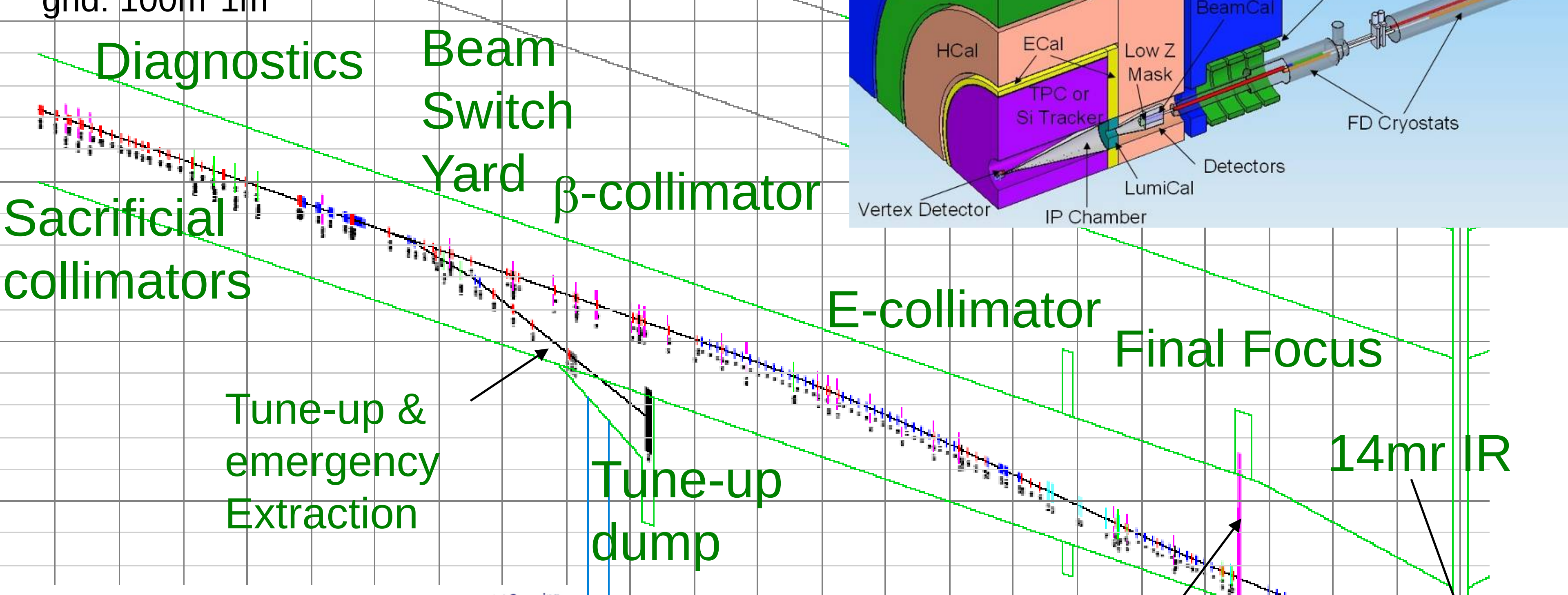
Plan of the talk

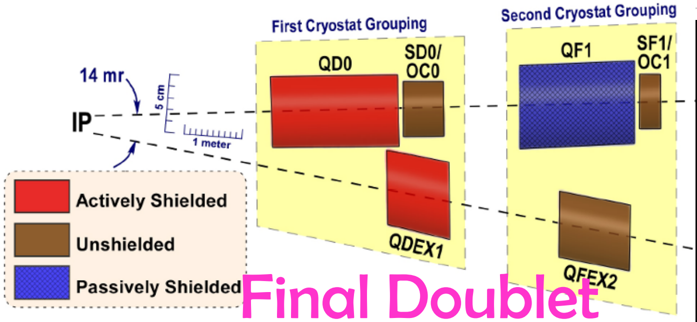
- BDS status and deliverables for TDP
- Organization
- IR Integration – MDI-D
  - IR Interface document
  - Next: design optimization
  - SC FD & test at ATF2
- Beam dump design; Crab cavity
- Explorations of ideas & options
  - long L*, Crystal collimation
- Low P parameters
- Staging & $\gamma\gamma$ study
- Plans for optics for new baseline & min machine

BDS RDR design

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







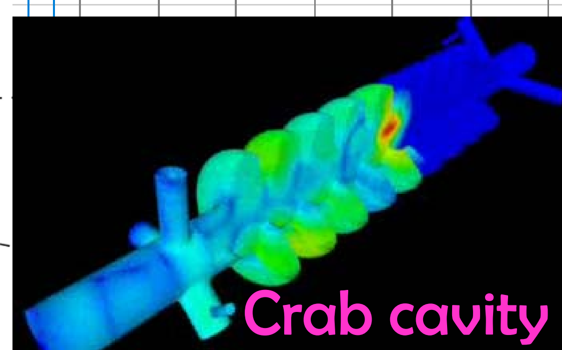


Table 3.4: TD Phase Beam Test Facilities Deliverables and Schedule.

Test Facility	Deliverable	Date
Optics and stabilisation demonstrations:		
ATF	Generation of 1 pm-rad low emittance beam	2009
ATF-2	Demonstration of compact Final Focus optics (design demagnification, resulting in a nominal 35 nm beam size at focal point).	2010
	Demonstration of prototype SC and PM final doublet magnets	2012
	Stabilisation of 35 nm beam over various time scales.	2012

BDS in GDE Technical Design Phase plan

3.3.5 Beam Delivery System

The main R&D focus for the BDS is the ATF-2 programme at KEK which will allow demonstrations of many of the key BDS components and design concepts, the Machine-Detector activity for optimization of the Interaction Region, and design for those BDS subsystems which are critical for system performance or which may expand the physics capabilities of the collider. Examples of R&D are:

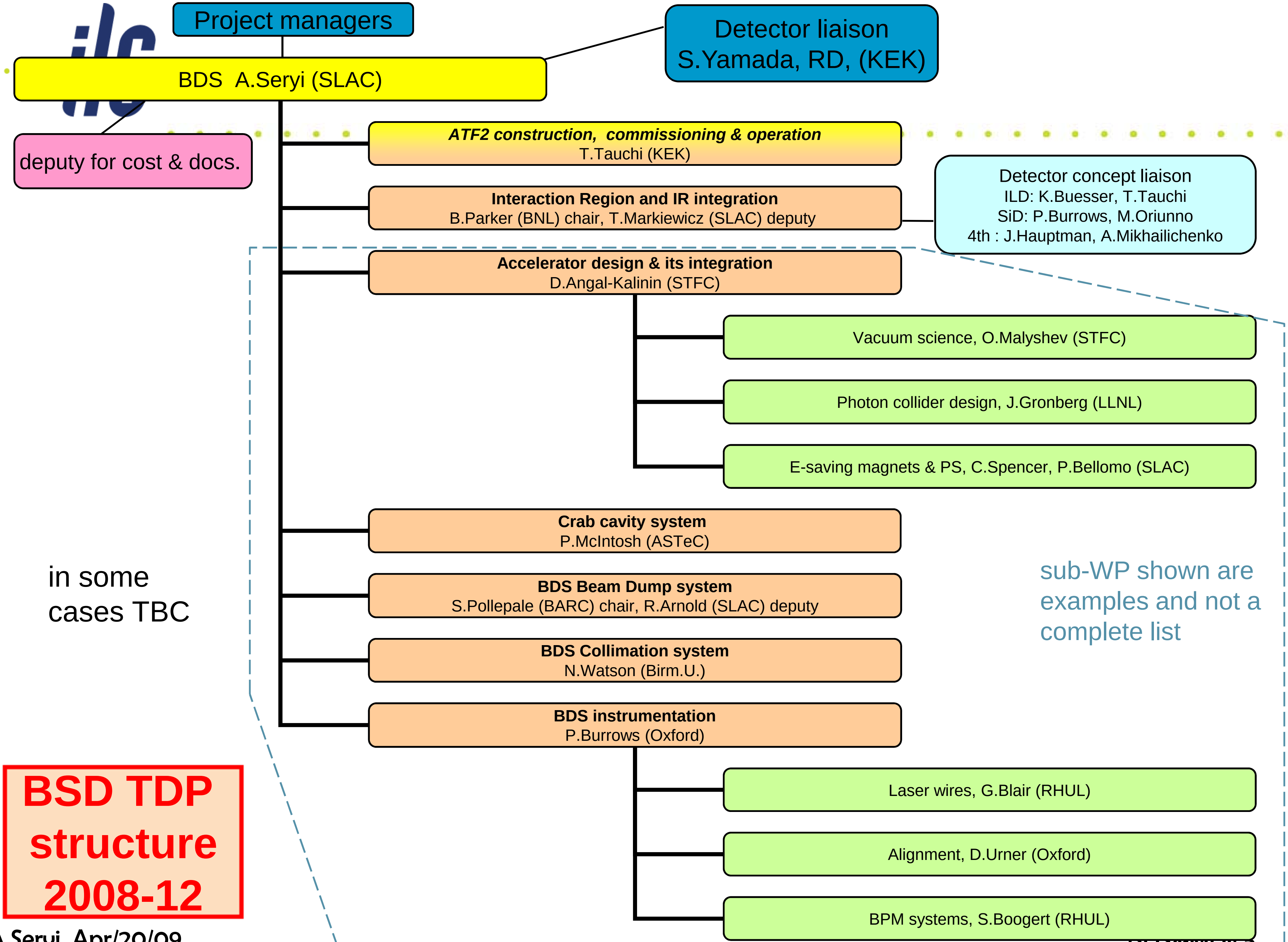
- Development of instrumentation (e.g. laser-wires), algorithmic control software, beam-based feedback systems and emittance-preservation techniques to achieve the small beam-size goals (2010)
- Developing of IR Interface Document defining MDI specifications and responsibilities (2010) and design or optimised IR (2012)
- Development of the prototype of the Interaction Region SC Final Doublet (2012)
- Development of Interferometer system for FD stability monitoring (2012)
- Design of the beam dump system (2012)
- Tests of SC and PM Final doublet at second stage of ATF2 (2012)
- Design studies for the photon collider option (2012)
- Collimation and dump window damage tests at ATF2 (2010)
- Development and demonstration of the SCRF crab-cavity system (2010)

Plus, the min machine study

may be delayed

may be limited in scope

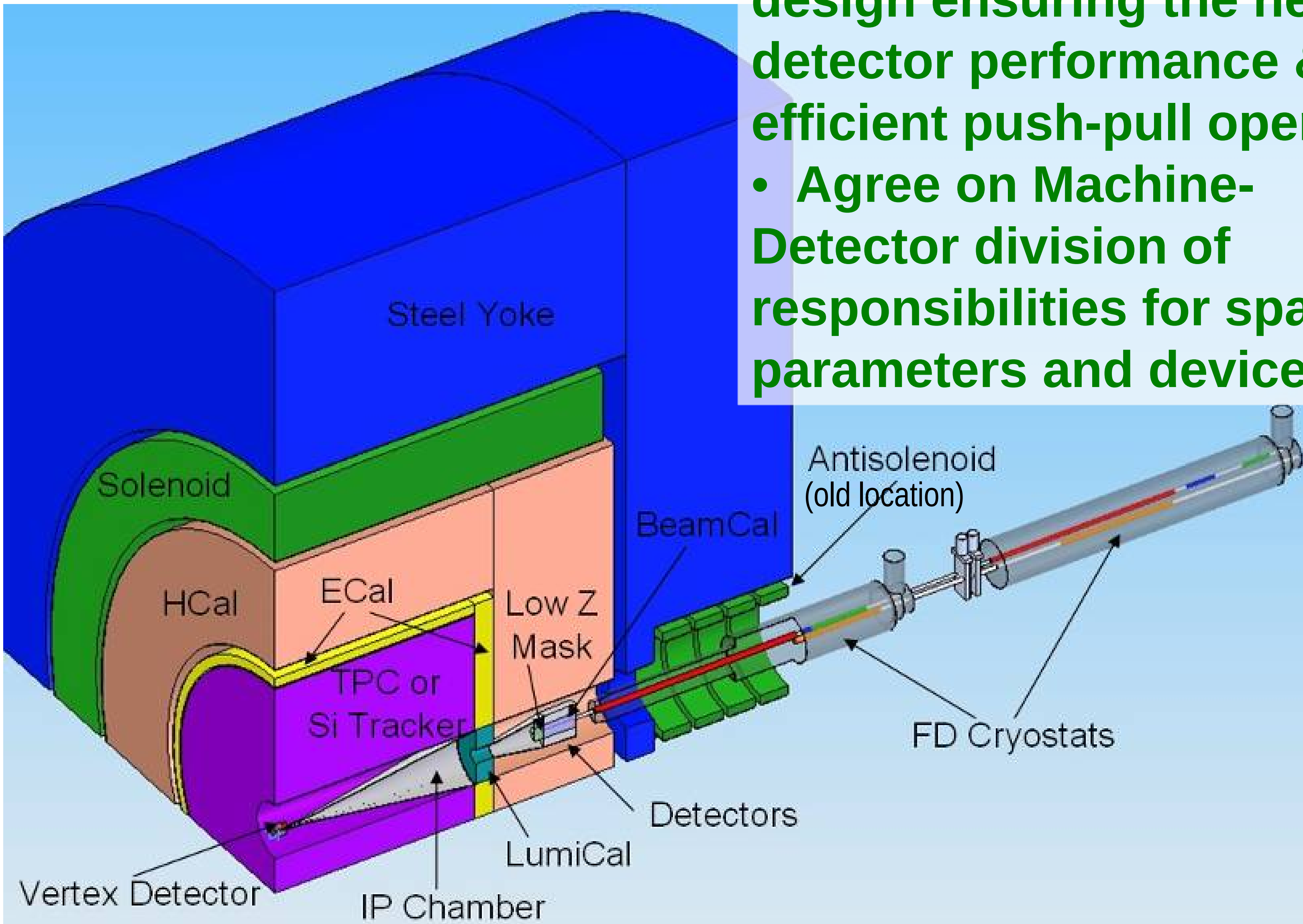
BSD TDP structure 2008-12



in some cases TBC

sub-WP shown are examples and not a complete list

IR integration & MDI

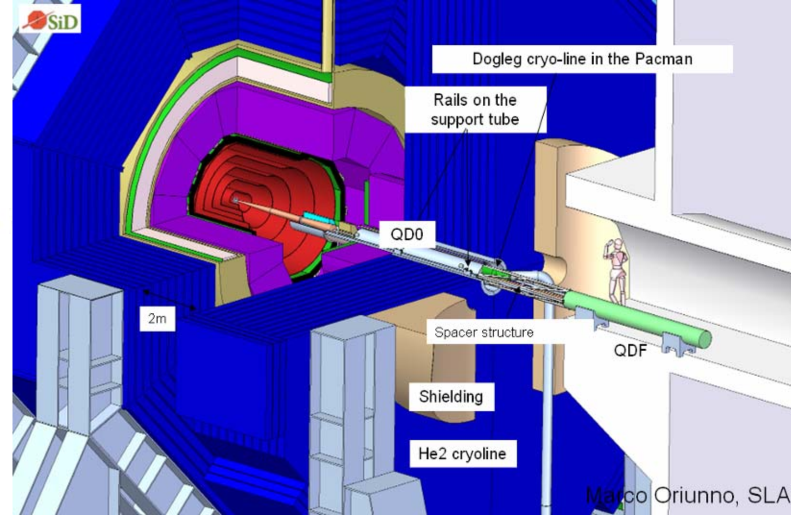


Challenges:

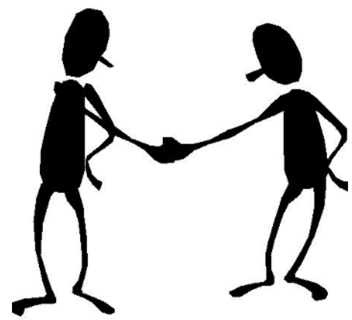
- **Optimize IR and detector design ensuring the needed detector performance & efficient push-pull operation**
- **Agree on Machine-Detector division of responsibilities for space, parameters and devices**

IR integration

PLAN AS SHOWN IN EARLY 2008 (Sendai):



- Machine – Detector work on Interface issues and integration design is a critical area and a focus of efforts
- IR integration timescale
  - EPAC08 & Warsaw-08
    - Interface document, draft
  - LCWS 2008
    - Interface doc., updated draft
  - LOI, April 2009
    - Interface document, completed
  - Apr.2009 to ~2012
    - design according to Interface doc.



ILC-Note-2009-050
March 2009
Version 4, 2009-03-19

Functional Requirements on the Design of the Detectors and the Interaction Region of an e^+e^- Linear Collider with a Push-Pull Arrangement of Detectors

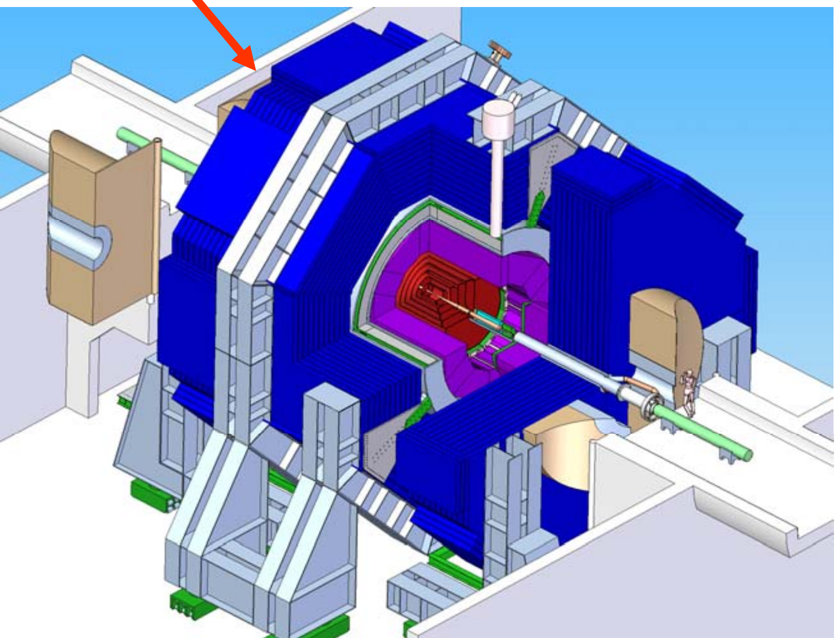
B.Parker (BNL), A.Mikhailichenko (Cornell Univ.), K.Buesser (DESY), J.Hauptman (Iowa State Univ.), T.Tauchi (KEK), P.Burrows (Oxford Univ.), T.Markiewicz, M.Oriunno, A.Seryi (SLAC)

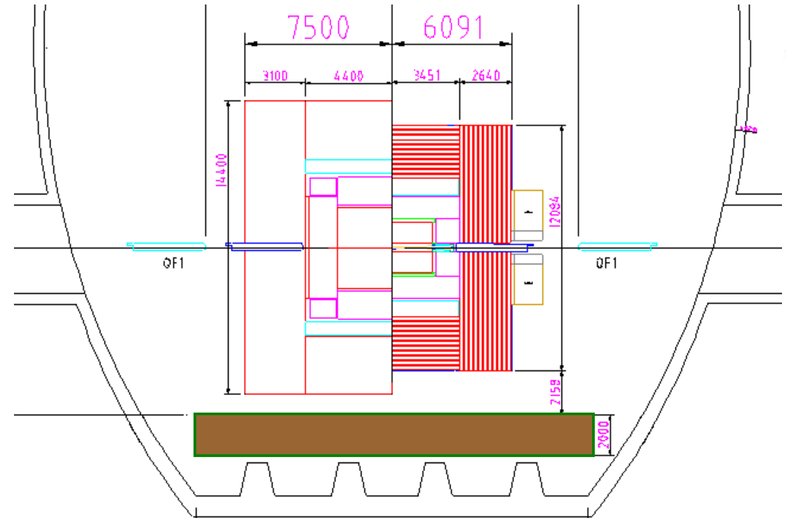
Abstract
The Interaction Region of the International Linear Collider [1] is based on two experimental detectors working in a push-pull mode. A time efficient implementation of this model sets specific requirements and challenges for many detector and machine systems, in particular the IR magnets, the cryogenics and the alignment system, the beamline shielding, the detector design and the overall integration. This paper

http://ilcdoc.linearcollider.org/record/21354?ln=en

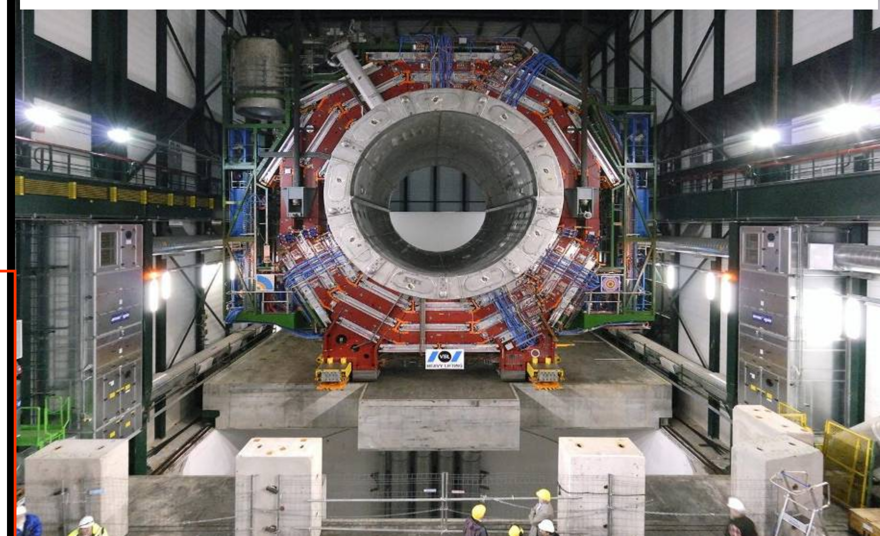
MDI issues to keep working on

Detector motion system with or without an intermediate platform



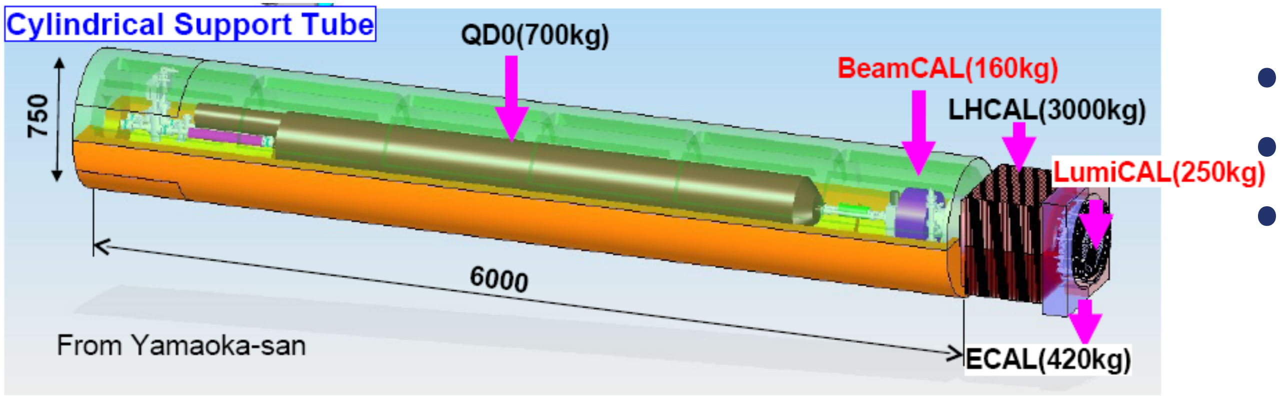


CMS platform – proof of principle for ILC



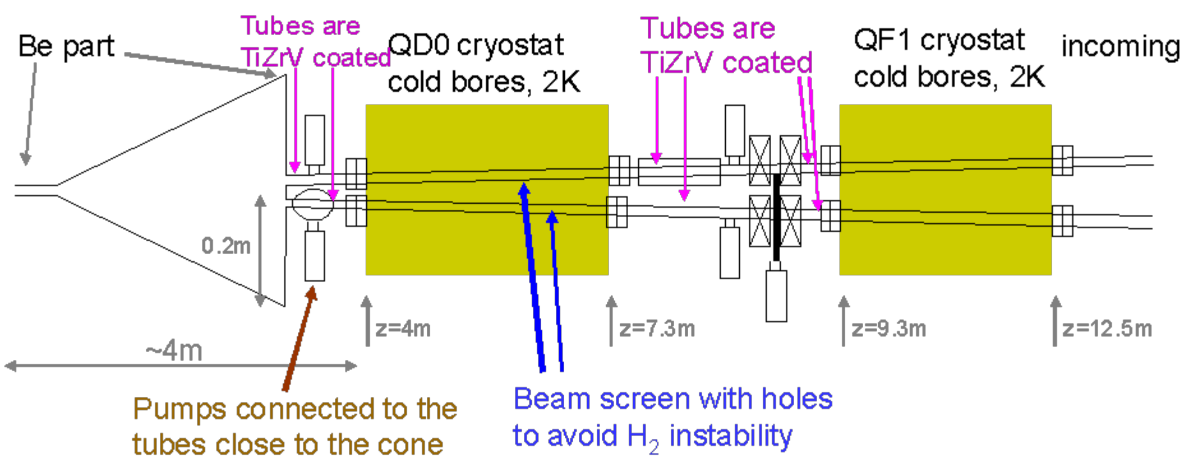
Planning for further design work aiming to bring different push-pull solutions to a compatible and cost effective design

Important MDI issues, examples



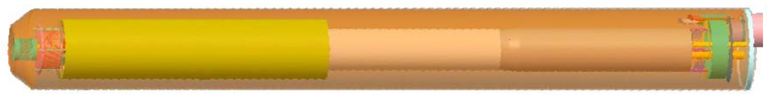
- < 50nm for QD0 stability
- compact movers for QD0
- support ~3t LHCAL mass such that it does not adversely affect the QD0 dynamics

• Recently re-started Vacuum Science task force, led by Oleg Malyshev, STFC, focusing on IR vacuum system

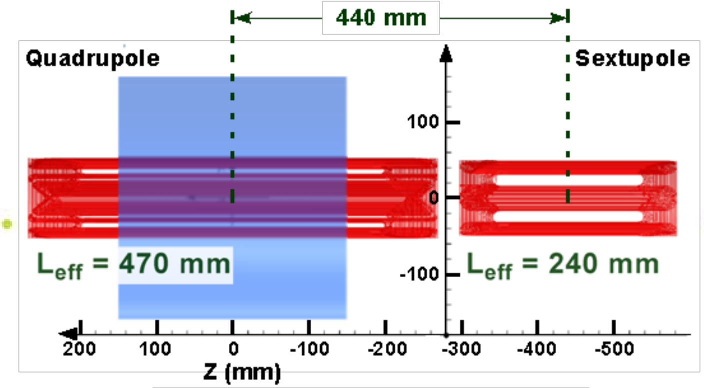


- May need pump close to IP
- Do not rely solely on QD0 cold bore cryo-pumping
- High Order Modes
- Support and alignment of IR chamber and VX
- Assembly, flanges…

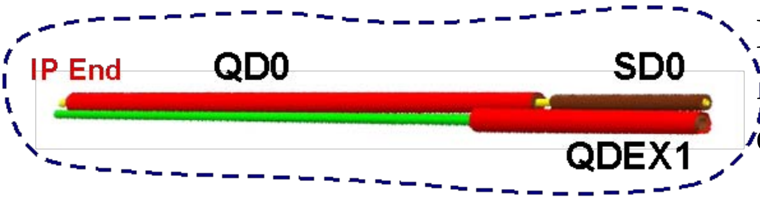
SC FD modified plans and ATF2 tests



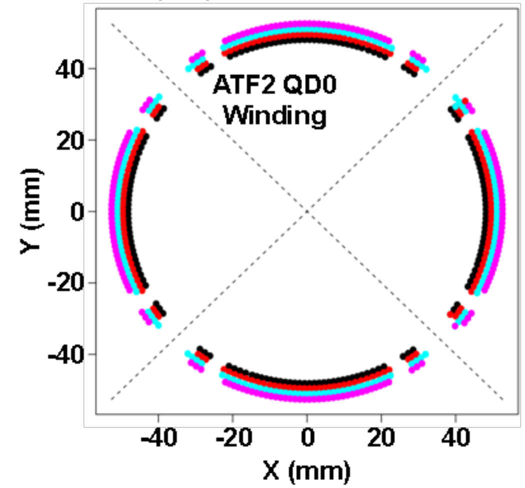
QD0 Cryostat Design for L* = 4.5 m.



Brett Parket, at al, BNL



Earlier plan was to prototype ILC-like QD0 magnet with cryostat & study its stability

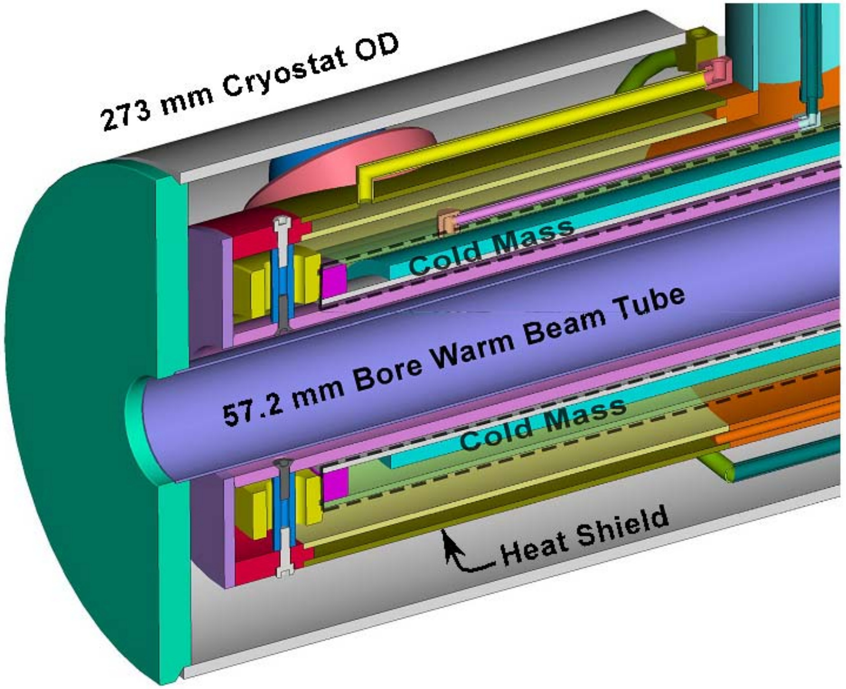


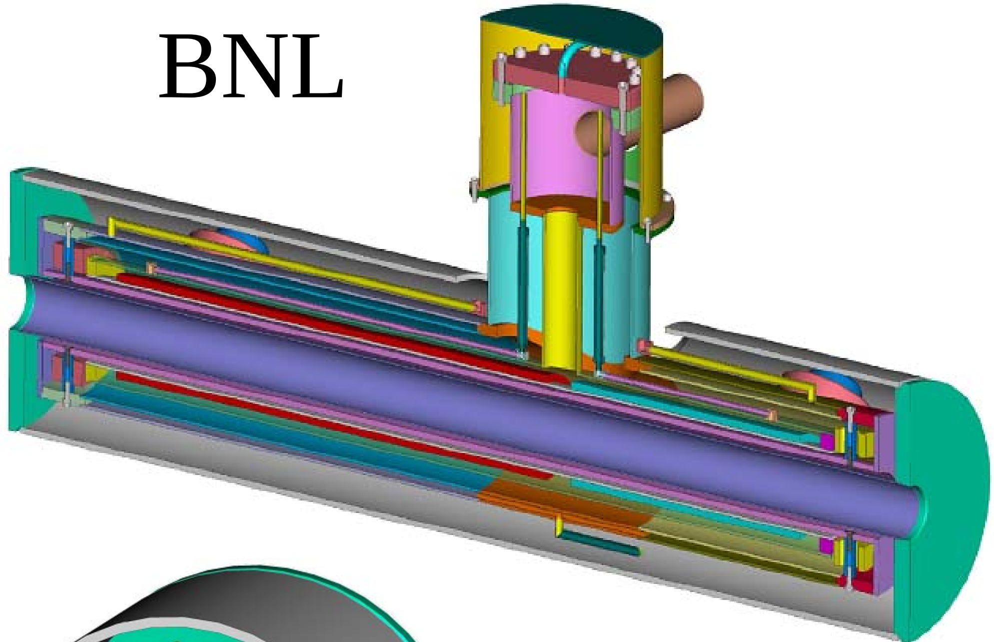
- In TDP, plans for SC FD prototype at BNL were adjusted
  - delay efforts on ILC-like FD prototype; for near-term only make long cold mass and perform its field tests (cryostat later)
  - enhance efforts on ILC-technology-like SC Final Doublet for ATF2 upgrade

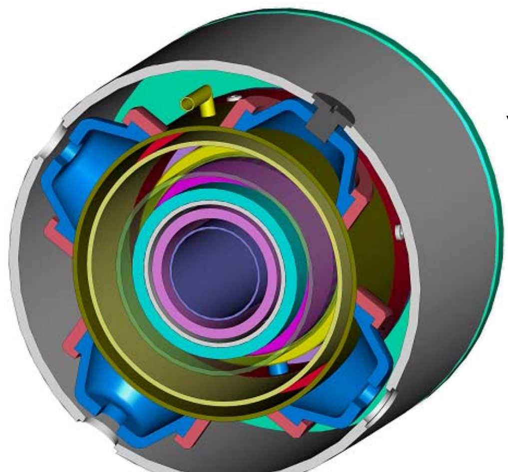
- Only produce one quadrupole/sextupole magnet combination (in common cryostat).
- No self-shielding or anti-solenoid (simple).
- KEK Cryogenic system (major challenge).
- 50 mm aperture but with a warm bore (i.e. optimize to limit cold mass heat leak).
- Minimum degrees of freedom (correctors).
- Found it easy to match corrector coils and main coil magnetic lengths.

SC FD for ATF2

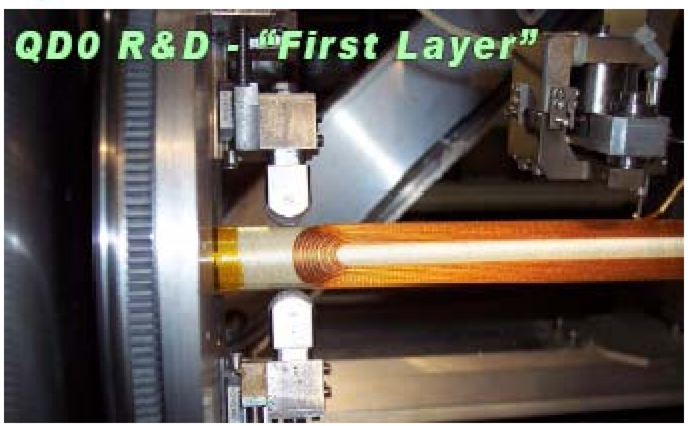
BNL





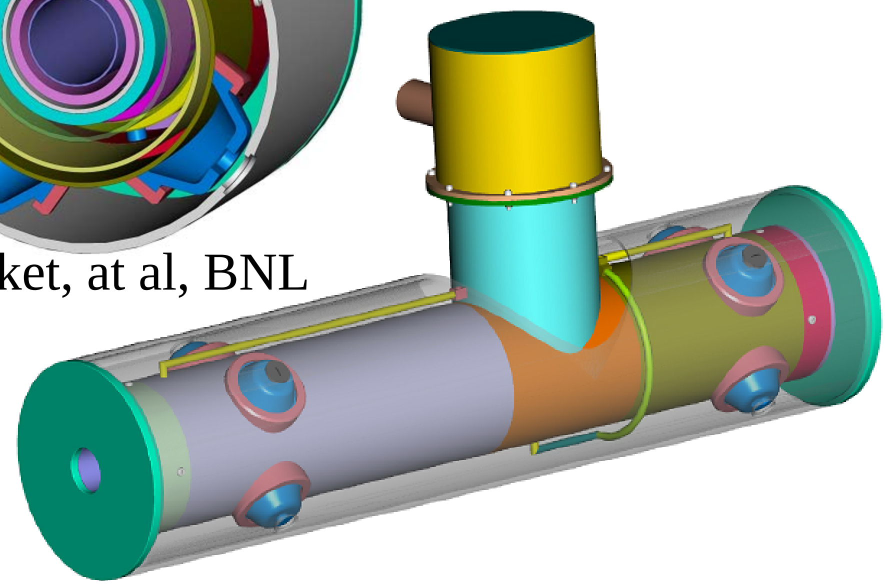


View Inside Cryostat of Support Structure



Long coil winding

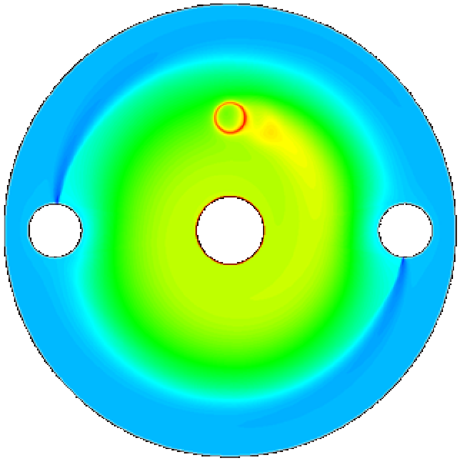
Brett Parket, at al, BNL



Cross Section View at Support Location

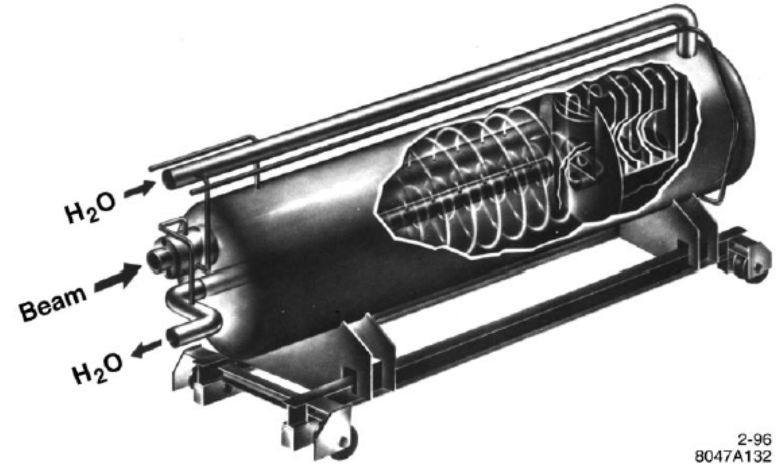
18MW Beam dump

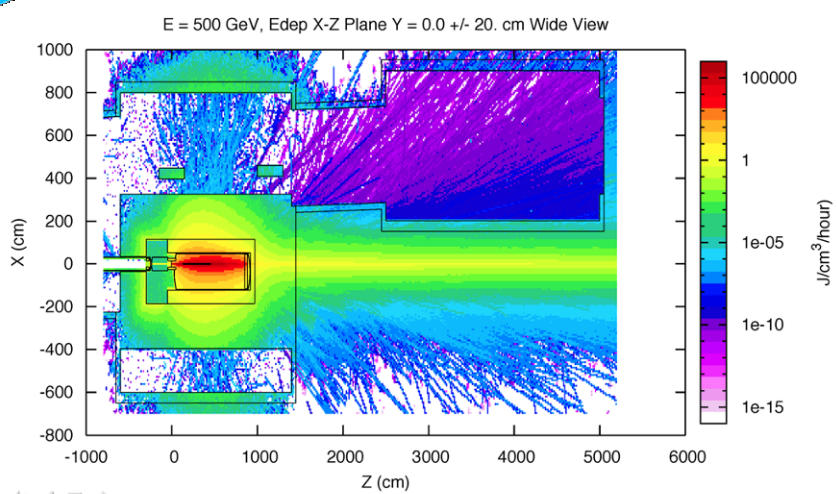
BARC, India, & SLAC, collaboration

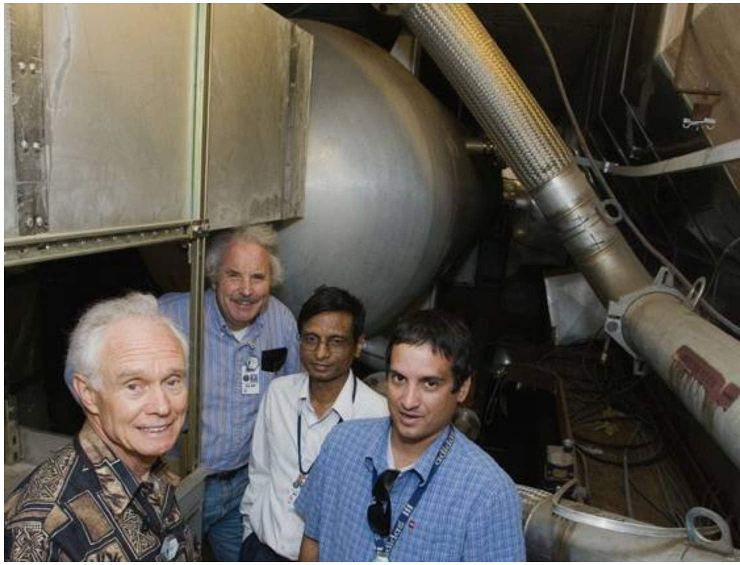


Beam dump with double header (Satyamurthy Polepalle et al, BARC-SLAC)

Maximum Temperature – 147^0C
Maximum delta T – 28^0C





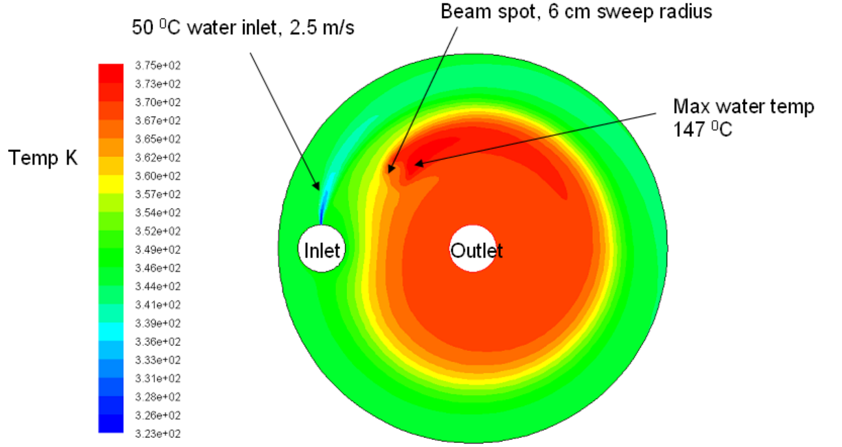


Dieter Walz, Ray Arnold, Satyamurthy Polepalle (BARC, India), John Amann, at SLAC beam dump area (February 2008)

Planning for the next working meeting of the task force at SLAC in ~May 2009, to continue the work on beam dump design

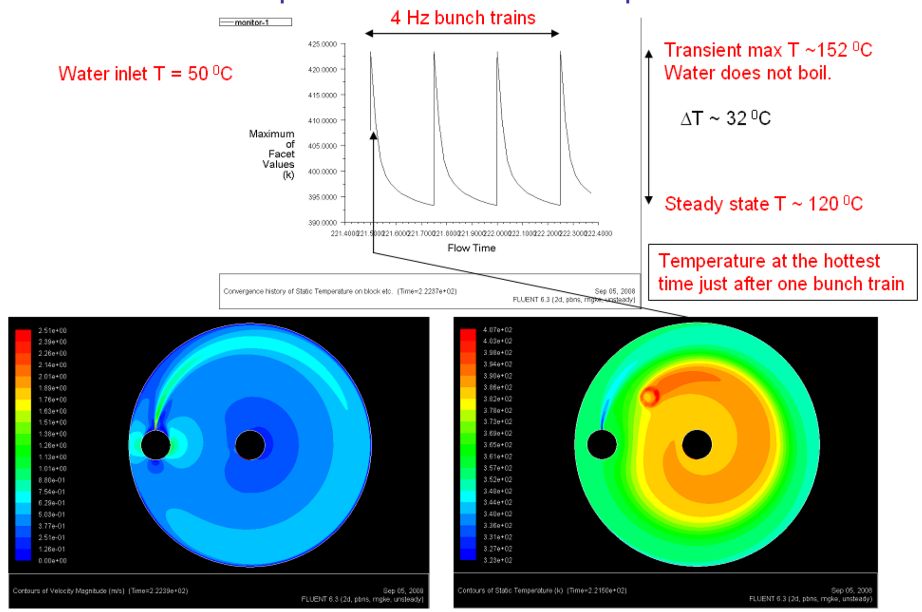
Space Distribution of Steady State Water Temperature

Use 2-D FLUENT models to study water velocity, header size, beam spot location, sweep radius.



Temperature contours for CASE 5b (At location of Z=1.82 m for 2.50 m/s nozzle velocity without blocking outlet)

Time Dependence of Water Temperature

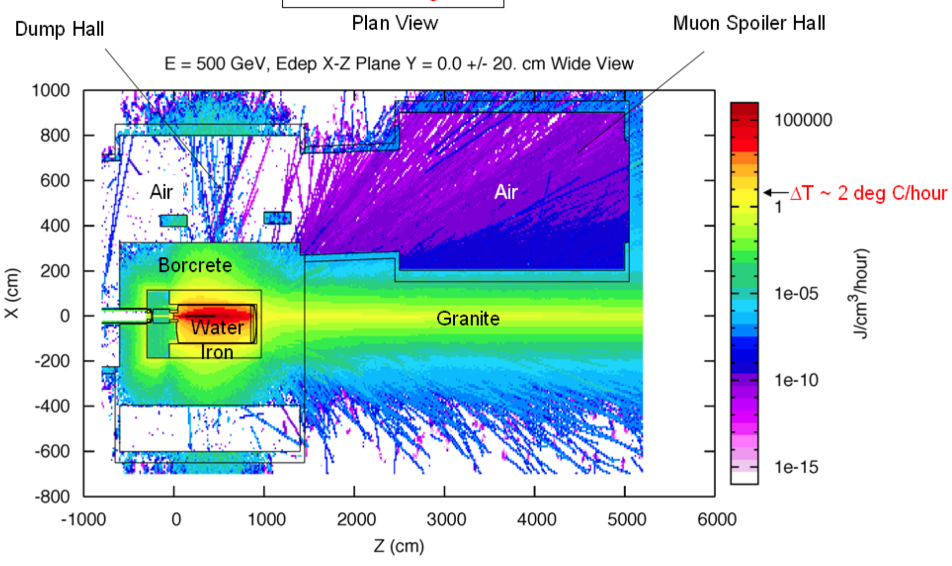


Velocity distribution at 222.3 seconds

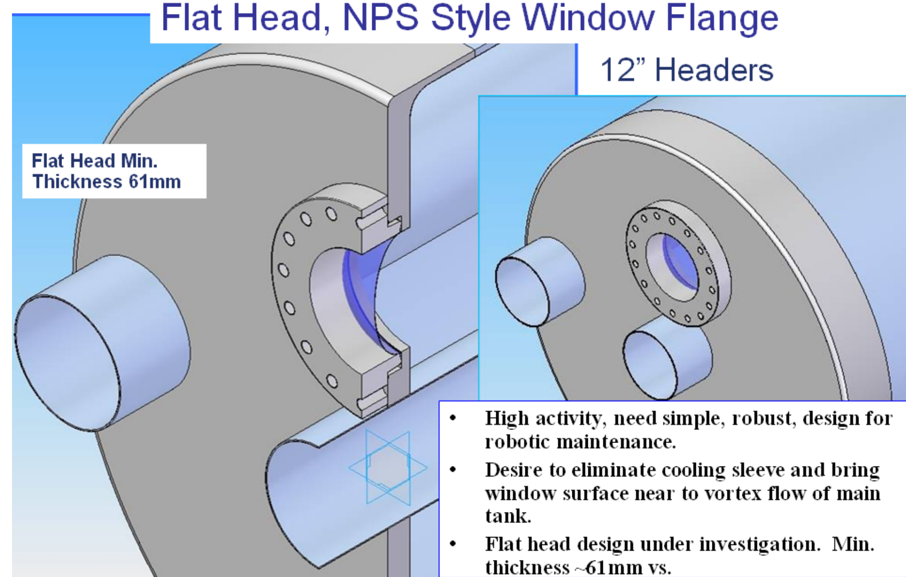
Temperature Distrubution at 221.5 seconds

Prompt Energy Deposition - J/cm^3/hour - Geometry V2

Even the rocks get hot!



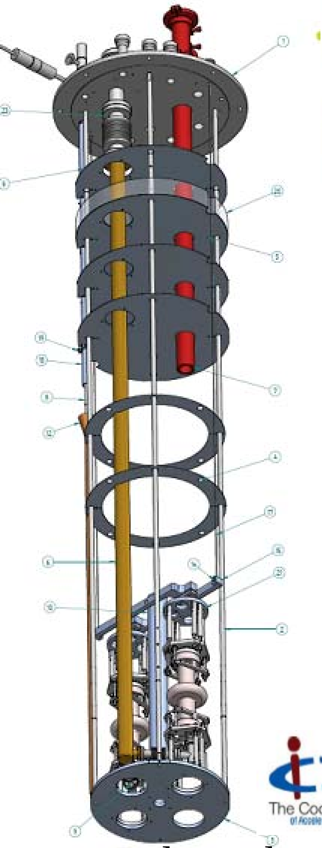
Variation of Baseline Design
Flat Head, NPS Style Window Flange

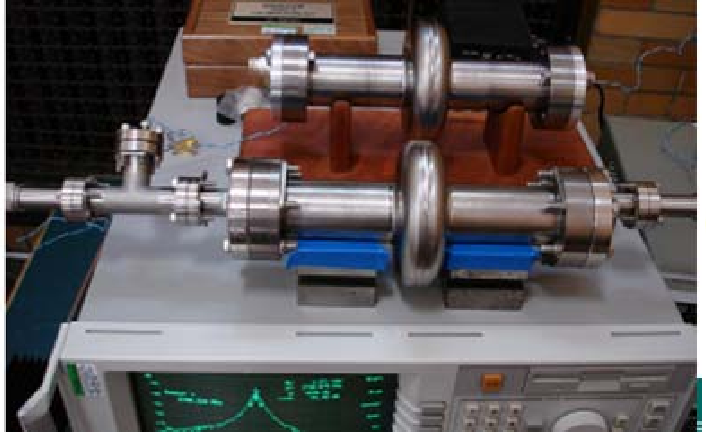


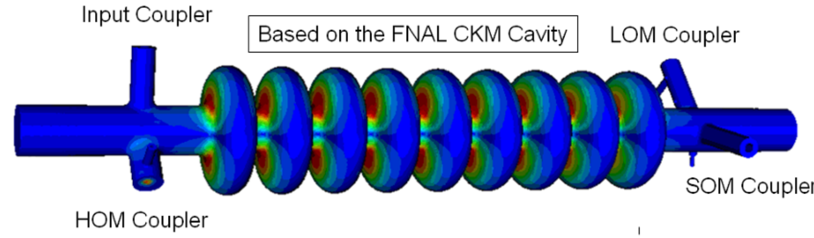
- High activity, need simple, robust, design for robotic maintenance.
- Desire to eliminate cooling sleeve and bring window surface near to vortex flow of main tank.
- Flat head design under investigation. Min. thickness ~61mm vs.

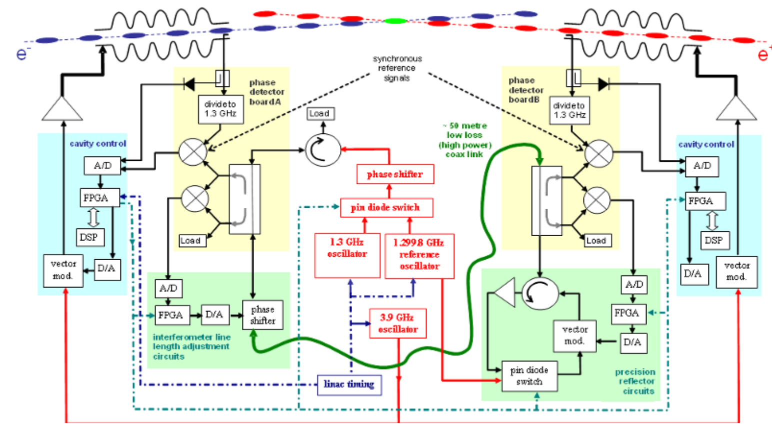
BDS updates, continued

- Re-started work with Rad. physics group (KEK & SLAC colleagues) for shielding calculations
- The power saving magnet group is proceeding with their work
- Collimation – prepare for beam damage tests at ATF2
- Crab cavity work proceeding at STFC, looking for improvement of stability results
  - very promising results (illustration on next page)
  - further steps after this year being discussed
  - very tentative considerations of CC test at ATF2 (to create trav. focus) – (issues: cryostat & cryo integration)

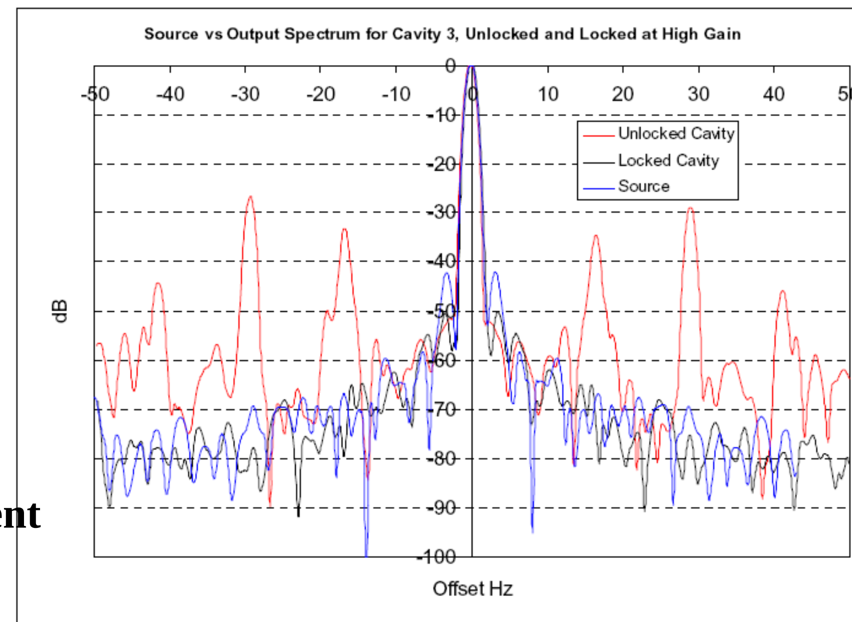








Cavities limited in gradient to 1 MV/m (~40kV/cell) – shielding implications.



Independent phase lock achieved for both cavities:

– **Unlocked => 10º r.m.s.**

– **Locked => 0.135º r.m.s.**

• Performance limited by:

– **Source noise (dominant); ADC noise; Measurement noise; – Cavity frequency drift; Microphonics**

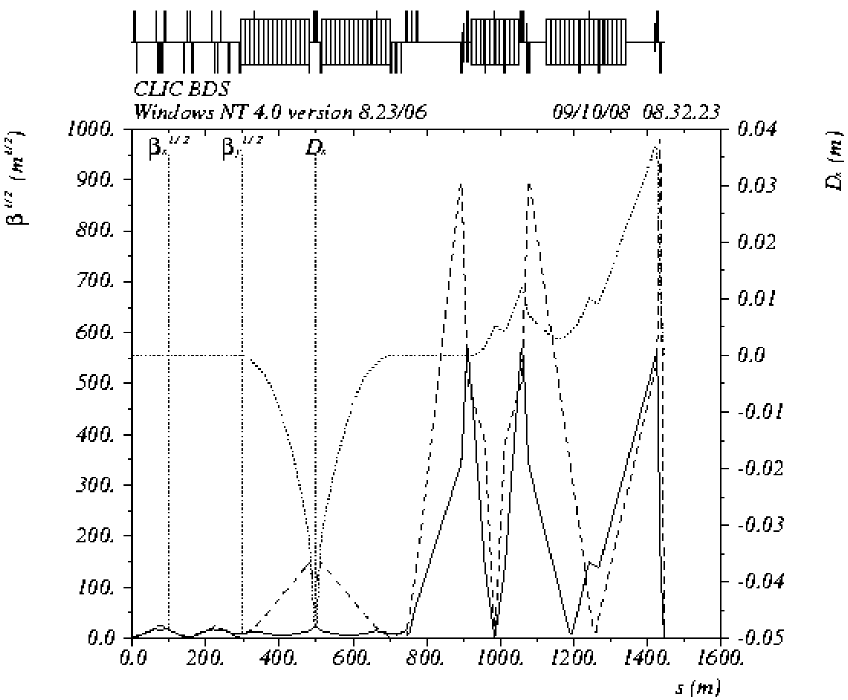
• Improvements being made; new tests being prepared

P.McIntosh at al

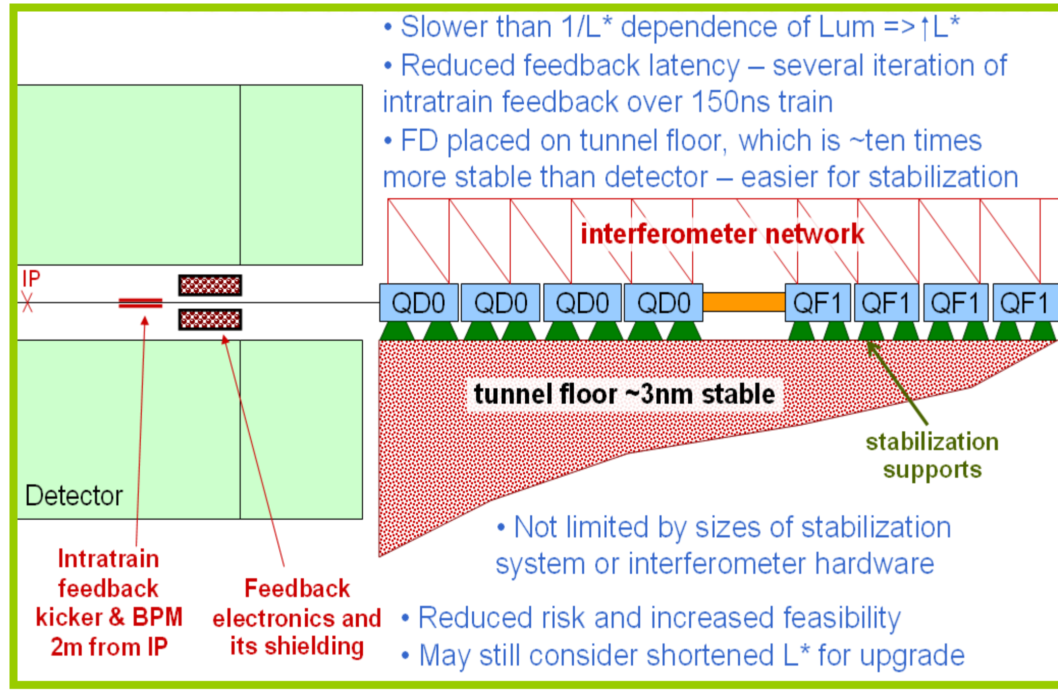
Exploration of ideas & tests for more performing machine

- Longer L* or smaller beta*
  - Minimal machine may require tighter focusing at IP
  - CERN/CLIC colleagues suggested to study squeezed y-beta* at ATF2 (0.025 mm instead of 0.1 mm nominal)
    - Squeezed beta* study at ATF2 is one of example of strong synergy and mutual benefits of ILC-CLIC collaboration
  - Such study may support
    - Test of high chromaticity FF, as in CLIC FF design
    - Smaller β^* for "New Low P" parameters of ILC
    - Lengthening L* for easier MDI
- Crystal collimation
  - Exploring Volume Reflection radiation in bent crystals as a phenomena to improve collimation system of linear collider

Longer L* or smaller beta*



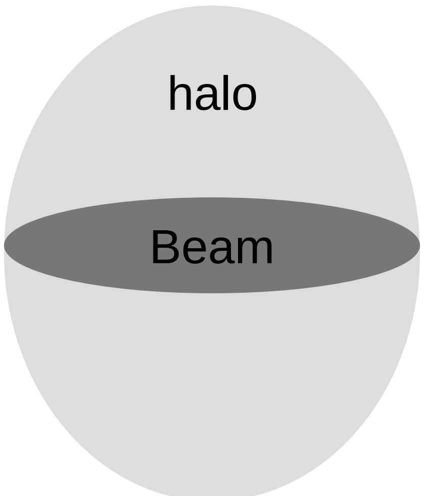
“ Doubled L* design ”, L*=8m, 3TeV CMS CLIC

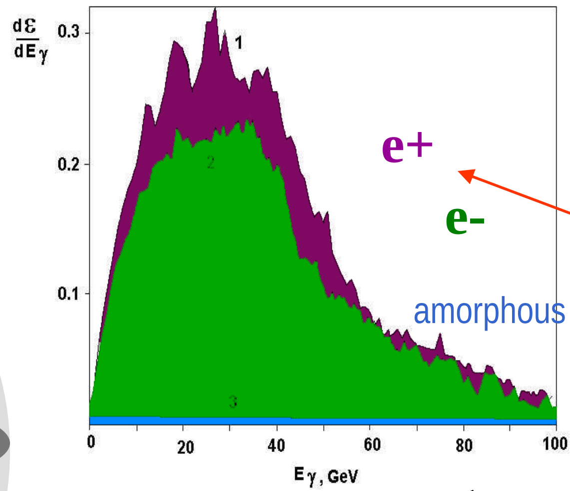


- Study prompted by the CLIC FD stability challenge (< 0.2nm)
- Double the L* and place FD on a stable floor
- Initial study show that L*=8m optics is possible (CLIC08 workshop)
  - CLIC colleagues are studying impact on field and alignment tolerances

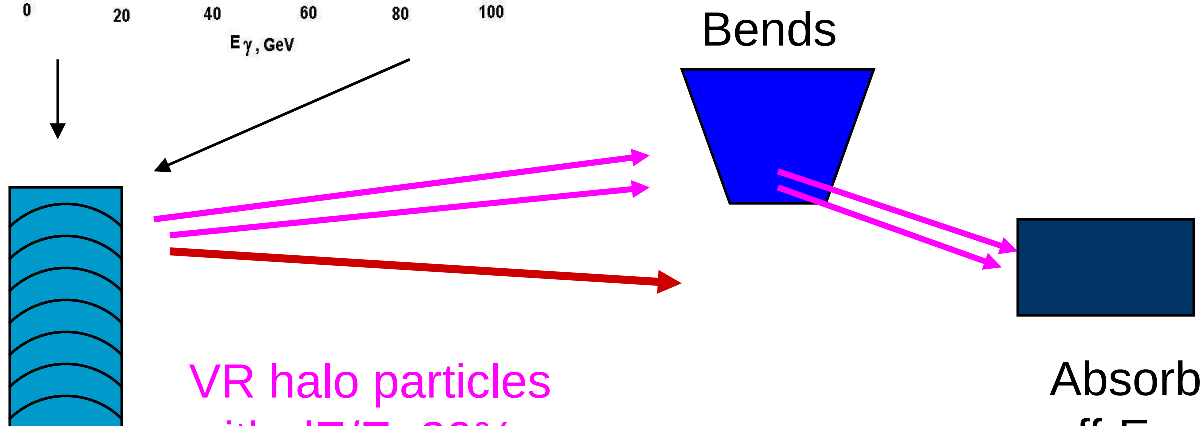
LC Collimation concept based on Volume Reflection radiation

VR radiation is very similar for both e+ & e-, and has large angular acceptance – it makes this phenomena good candidate for collimation system of linear collider





Volume reflection radiation spectrum of 200GeV e+ or e- on 0.6mm Si crystal (R_{bend}=10m) Yu. Chesnokov et al, IHEP 2007-16



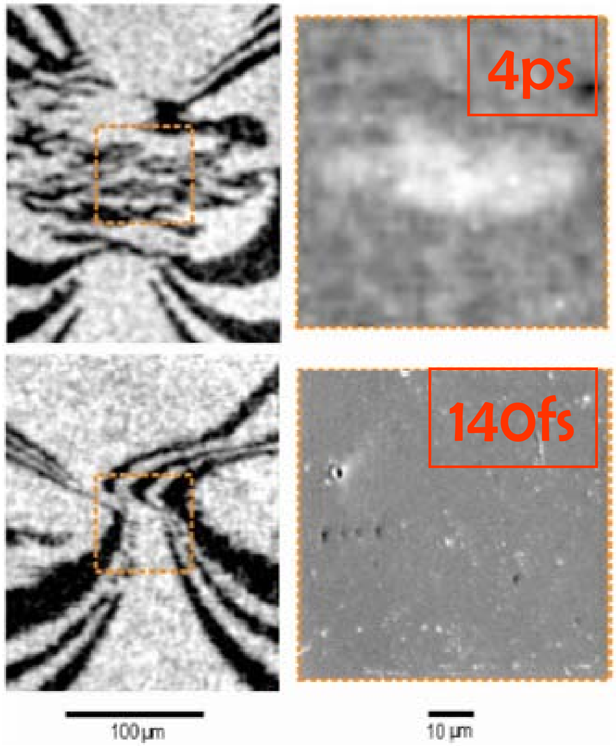
Crystal & Volume Reflection

VR halo particles with dE/E~20% loss due to VR radiation

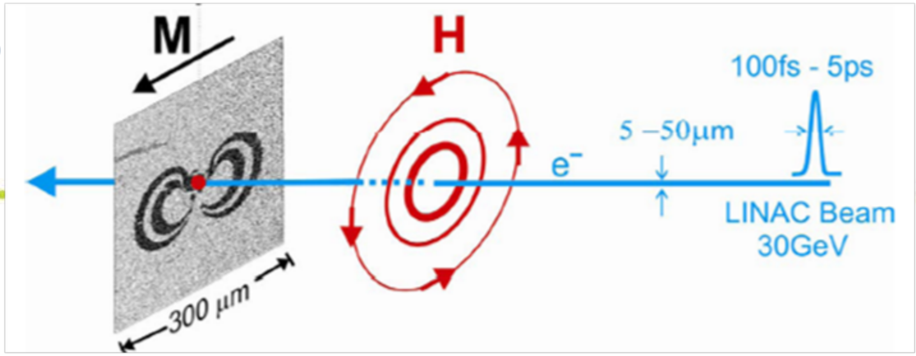
photons of VR radiation (to be absorbed in dedicated places)

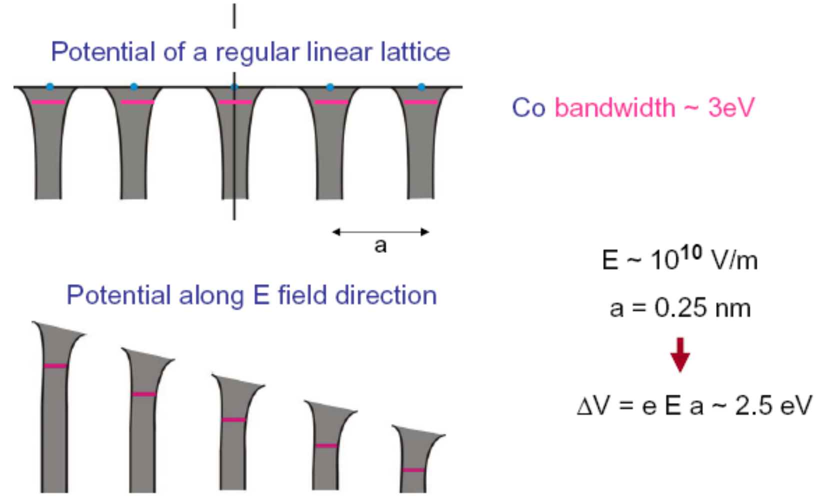
Absorb off-Energy particles & photons

Crystal (or spoiler) survivability



*New effect observed: while there was damage of a sample observed for 4ps beam, this damage disappeared for a shorter 140fs beam.





For short bunches the field gradient exceeds 2.5V over distance between atoms.

Potential wells around each atom shift, and conduction zones do not overlap any more.

=> breakup of conduction path, no current, no heat transfer and no damage.

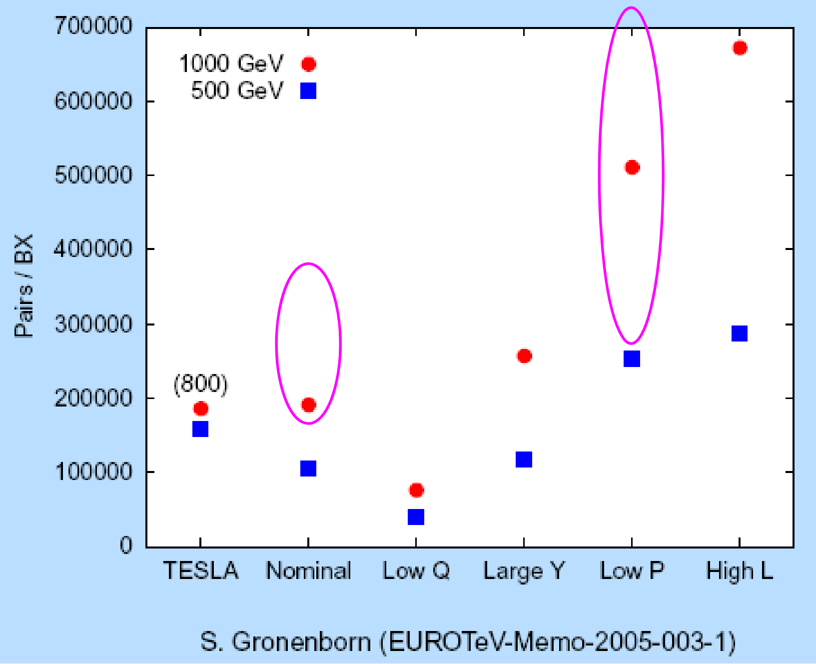
Energy still goes into the material, but is probably dissipated via emission of terahertz photons

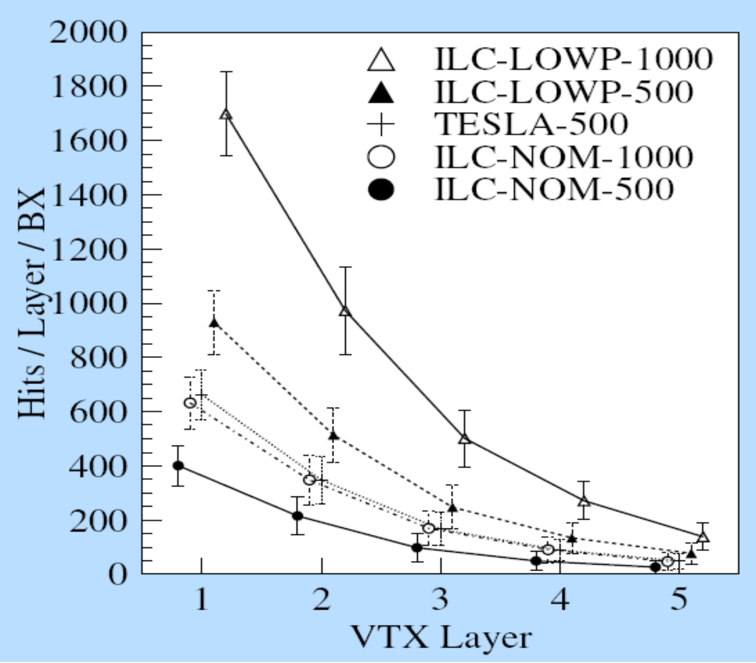
J. Stohr (SLAC), et al, "Exploring Ultrafast Excitations in Solids with Pulsed e-Beams", presented on Feb 19, 2008 at SLAC FACET review, http://www-group.slac.stanford.edu/ppa/Reviews/facet-review-2008/Agenda.asp

This may show that approach to collimation design has been conservative

Low Power option

- Motivation: reduction of beam power => potential cost reduction; reduced cryo system; smaller diameter damping rings, etc.
- The RDR "low power" option may be a **machine** "cost saving" set but it is not a favorite set for detectors:





- Improved Low P may require tighter IP focusing, and use of "travelling focus" [V.Balakin, 1990]

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 $\delta E/E$	**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 $\sigma_z*2*3^{1/2}$

Travelling focus allows to lengthen the bunch

Thus, beamstrahlung energy spread is reduced

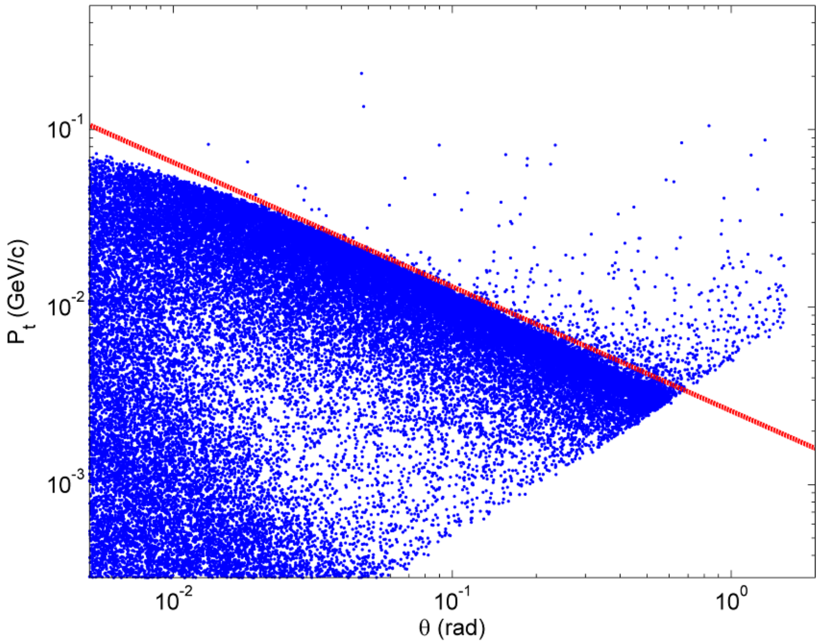
Focusing during collision is aided by focusing of the opposite bunch

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

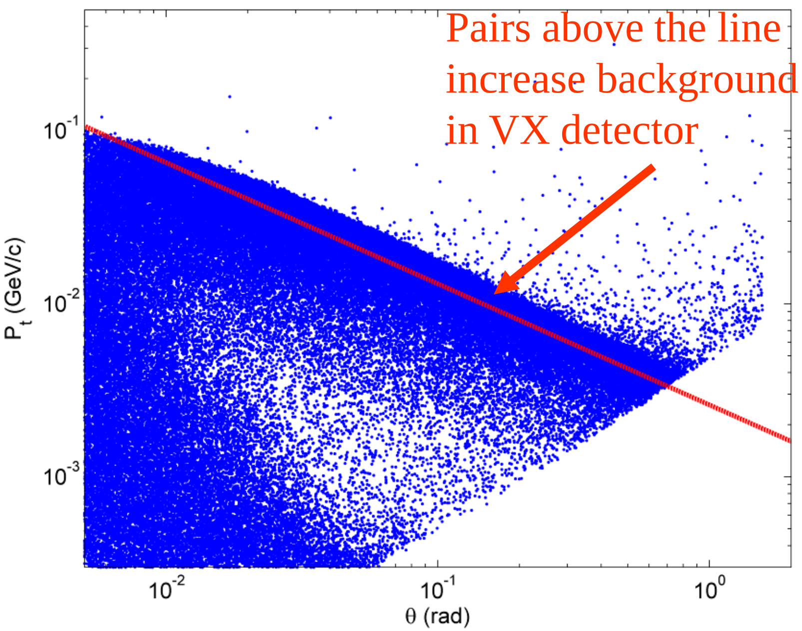
e+e- pairs

- Edge of pairs distribution in θ-P_t important for VX background
- RDR Low P: edge higher=> unfavorable for background
- New Low P: edge location similar as RDR Nominal

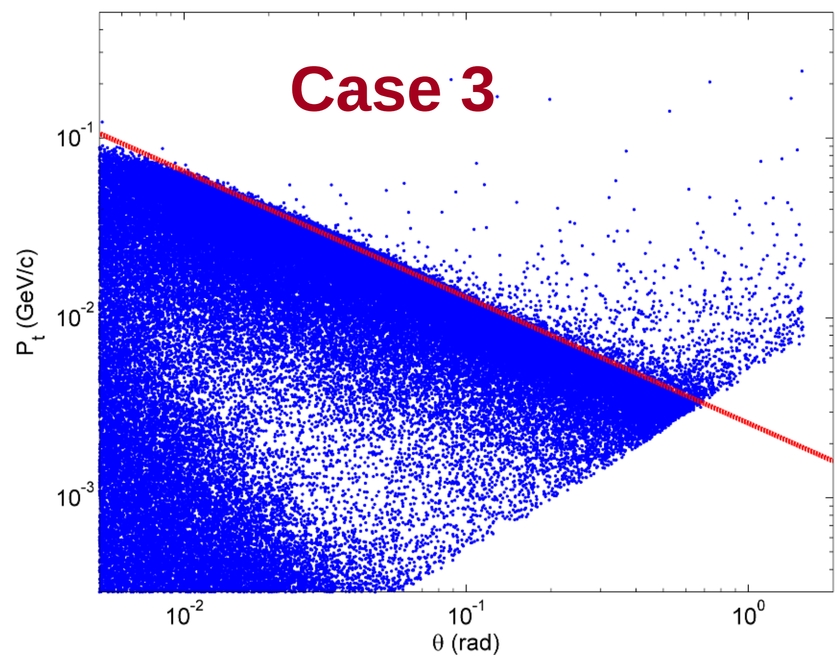
RDR Nominal



RDR Low Power



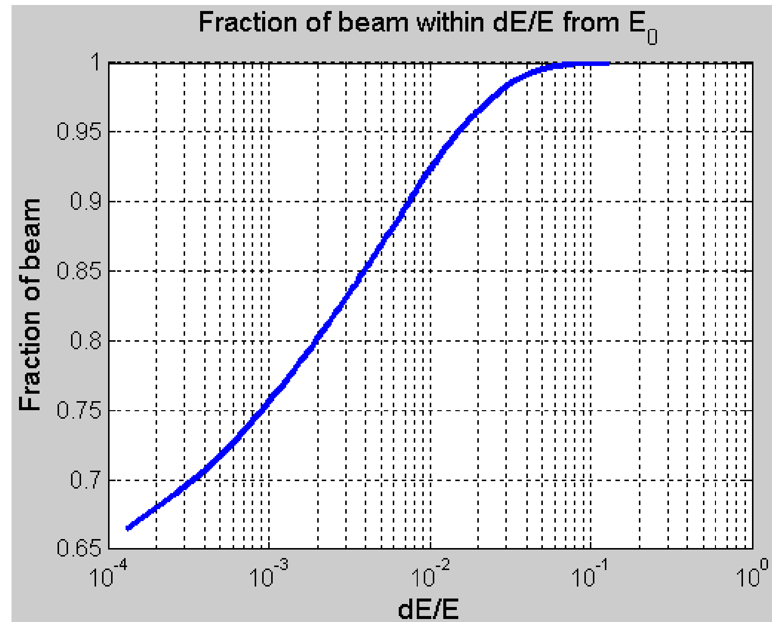
New Low Power (Travelling focus)



Independently confirmed by Takashi Maruyama

	Nominal RDR	**E-Recycle** trav. foc.
E CM (GeV)	500	500
N	2.0E+10	**5.0E+09**
n_b	2625	**11000**
Tsep (ns)	369.2	90.0
Iave in train (A)	0.0087	0.0089
f_{rep}(Hz)	5	5
P_b (MW)	**10.5**	**11.0**
$\gamma\varepsilon_X$ (m)	1.0E-05	4.0E-06
$\gamma\varepsilon_Y$ (m)	4.0E-08	2.0E-08
β x/y (mm)	20 / 0.4	20 / 0.4
σ x/y (nm)	639 / 5.7	404 / 4.0
σ_z (mm)	0. 3	**0.6**
Dy	19.0	21.2
Uave	0.047	0.009
δ_B	**0.023**	**0.002**
P_Beamstrahlung (MW)	0.24	0.024
ngamma	1.29	0.53
Hd	1.70	**1.53**
Geom Lumi (cm-2 s-1)	1.14E+34	6.69E+33
Luminosity (cm-2 s-1)	**1.95E+34**	**1.02E+34**

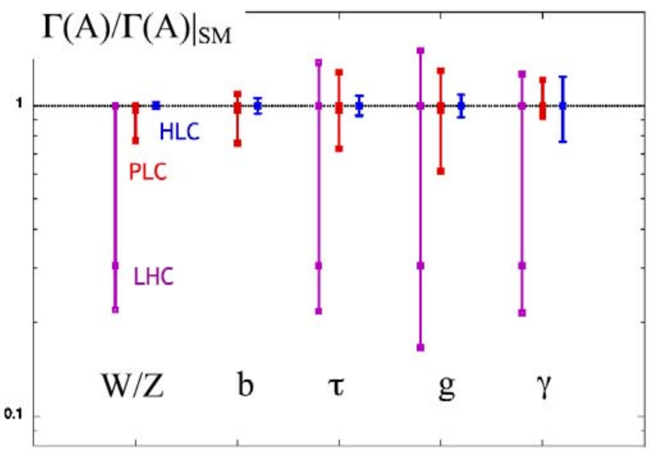
- Spin-off of the study:
- an academic curiosity
- Parameter sets with very low beamstrahlung

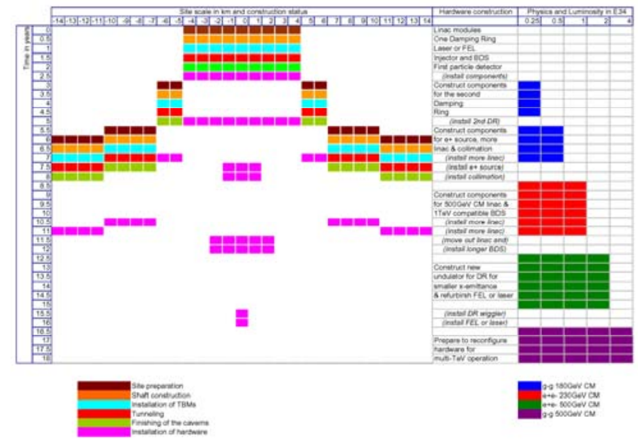


- About 92% of outgoing beam have dE/E < 1%

Contribution to the report on staging

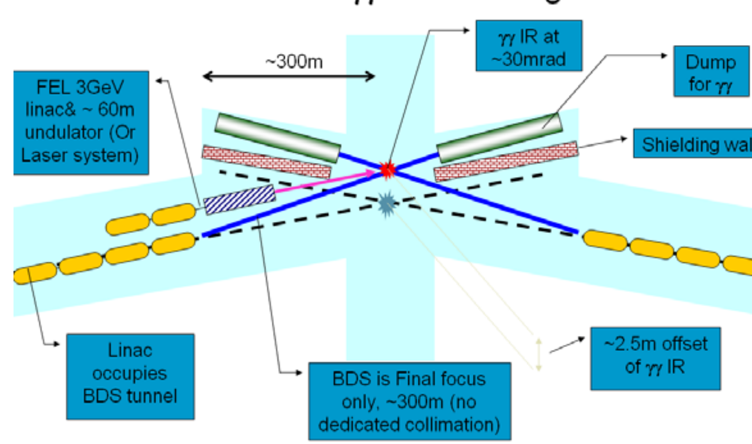
Stage	E CM (GeV)	Mode	E reach (GeV)	BDS (km per side)	Total site (km)	Lumi E34	Physics program (yrs)	Features
1st	180	$\gamma\gamma$	128	0.3	8.8	0.25	2	Single DR
2nd	180	$\gamma\gamma$	128	0.3	8.8	0.5	2	Faster kicker
3rd								or second DR
4th	230	e^+e^-	230	0.8	12.1	0.9	3	Add e+ source Lengthen BDS Add dedicated collimation
5th	500	e^+e^-	500	2.2	27.2	2	5	Lengthen BDS to 1 TeV layout
6th	500	$\gamma\gamma$	400	2.2	27.1	4.5	2	Lower DR x-emittance





- GDE requested to evaluate $\gamma\gamma$ as 1st stage – a report edited by M.Peskin, T.Barklow, J.Gronberg & A.S.
  - Physics case, machine configuration, IP parameters, laser or FEL photon driver, tentative cost
- Cost comparison (P.Garbincius)
  - 180 GEV CM photon collider PLC (costs 52% of ILC RDR)
  - 230 GeV CM e+e- collider HLC (costs 67% of ILC RDR)
- Path for further cost reduction of 1st stages outlined
- Enabling technologies described

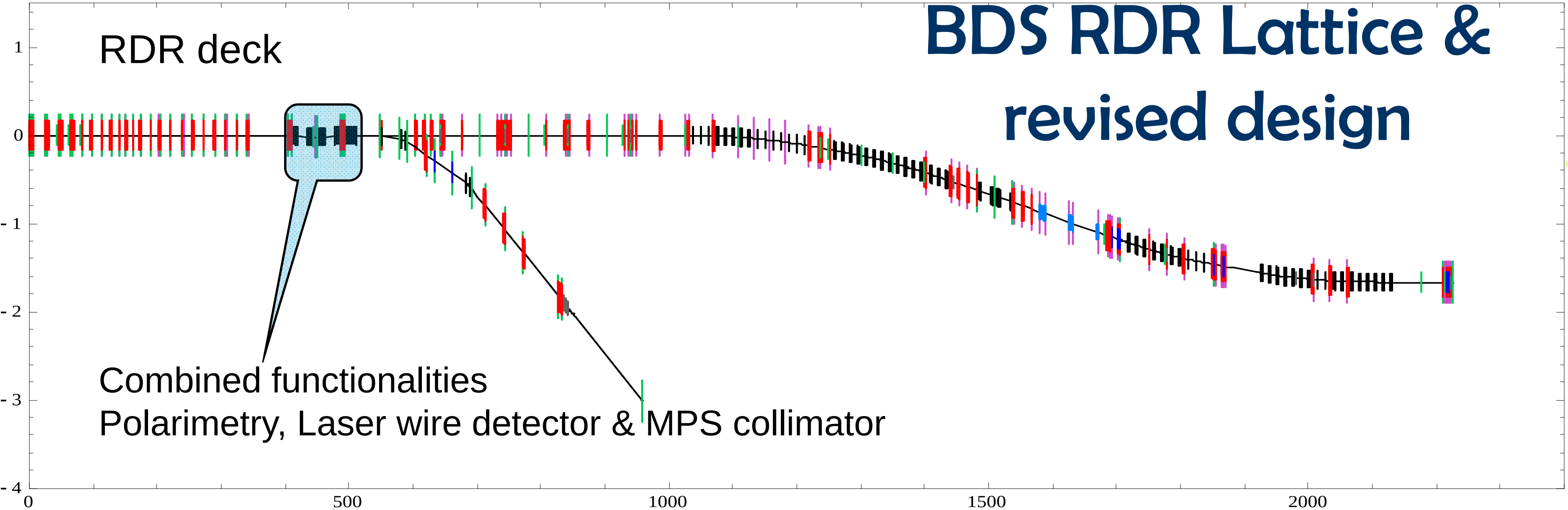
180GeV CM $\gamma\gamma$ initial configuration



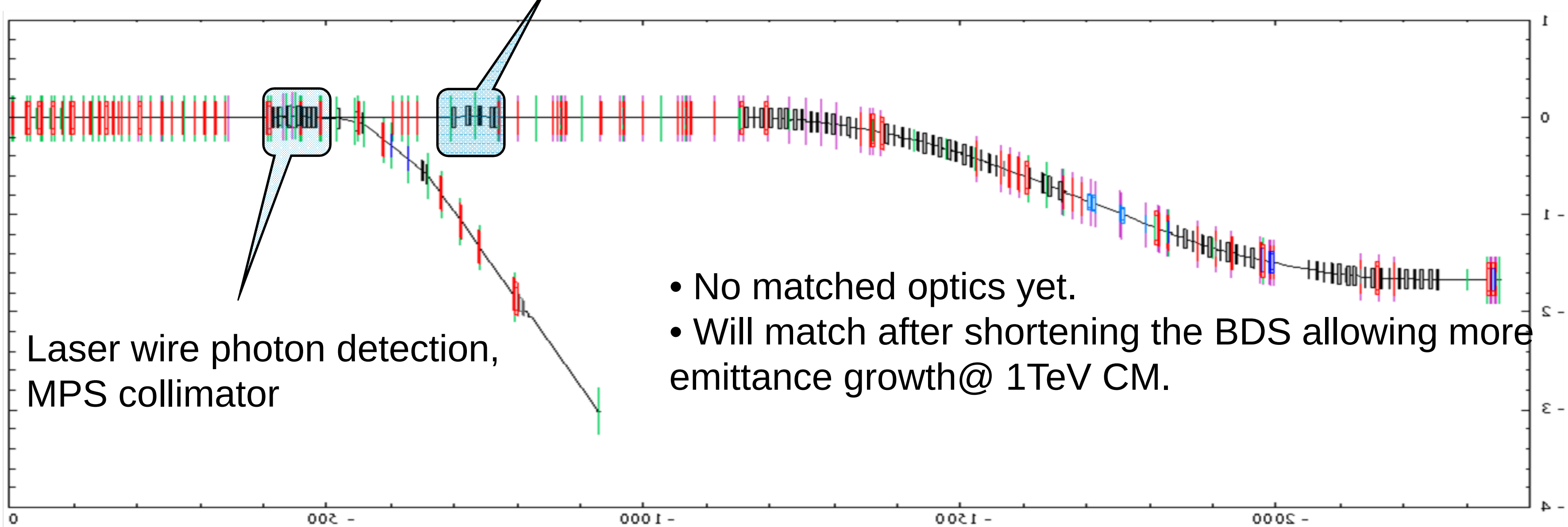
BDS Lattice for revised design

- BDS Lattice design plans:
  - next steps of modifying the RDR deck to separate combined functionalities of upstream polarisation measurements + laser wire detection + MPS
  - Reduction in BDS length to allow more emittance growth @1TeV CM.
  - Studies for minimum machine with central integration region
- The layouts presented here are based on the discussion and actions from the BDS optics meeting of 29/01/09, attended by
  - D.Angal-Kalinin, F. Jackson, J. Jones, Y. Nosochkov, A. Seryi, M.Woodley
  - http://ilcagenda.linearcollider.org/getFile.py/access?contribId=1&resId=0&materialId=minutes&confId=3344

BDS RDR Lattice & revised design



Include additional chicane for polarimetry:

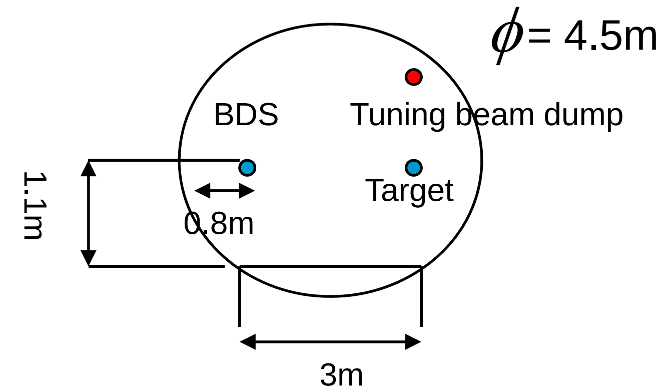


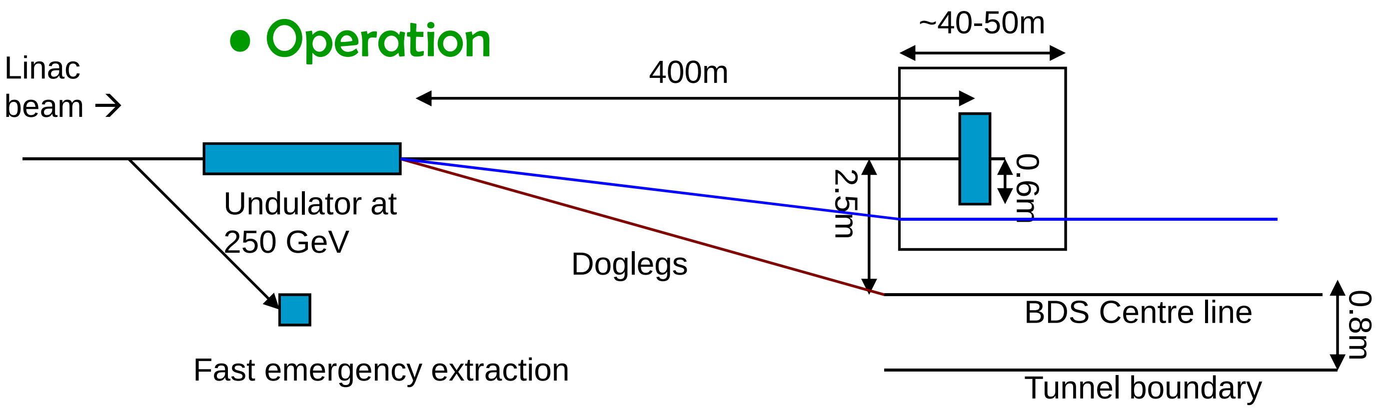
D.Angal-Kalinin, F. Jackson, J. Jones, Y. Nosochkov, A. Seryi, M.Woodley

Central region integration : Minimum Machine, BDS

Integration studies needed:

- Radiation
- Optics
- Engineering
- Installation
- Commissioning
- Operation

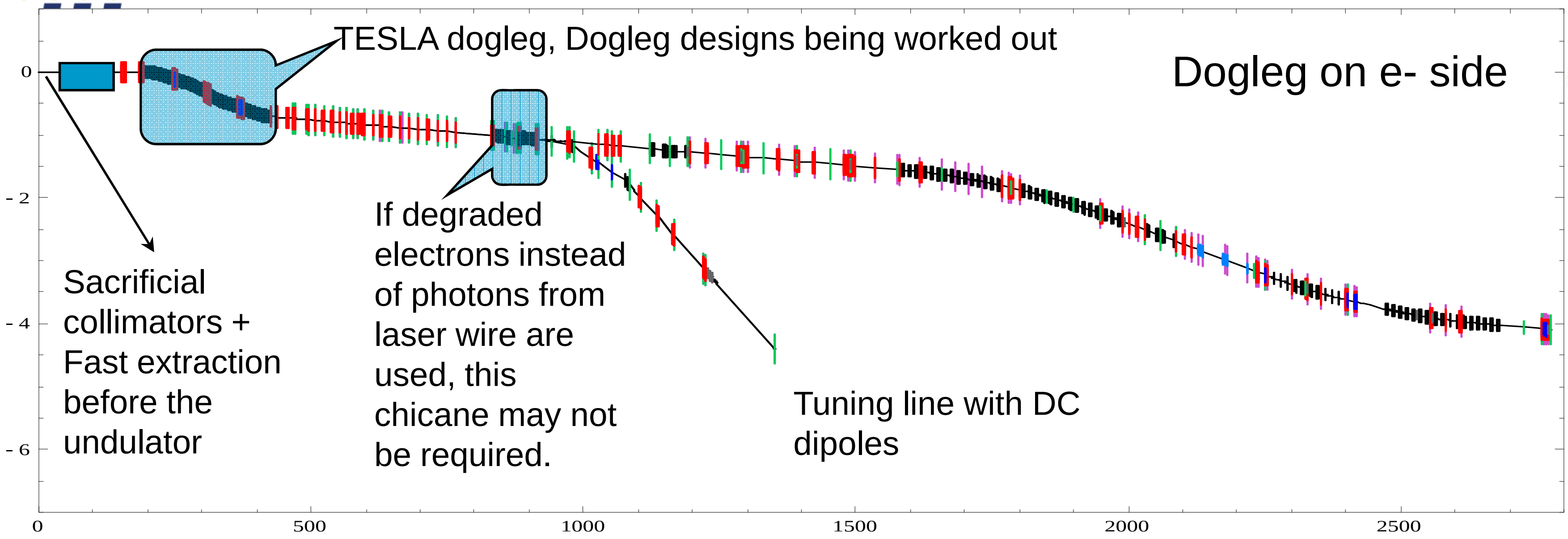


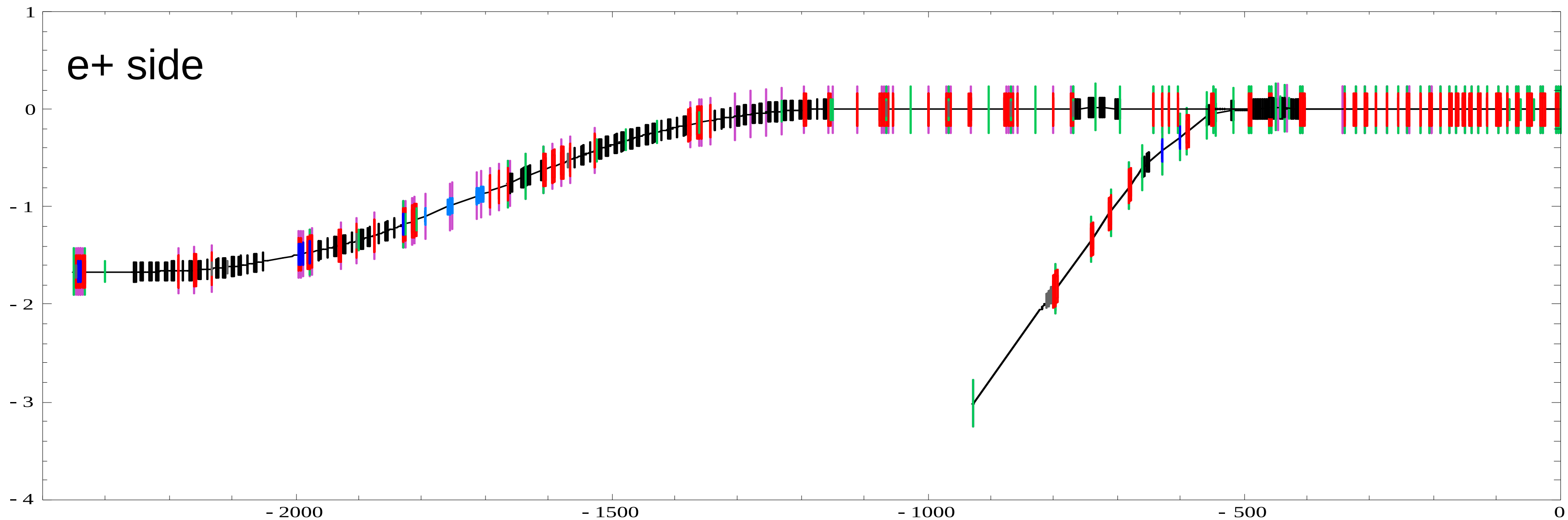


- 2.5m can be reduced to up to 1.5m if beam passes through a drift space for ~40-50m without any components through the remote shielding block of the target.
- If 2.5 m, not enough space for tuning beam line. Take the beam vertically to beam dump?

Based on discussions with positron source team

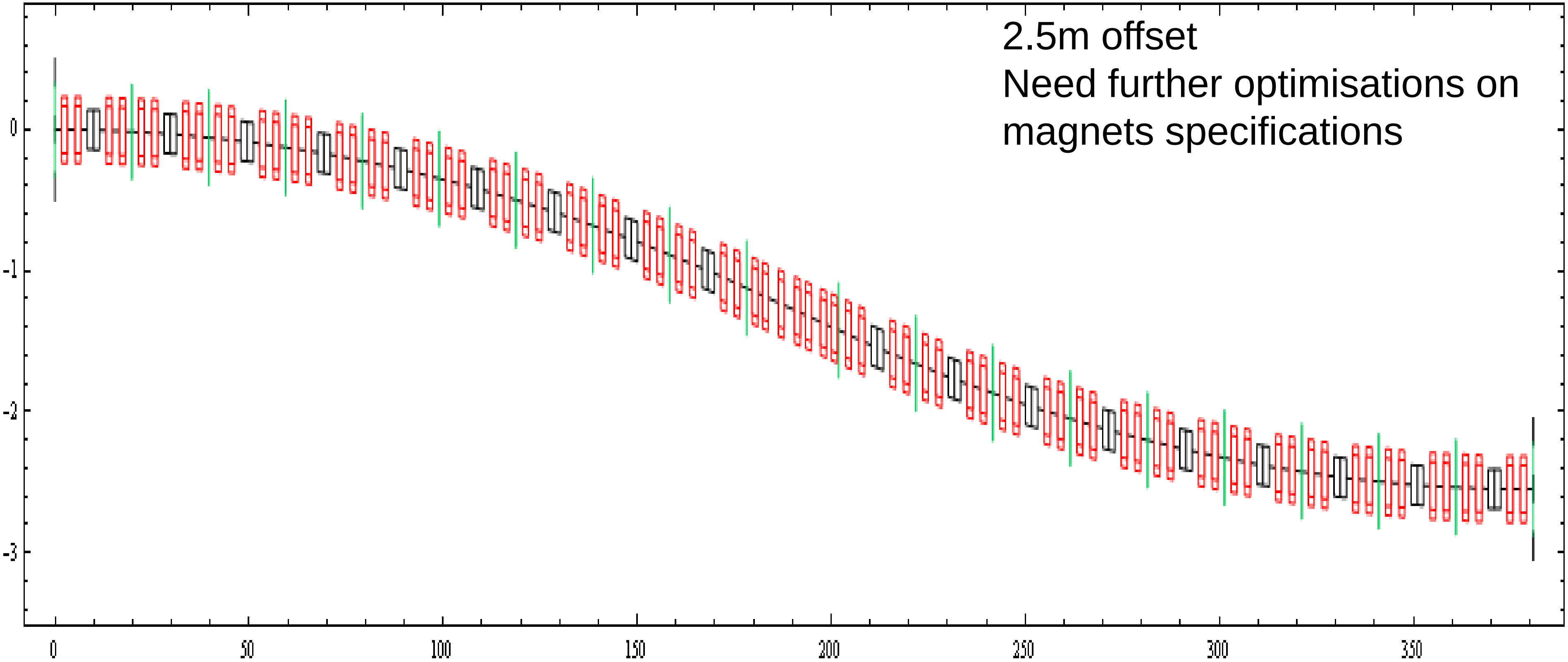
Minimum Machine





Dogleg Chicane Designs

- Studying TME (Theoretical Minimum Emittance) lattices for dogleg with different offsets and missing magnet schemes for smaller offsets.



J. Jones

Plans for optics design

- Revised RDR lattice with
  - Shortened RDR allowing higher ε growth at 1TeV CM
  - Separate chicane for upstream polarimeter
- Minimum machine with dogleg chicane
  - With different offsets
- Plan to have revised lattices ready by October'09.

Conclusion

- The BDS group, in TDP phase, is focused on
  - ATF2 test facility
  - Machine Detector Interface
  - and several other key systems
- that may make significant contribution to reduction of cost, risk and increase of machine performance