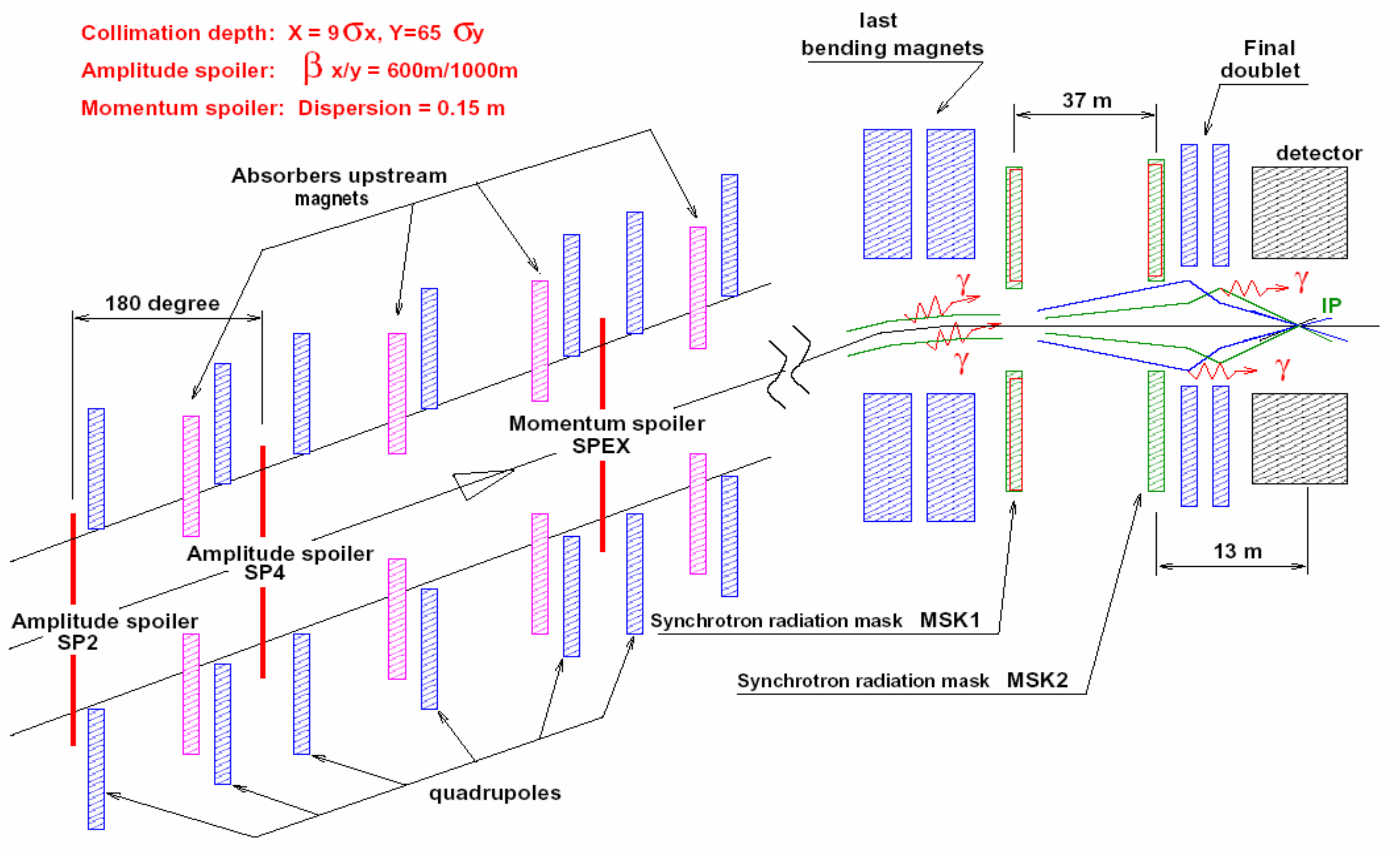
Collimation and Backgrounds Summary

N. Mokhov, T. Tauchi, N. Watson



AGENDA-I

1. Daniel Schulte "Halo & Tail Generation Studies"
2. Karsten Buesser "Pair Backgrounds in the Large Detector"
3. Toshiaki Tauchi "Pair Backgrounds with the ILC Parameter Sets in the GLD"
4. Ilya Agapov/Grahame Blair "Collimation System Studies"
5. Tom Markiewicz/Takhashi Maruyama "Backgrounds in 2/20 mrad IR"
6. Alexander Drozhdin "STRUCT Modeling of Collimation and Extraction System Performance"
7. Nikolai Mokhov "MARS Modeling of Energy Deposition and Backgrounds"
8. Carl Beard "Wakefield Simulations for ESA BEAM Tests"

AGENDA-II

9. Adrian Vogel "Simulations of Neutron Background in a TPC Using GEANT4"
10. Cecile Rimbault "Status of Beam-Beam Simulations"
11. John Carter "2-mrad Extraction Line Backgrounds"
12. Frank Jackson "Collimation Depths and Performance for 2 and 20-mrad BDS Collimation"

Progress Since 1st ILC Workshop

Volunteers to push different aspects, now → Snowmass?

- Critical choices:
  - Detector tolerances (hardware damage and operation)
  - Need integrated IR-detector model (including mask and SC quad optimizations), iterate with detector group on background tolerances.
  - Operational and accidental beam loss scenarios
  - Muon spoilers
  - Apertures+pair&halo masking
- Simulation standards and interfacing, very important
- Iterations with optic designers on collimator locations and parameters.
- Optimization of individual spoiler and absorber configurations, dimensions and material w.r.t. to their performance, survivability and impedance.

Progress Since 1st ILC Workshop

- Modeling of beam loss in BDS, IR & extraction line followed by realistic energy deposition simulations in BDIR, detector and extraction components (including tunnels and experimental halls) to minimize backgrounds, radiation loads and environmental impact.
- Based on results of simulations, iterations with conventional construction group on tunnel magnetic spoilers, tunnel and experimental hall parameters.
- Validation, inter-comparison and improvements of simulation codes used in the BDIR studies: tracking, production models, energy deposition, thermal/stress/DPA analyses,wakefield.

Synchrotron Rad$^{n.}$ Generator

Burkhardt/Schulte

the cumulative synchrotron radiation photon spectrum in units of the critical energy :

$z = E / E_{cr}$ SynRadInt(0) = $5\pi/3$

$$\text{SynRadInt}(z) = \int_z^\infty \int_x^\infty K_{5/3}(t)dt\,dx$$

the fraction of photons below z

$$\text{SynFracInt}(z) = \frac{3}{5\pi} \int_0^z \int_x^\infty K_{5/3}(t)dt\,dx = 1 - \frac{3}{5\pi}\text{SynRadInt}(z)$$

Direct inversion : **fast** (Chebyshev polynomial P_{Ch}) **algorithm for (SynFracInt)$^{-1}$**

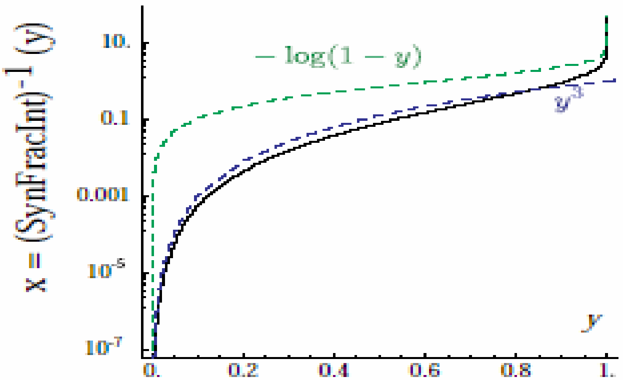
needs several intervals and suitable transformations inspired by the low and high y approximations

y="random" on (0,1)

$y < .7$: y^3 P_{Ch} (y)

$.7 < y < .9999$: P_{Ch} (y)

$y > 0.9999$: $-\log(1-y)$ P_{Ch} $(-\log(1-y))$



Targets for Snowmass: Detector

- Backgrounds x 3 detector concepts x 2 crossing angles
  - Sub-detector tolerance tables
    - ⇒ critical (damage to hardware)
    - ⇒ occupancy (unable to use data)
  - Separate origin of backgrounds
    - ⇒ μ, synchcrotron γ, neutrons, pairs
  - Mitigation methods
    - ⇒ e.g. change radius, light TPC gas, low Z mask, μ tunnel spoilers
- WWS preparing questions to all detector concept groups ~ 1 week

Targets for Snowmass: Machine

- Collimation efficiency
- Introduce engineering realism as soon as possible (e.g. length of protection collims, materials, alignment)
- Muon spoilers, solid tunnel filling vs. muon attenuator (magnetised iron pipes) vs. wide aperture dipoles, bypass tunnel
- Survivability of spoilers + other components
- Detector protection system
- Extraction beamline, including failsafe design

Simulation tools

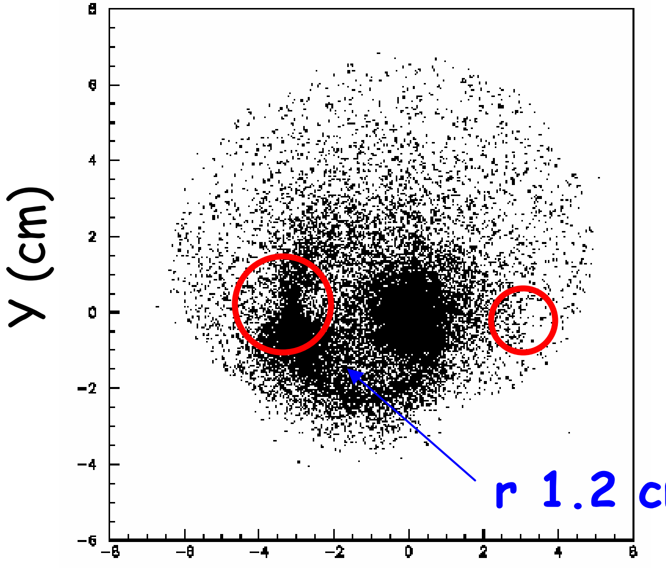
- Complementary, independent checks
  - Beam-beam interaction (Guineapig, cain)
  - Geant4 (BDSIM, LCBDS), Geant3
  - STRUCT, MARS
- Benchmarking
  - Physics processes, tracking,
  - Use ATF2 to introduce reality to tests

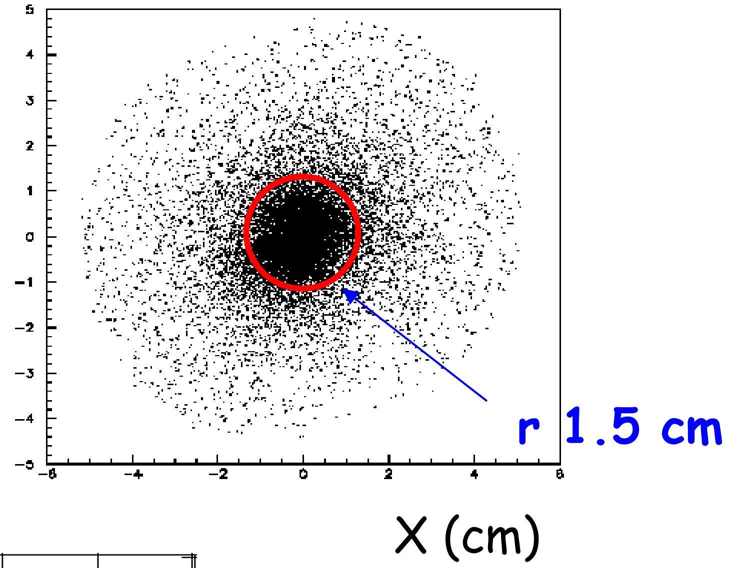
Machine-detector interface

- Need consistent, detailed bds+detector models
  - FNAL+SLAC will produce 2/20 mrad cases for SiD (aim: 1st results by Snowmass)
  - BDSIM+Mokka integration in progress
  - LCBDS+JUPITER in preparation
- From background origins to sub-detector response: proof of principle
- Short term plan, complete integration ultimate dream

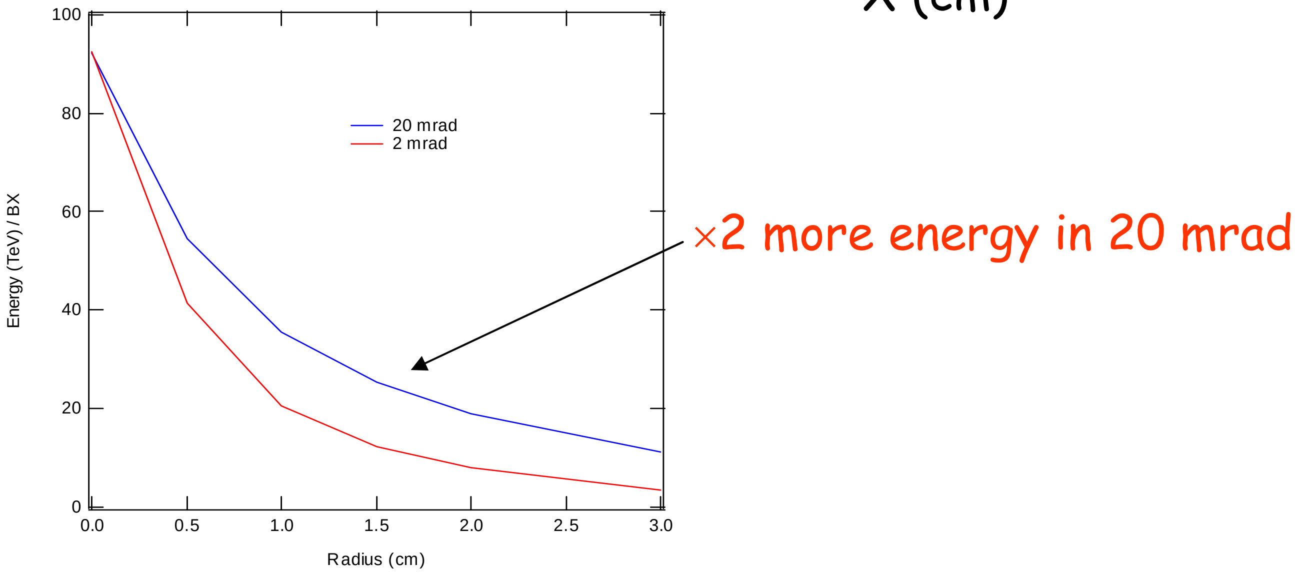
Murayama/Markiewicz

Pairs at Z = 300 cm





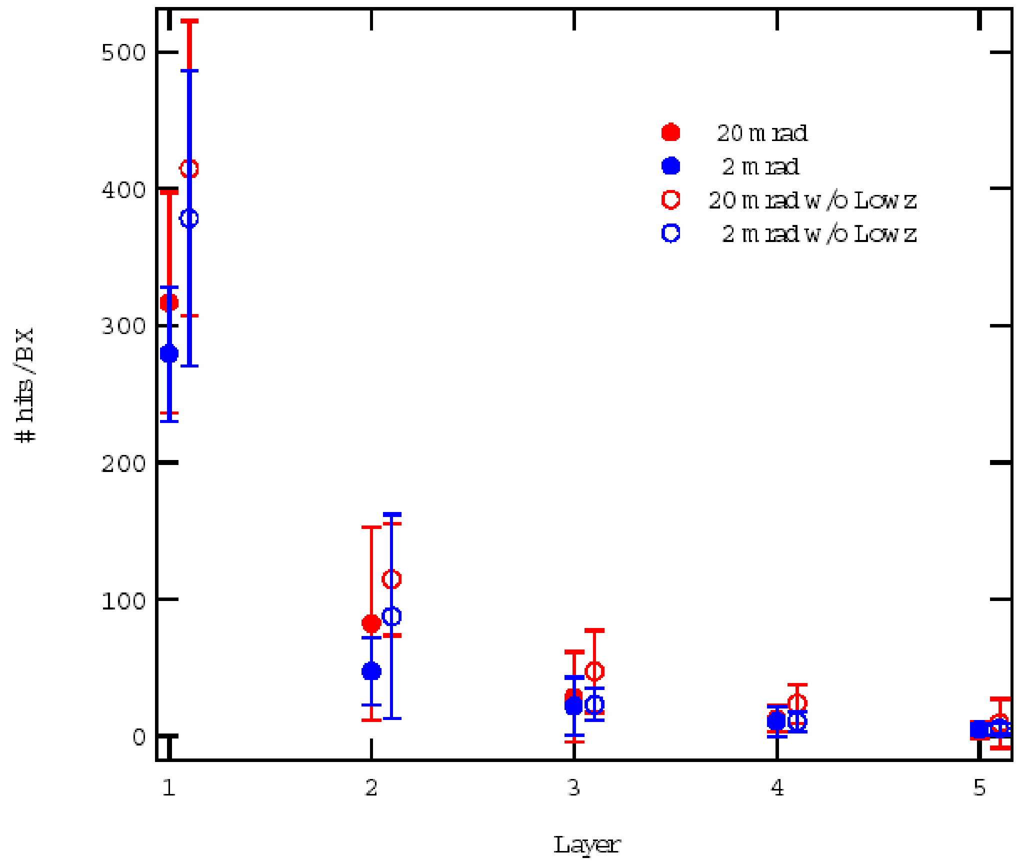
Pair energy in BeamCal



Average and RMS of VXD hits over 20 bunches

Full simulation

Barrel VXD

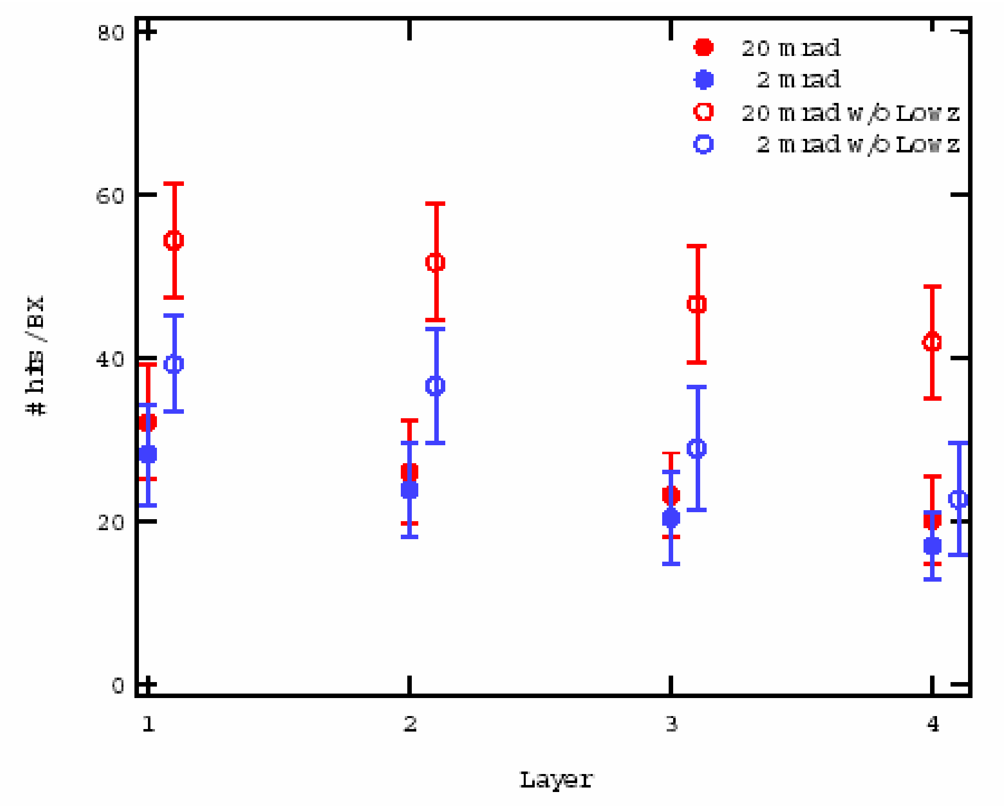


- ~10% more hits in 20 mrad
- But the difference is small compared to the bunch-to-bunch fluctuation.
- ~30% more hits if no lowz.

- 300 hits/BX (layer #1)
  - 0.027 hits/mm^2/BX
  - 77 hits/mm^2/Train

Average and RMS of VXD hits over 20 bunches

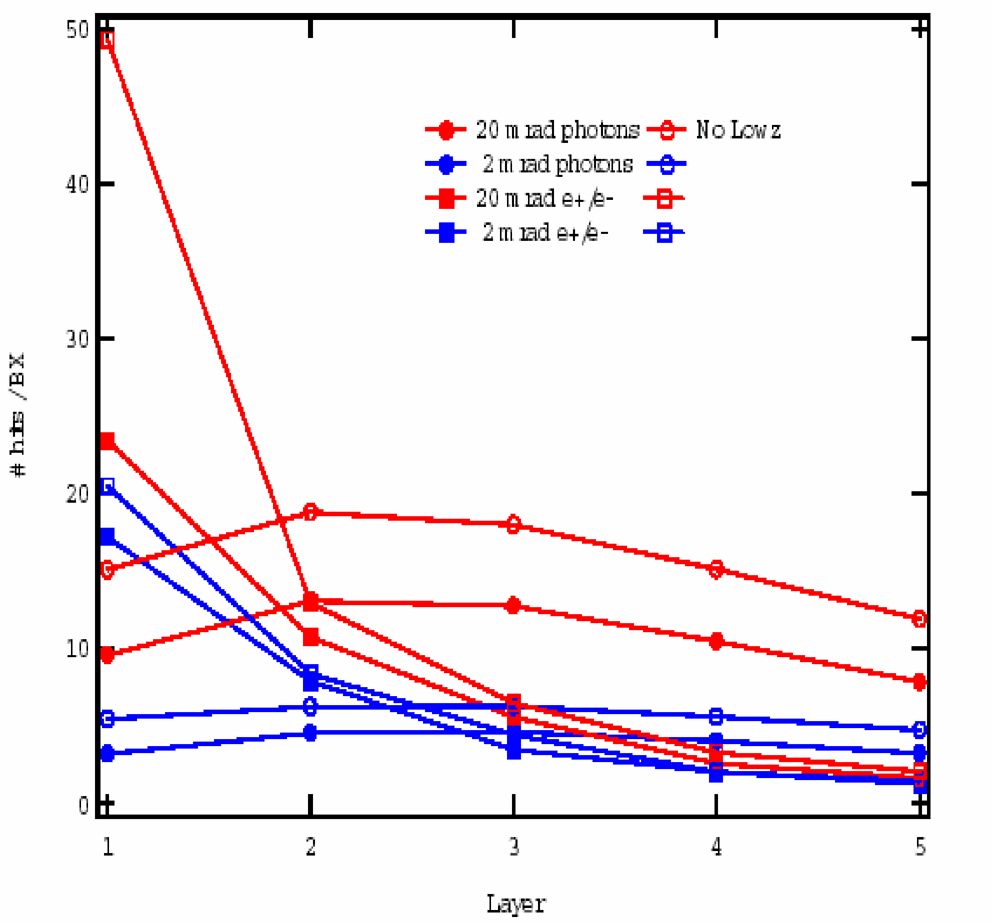
Endcap VXD



- ~10% of Barrel layer 1

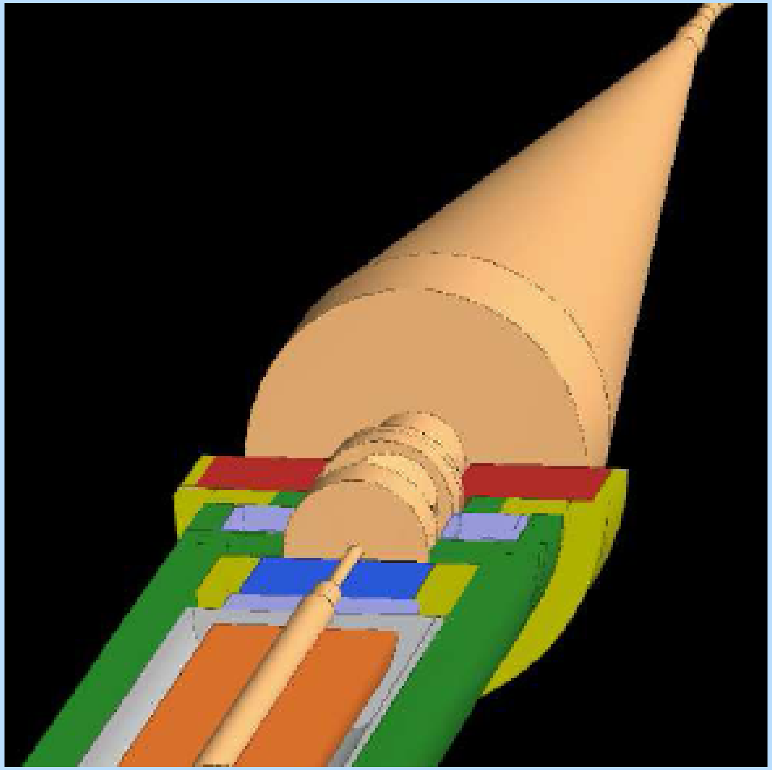
Si Tracker Hits

Forward Tracker

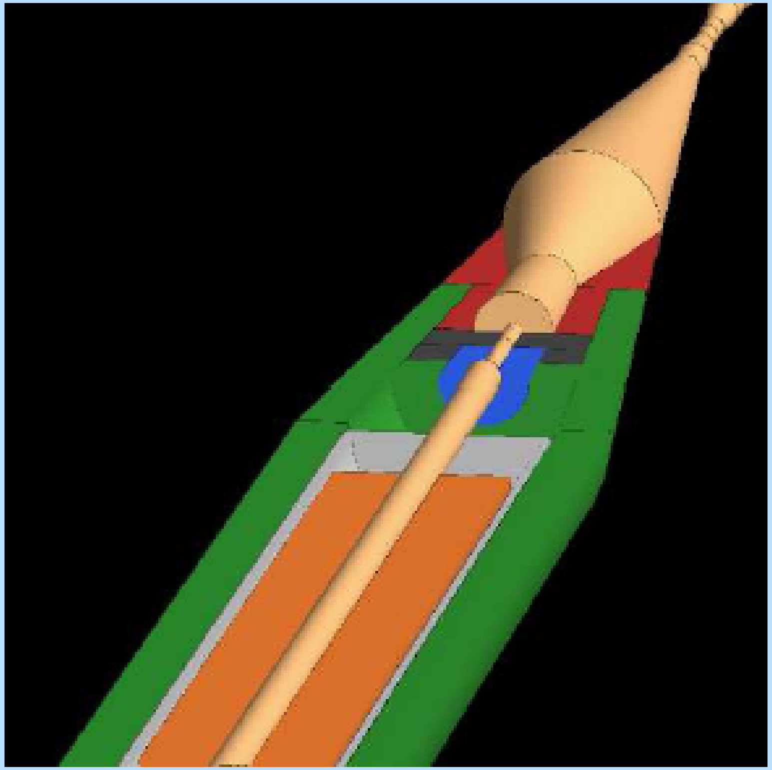


- Layer #1 hits
  20 mrad: 33/BX
  2 mrad: 20/BX

Geant 4 Detector Geometries in Mokka

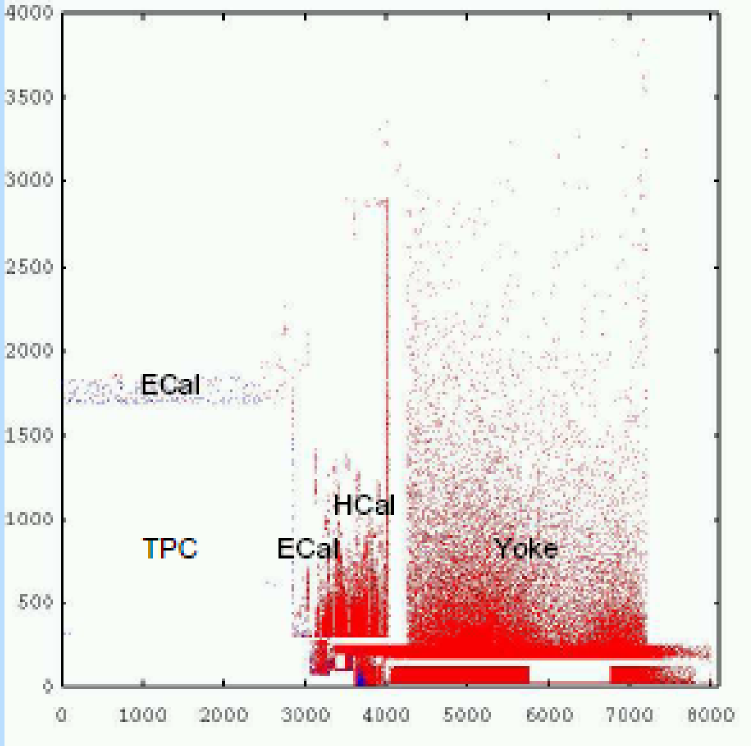


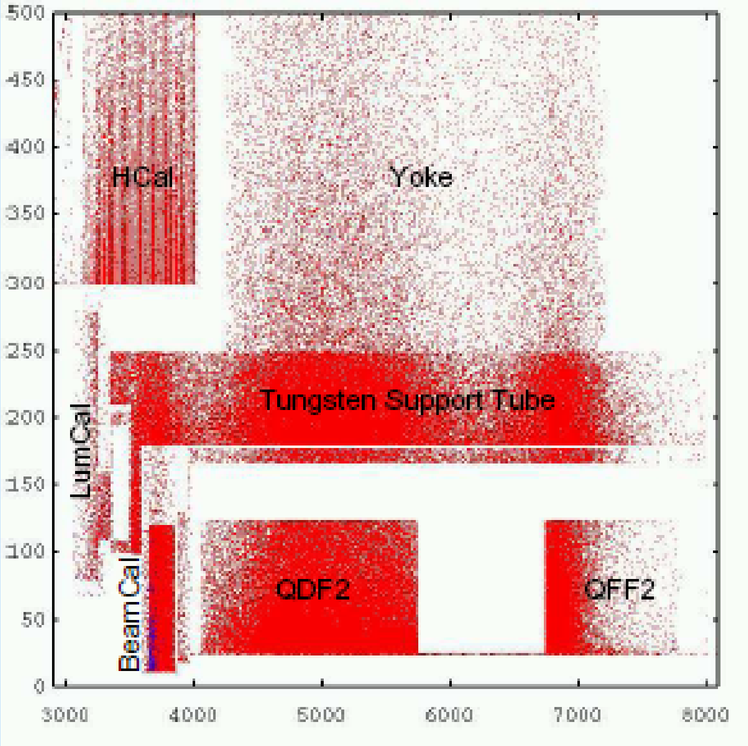
Stahl proposal
(L^* = 4.05 m)



TDR layout
(L^* = 3.00 m)

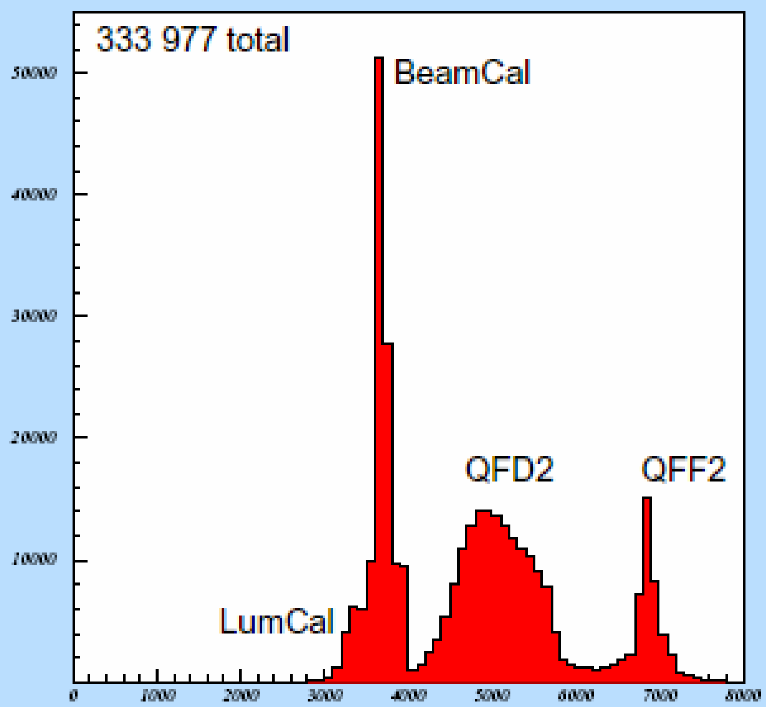
Neutron Production – Cross Section

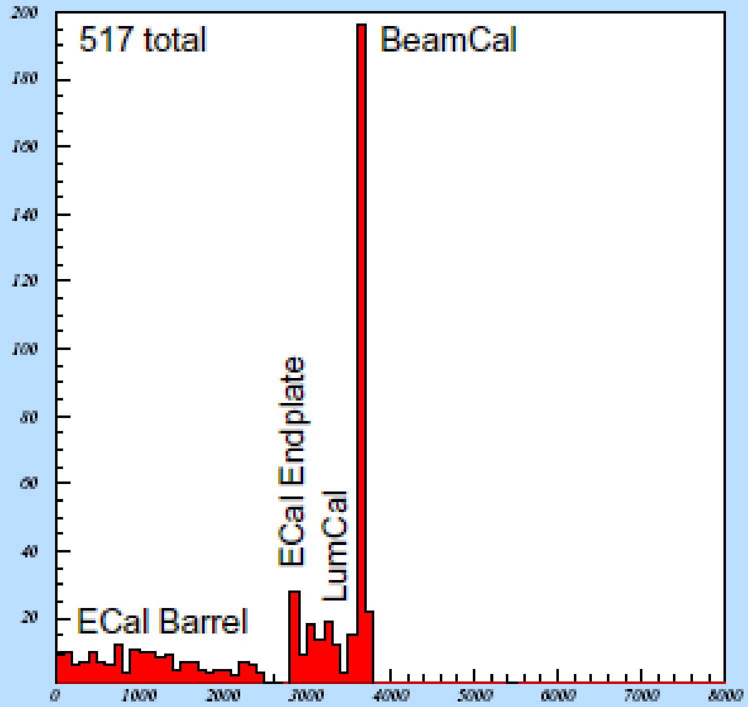




Origins of neutrons (blue ones reach the TPC)

Neutron Production – Distances

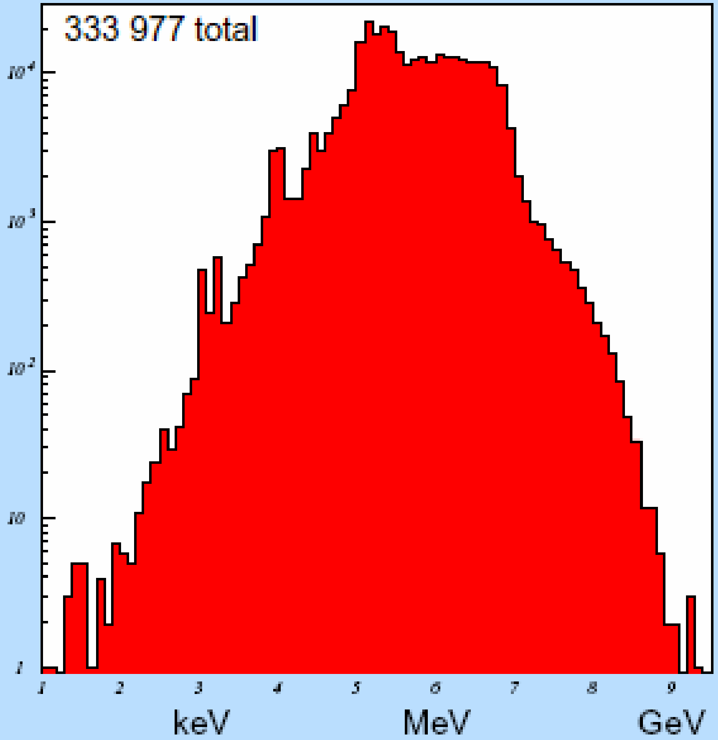


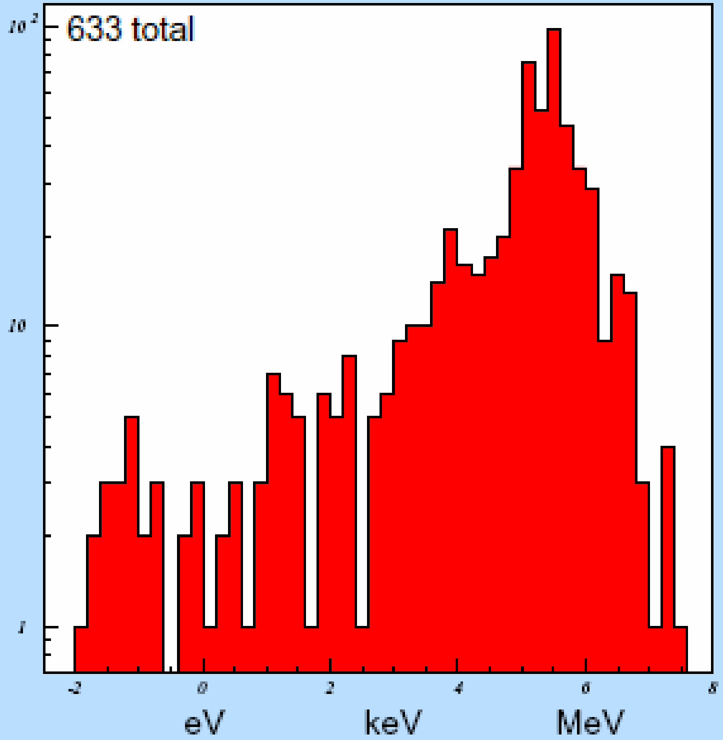


Origins of neutrons. . .

. . .reaching the TPC

Neutron Production – Energies



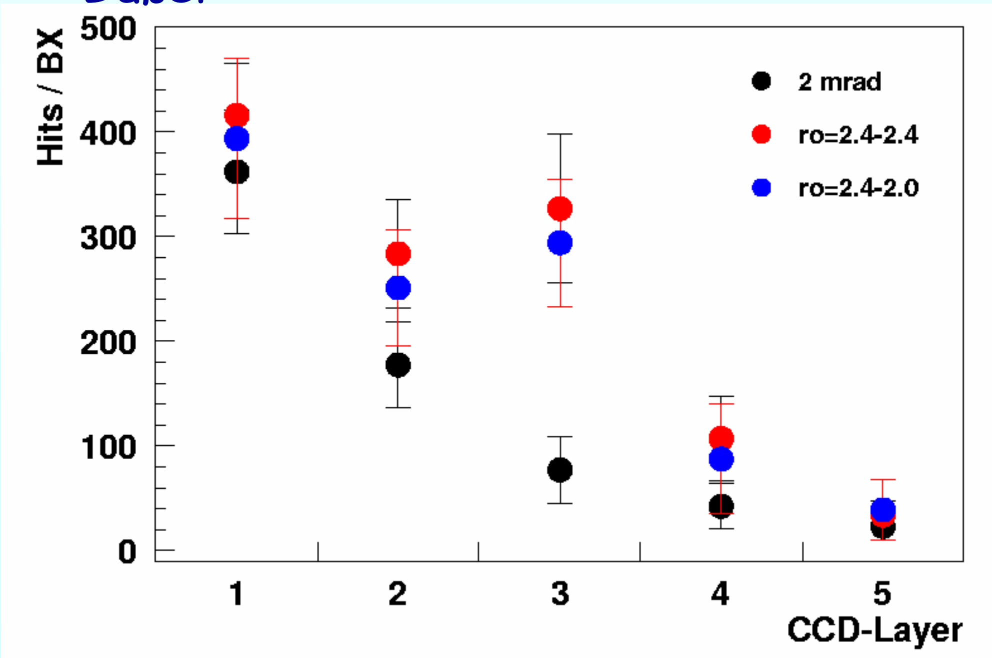


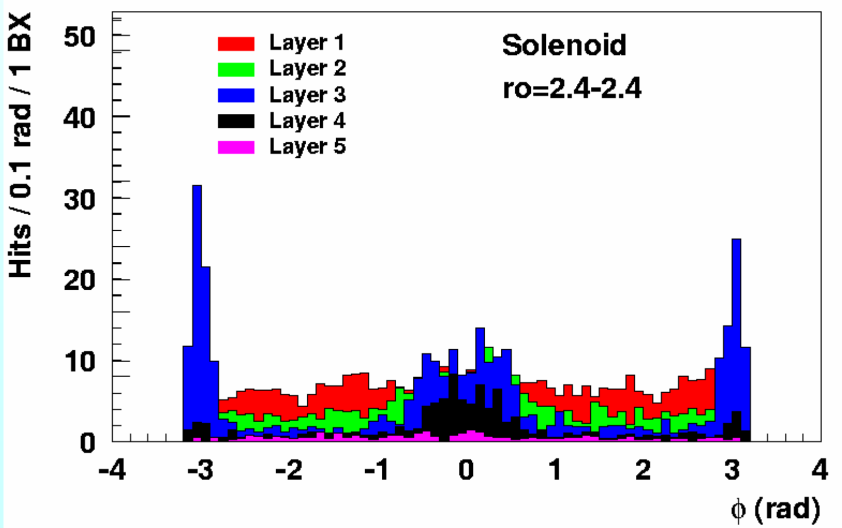
Energies of neutrons. . .

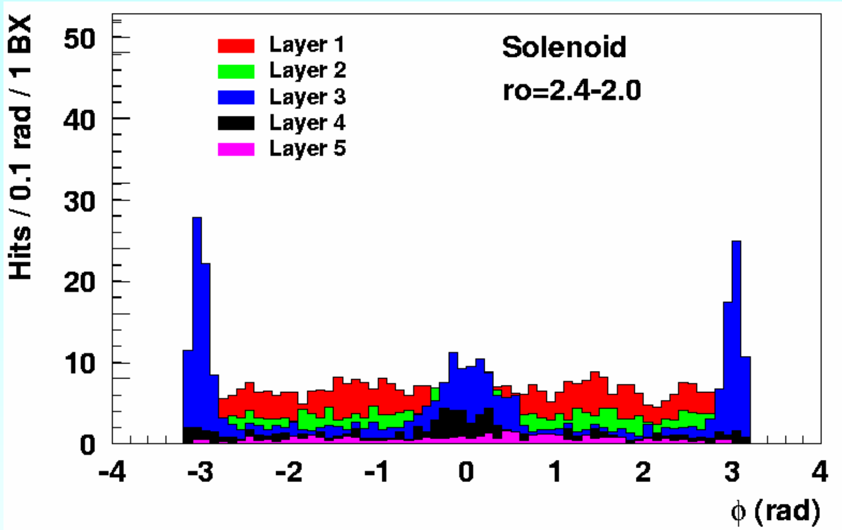
. . . when entering the TPC (some more than once)

Hits on the Vertex Detector with Solenoid Field

Büßer



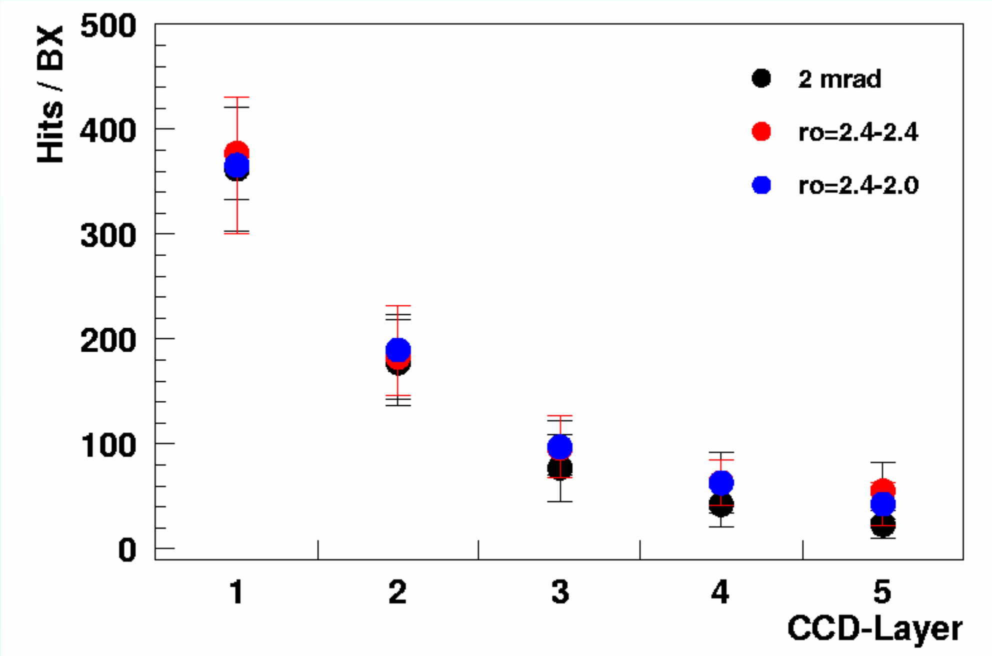


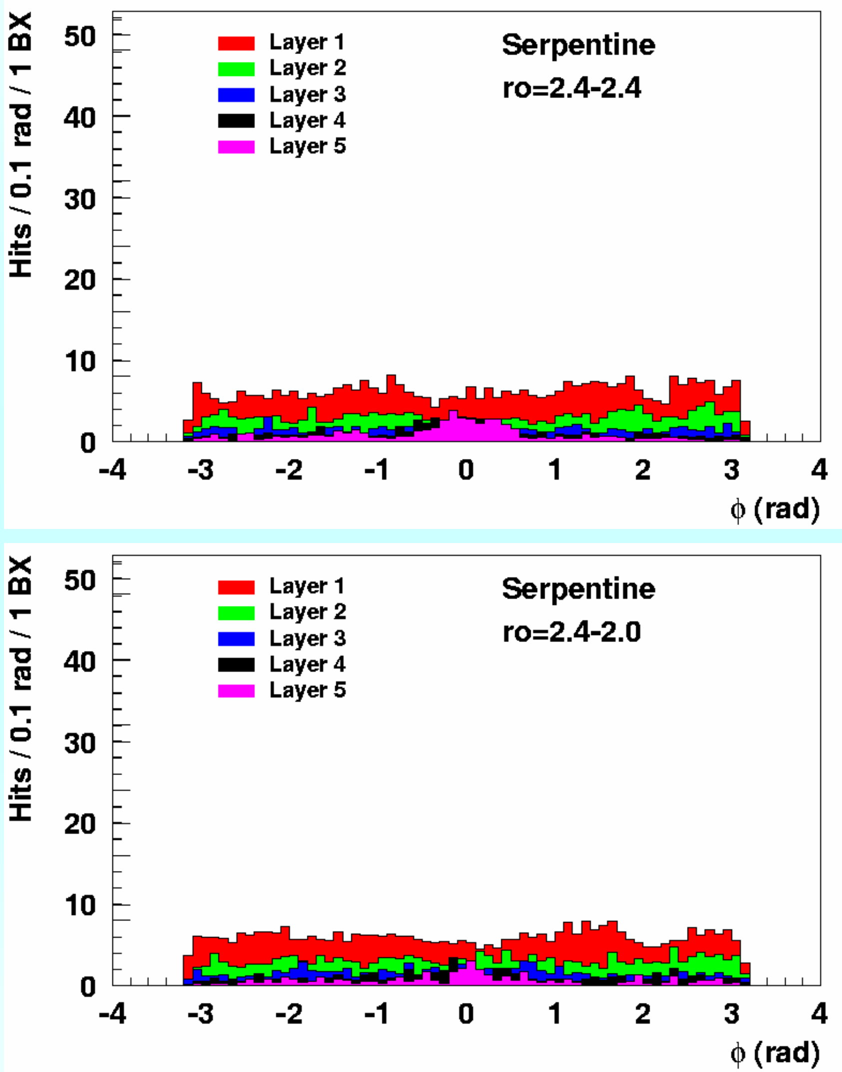


2 mrad for comparison

- Small effect of the changed graphite radius
- ‘Pictures’ from the holes produce asymmetries

Hits on the Vertex Detector with Solenoid+DID

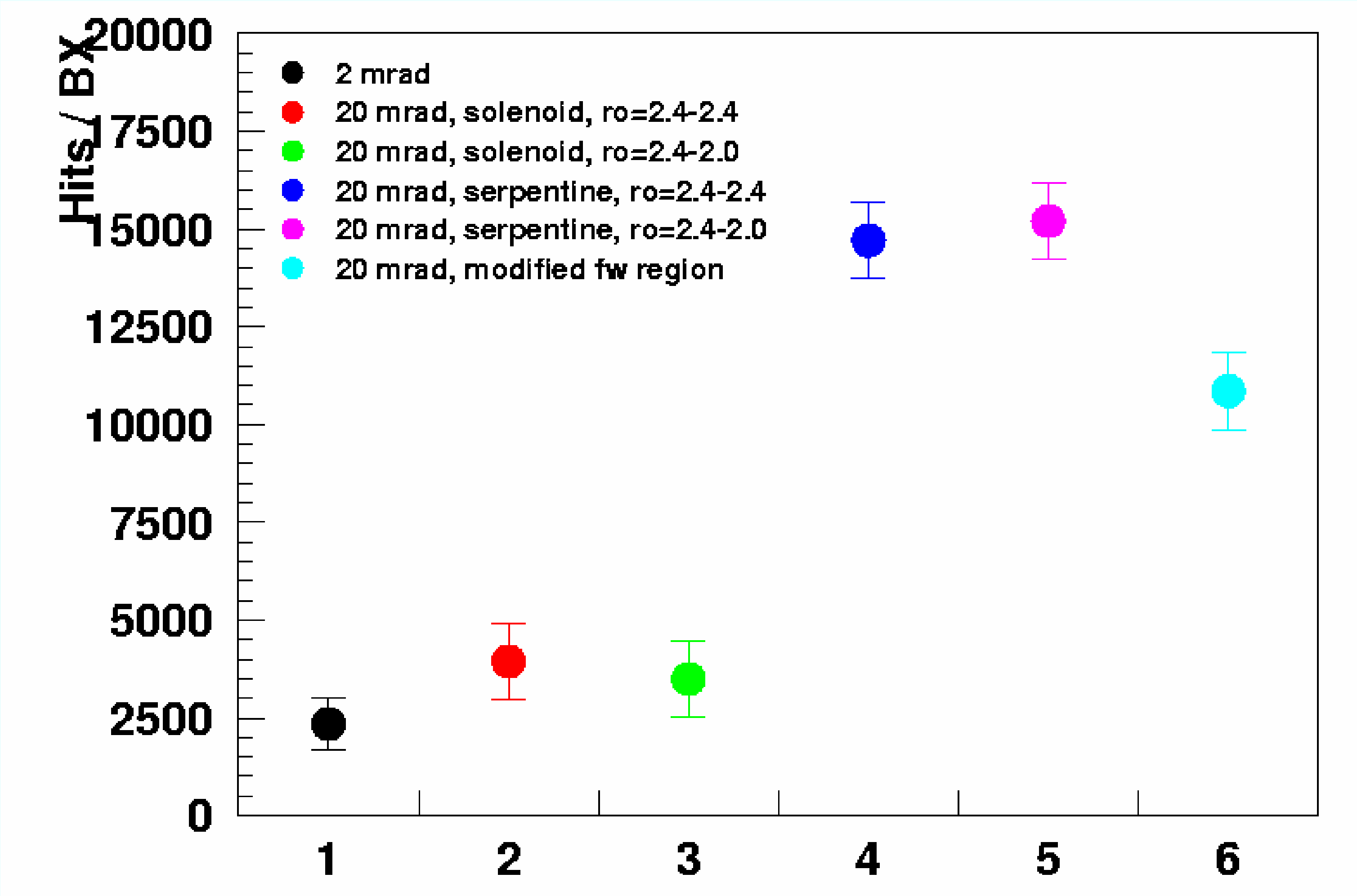




2 mrad for comparison

DID field removes asymmetries

Hits in the TPC Summary



Tauchi

Advantages of Low Q option

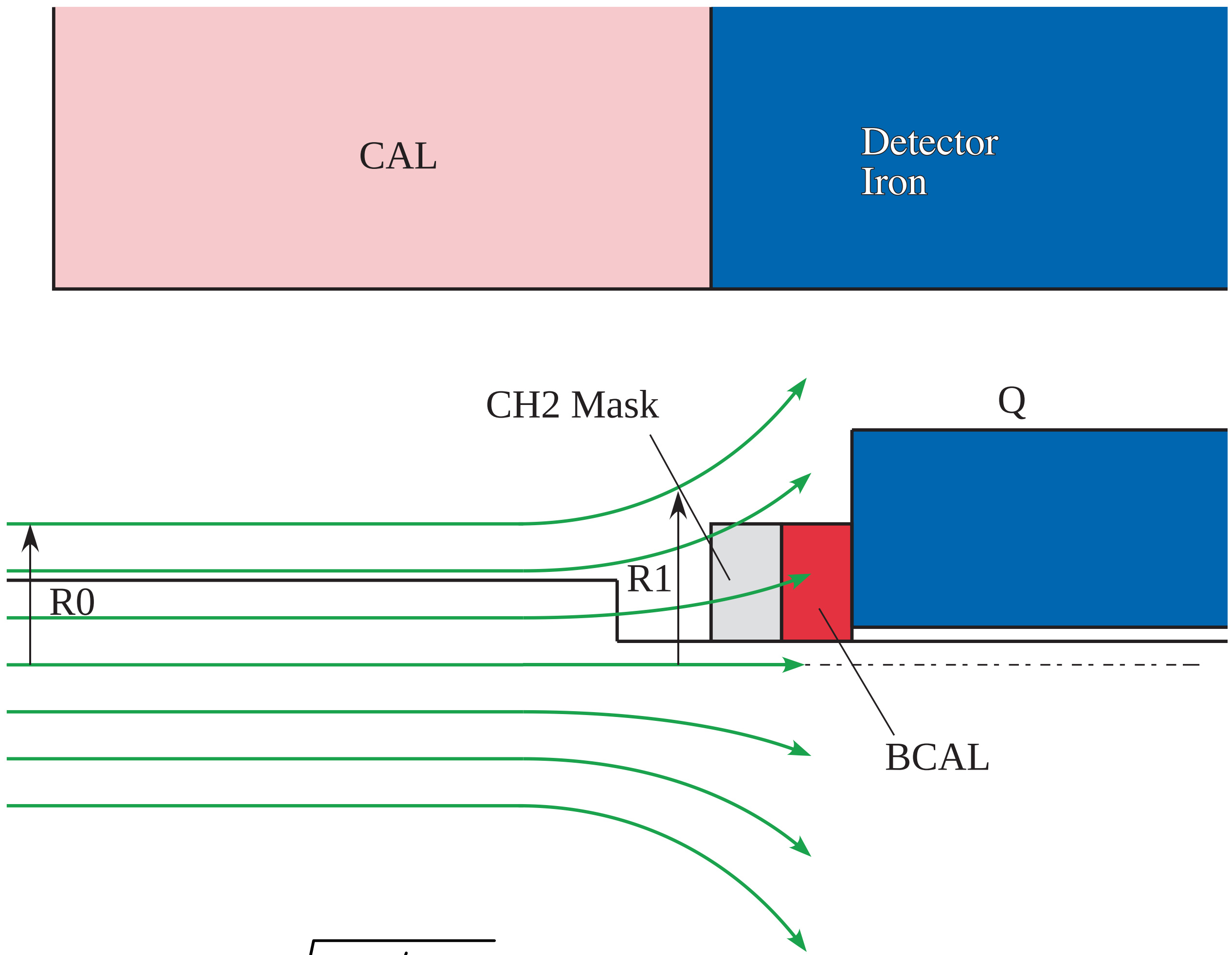
- Same Luminosity but less bunch Luminosity (1/2 of nominal option)
  - Less possibility of event overlap (2-γ events)
- Less beamstrahlung power
- Less incoherent pair background
  - Per BX: 1/3 of nominal option
    - Less b.g. hits in the Beam Calorimeter → Better veto efficiency
  - Per Train: 2/3 of nominal option
    - Less b.g. hits in the Vertex Detector

Disadvantages(?) of Low Q option

- Smaller beta functions and beam size
  - Compatible with large l^* ?
- Half bunch spacing (154ns) and double number of bunches
  - Hard job of the Damping Ring
  - No problem for FPCCD
  - How about other detector components?

Need answers from detector concepts

e+/e- backscattering

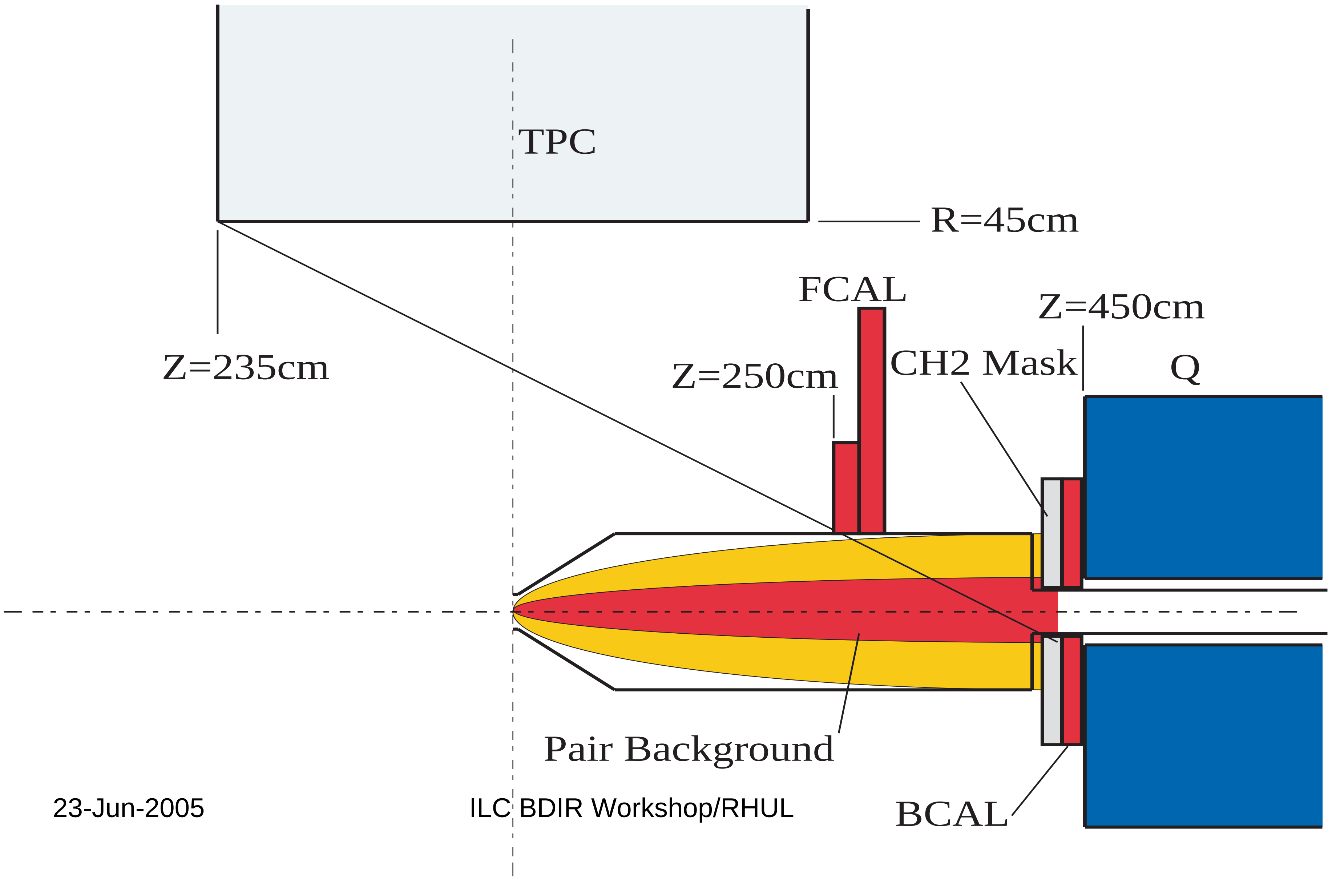


$$R0 / R1 = \sqrt{B1/B0} = 1.6 / 2.0 \quad L^{*}=4.5m$$

(Z1=4.3 m) 1.92/2.0 L*=4.1m

1.99/2.0 L*=3.6m

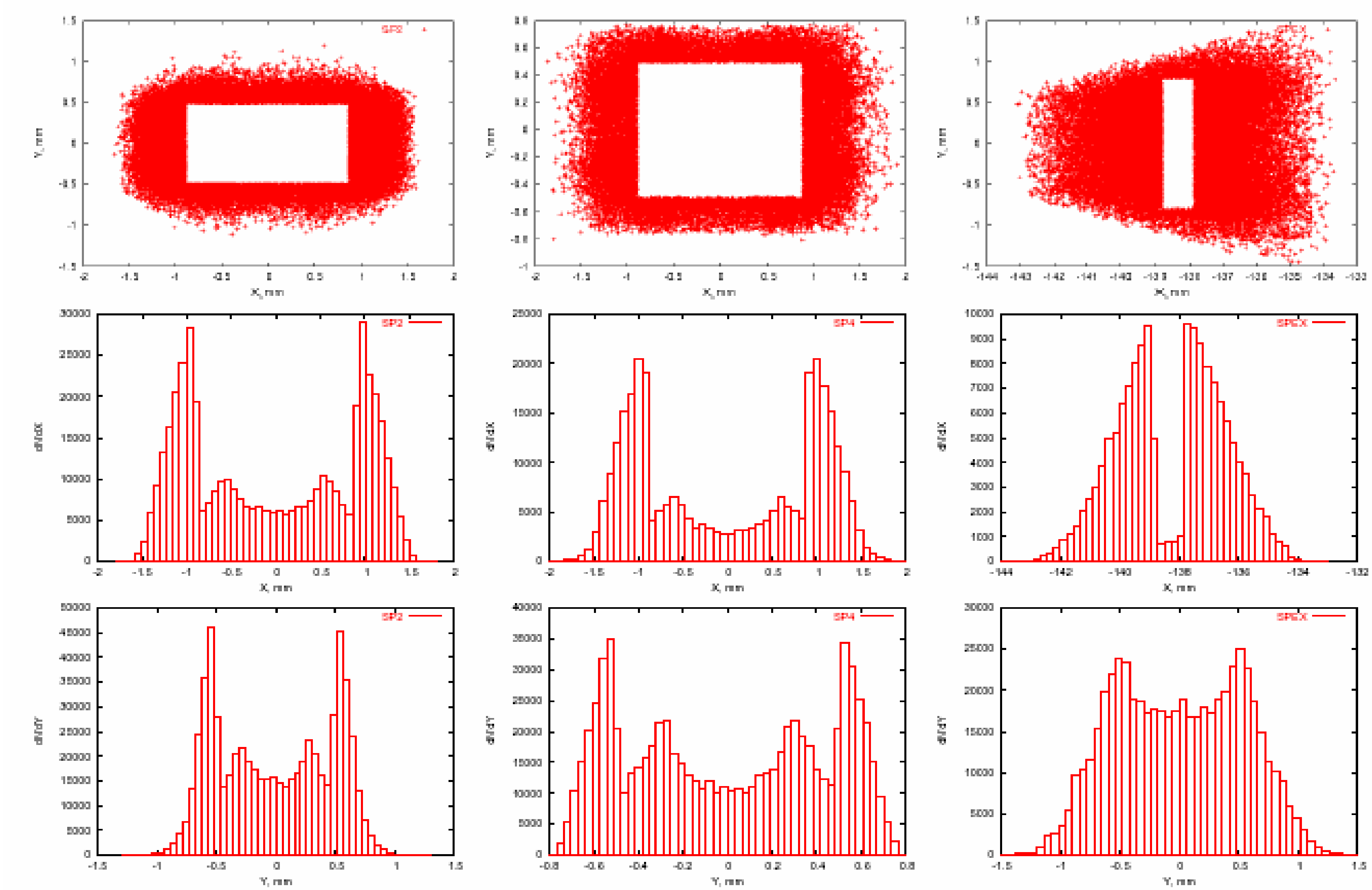
γ back scattering



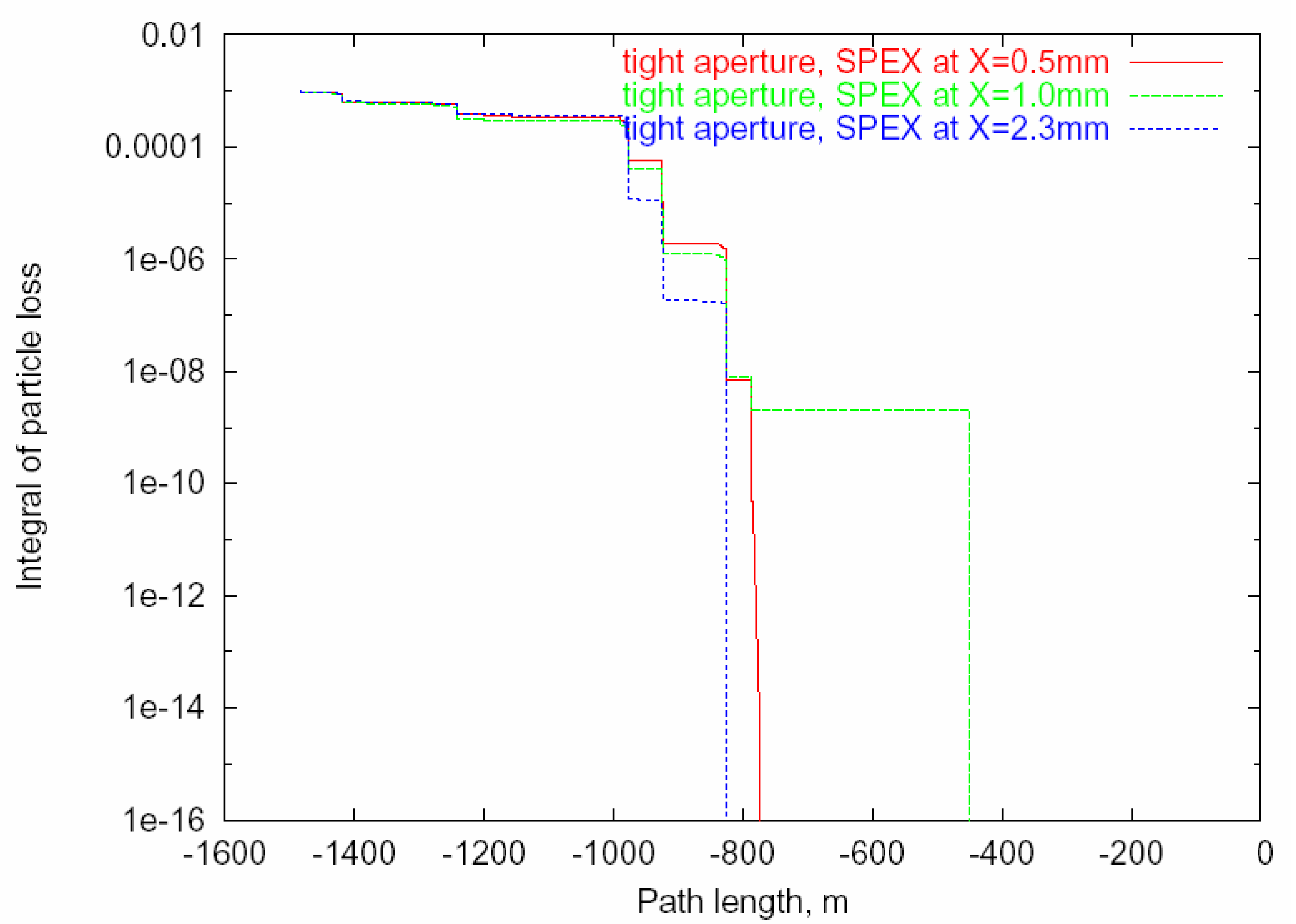
Summary

- LowQ option is attractive from the view point of the detector
- It has been confirmed by simulation study using CAIN and JUPITER that the LowQ option makes less background hits on the vertex detector than the nominal option
- L*=4.5m is highly desired for GLD

Drozhdin ILC Collimators, version ILCFF9.



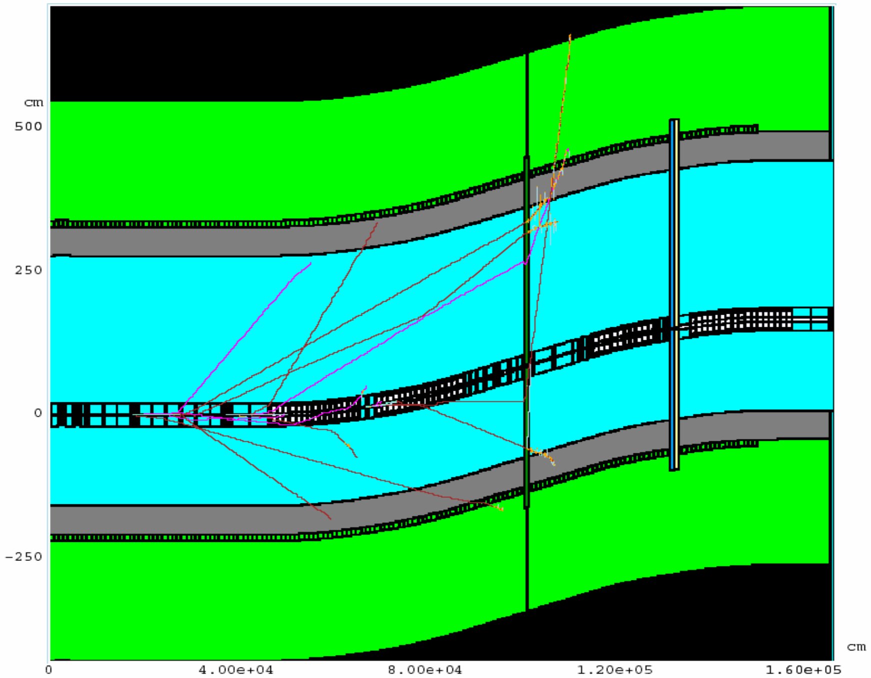
Primary particles distribution at the ILC spoilers SP2, SP4 and SPEX.



Collimation system performance assuming an incident fractional halo of 10^{-3}. Fractional loss of charged-halo particles, integrated back, starting at the IP, and normalized to the nominal bunch charge. The horizontal scale shows the distance from the IP.

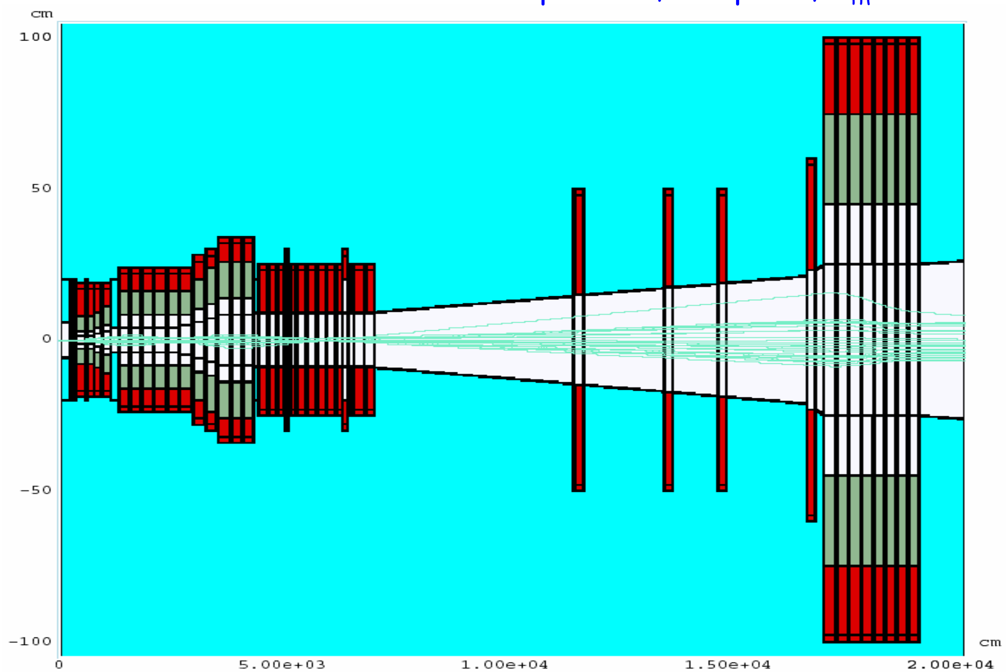
Mokhov

BDIR MARS MODEL



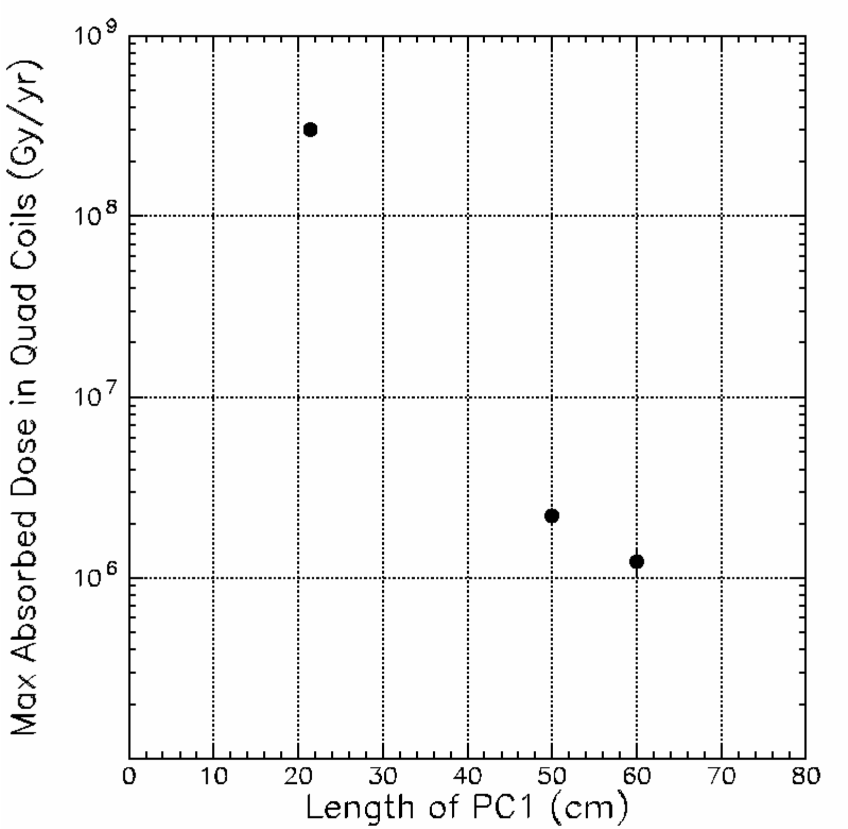
MARS model of extraction beam line (20-mrad crossing) has been built and tested and is ready for optimization studies.

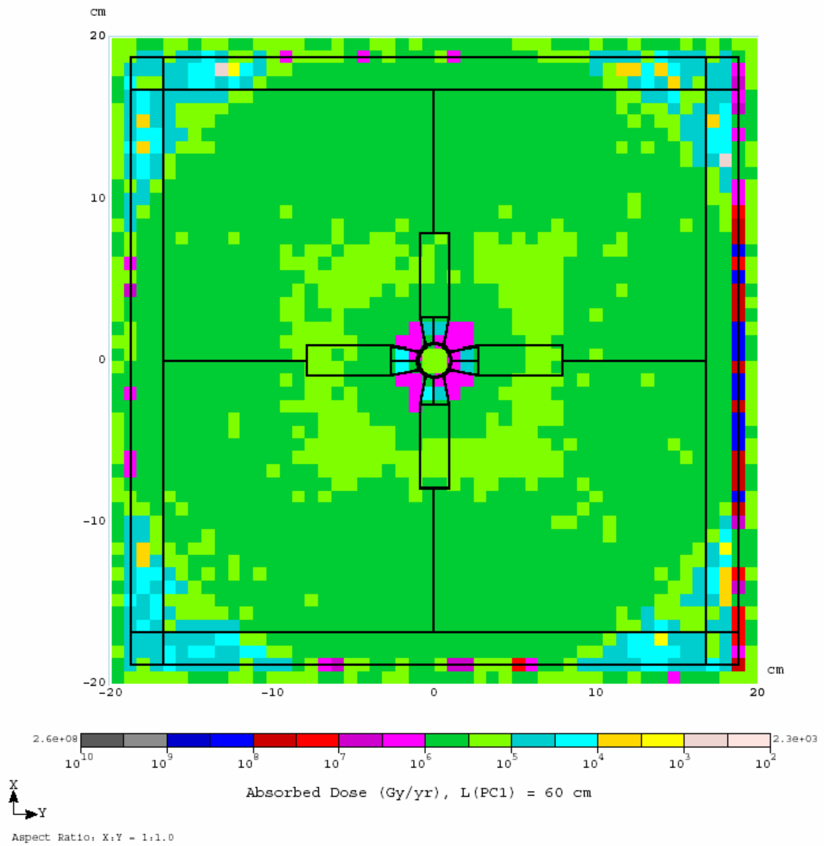
100 disrupted e^{+} , hor plane, E_{th}=10 GeV



BDS 1700 m upstream IP, with SiD detector at IP. MARS-GEANT4 collaboration between FNAL, SLAC and TPU on SiD has just started.

RADIATION LOADS ON BDIR COMPONENTS (2)

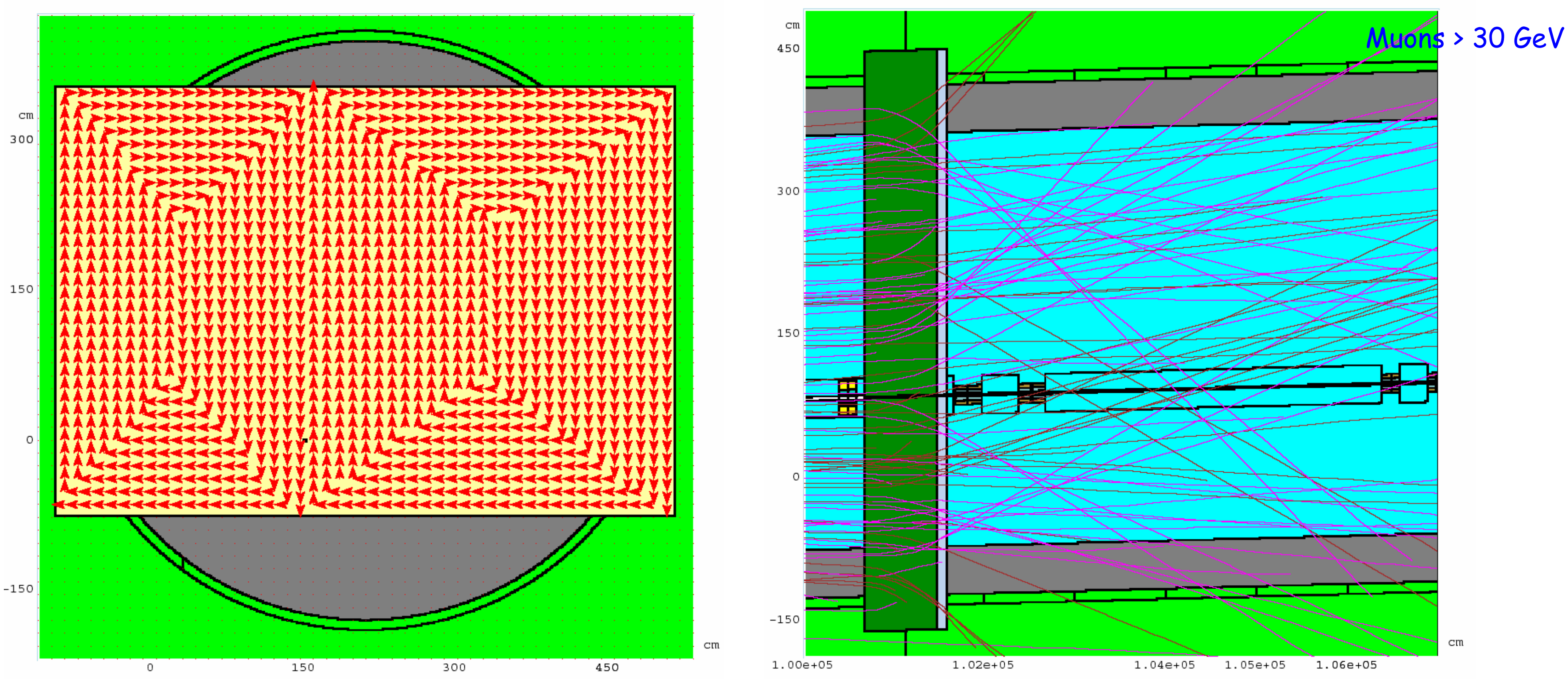




Increasing PC1 length from 21 cm to 60 cm of copper, reduces peak absorbed dose in the hottest coil by a factor of ~300, providing at least a few years of lifetime.

MUON SPOILERS IN BDIR TUNNEL

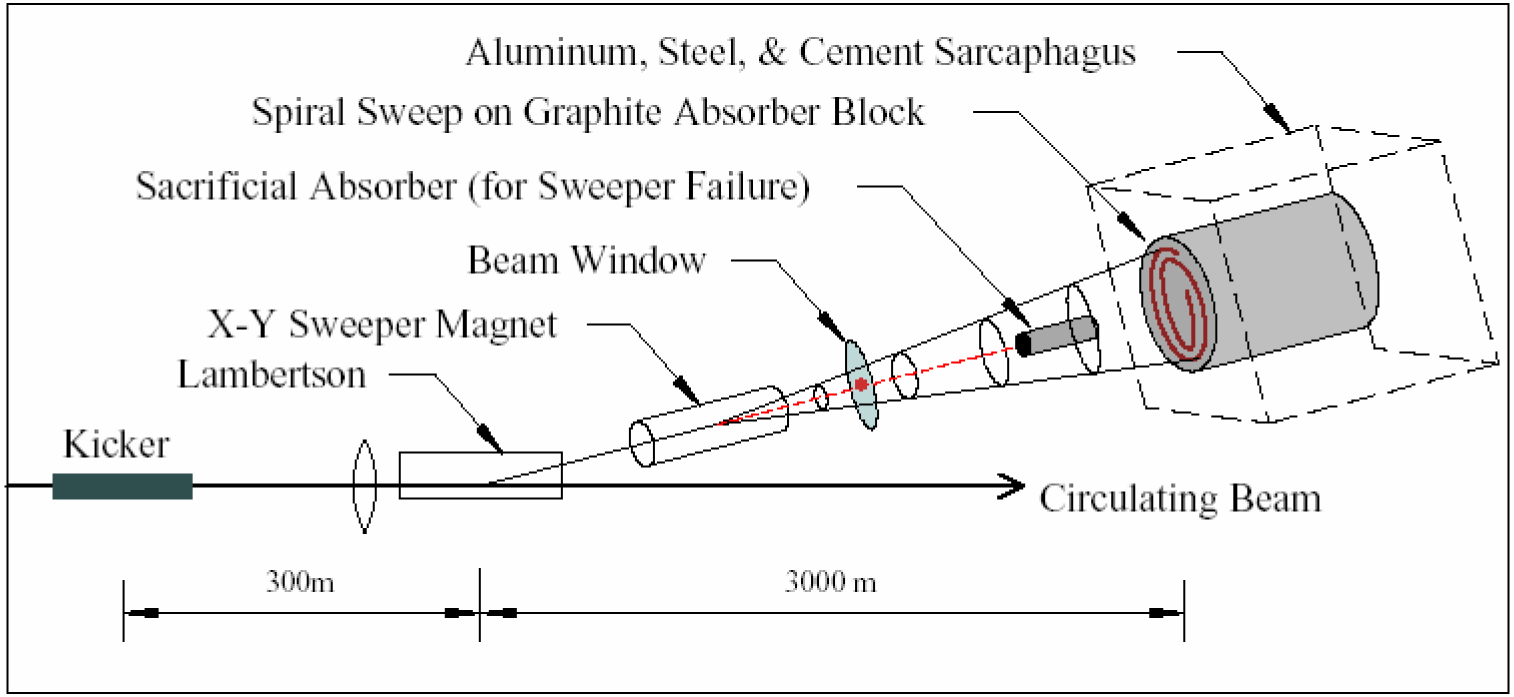
MARS15



Two iron 9 and 15-m thick spoilers at 1.5 T sealing tunnel at 660 and 350 m from IP. Muon flux is down by almost a factor of 10000: **0.8 muons per 150 bunches, meeting design goal!** Flux at 3.5 m from IP averaged over tunnel x-sec: $5x10^{-4}$ μ, 0.1 n, 400 γ, 94 e per cm^2 per sec.

SSC/VLHC-LIKE FAILURE-SAVE BEAM EXTRACTION

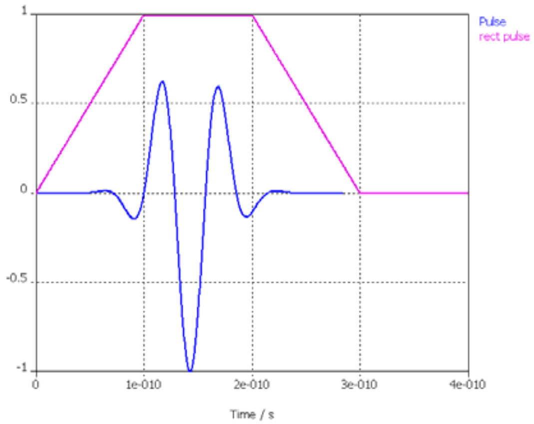
A 2-m long, 4-cm radius sacrificial graphite rod is positioned immediately upstream of the water dump window. If the beam is extracted with the sweeping magnets off, the beam damage will be confined to the rod, housed in a box to prevent the spread of radioactive debris. Additionally, to further protect the windows, the machine vacuum can be preserved by rapid acting gate valves, multiple windows acting in series or differential pumping with wire meshes.



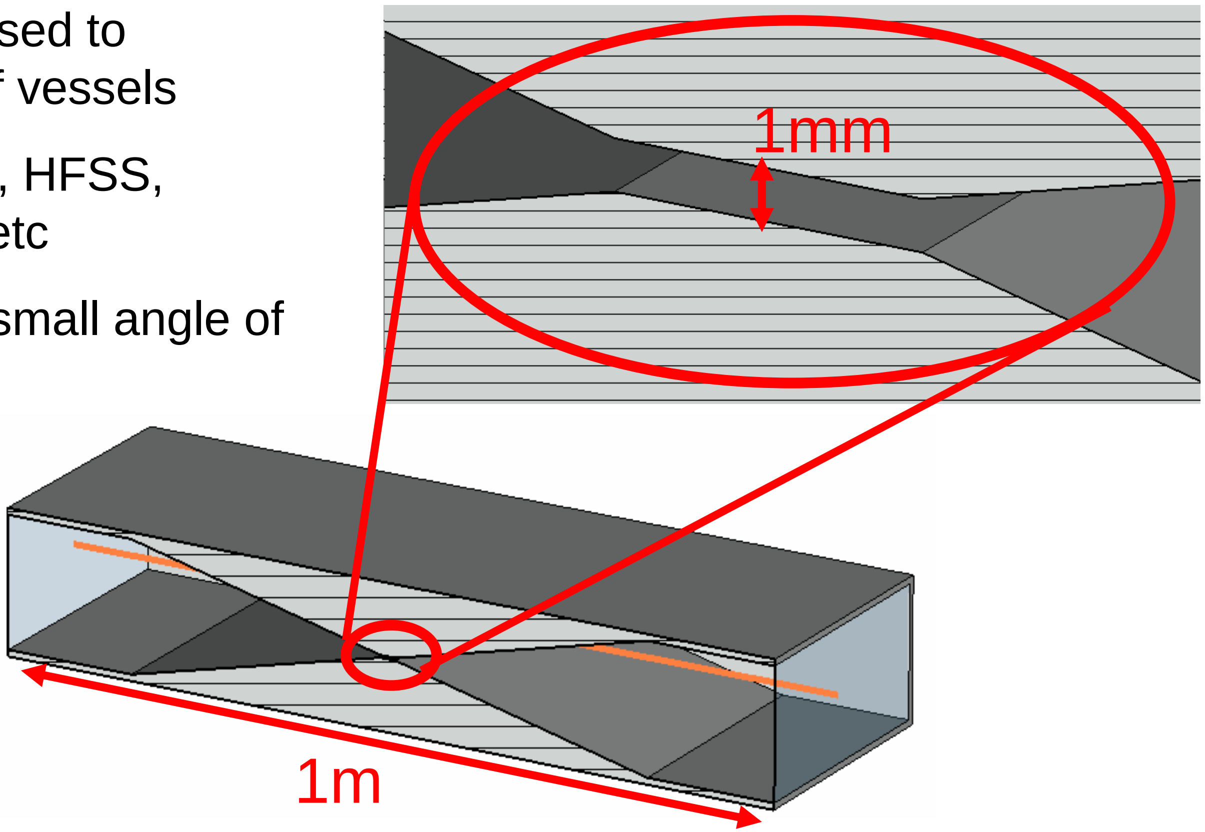
Computer Simulations of Spoiler designs

Beard

- Codes being developed/used to measure the impedance of vessels
  - ECHO2D, MWStudio, HFSS, GDFIDL, MAFIA, etc etc
- Calculation errors due to small angle of taper
- Off axis measurements



user defined pulse possible

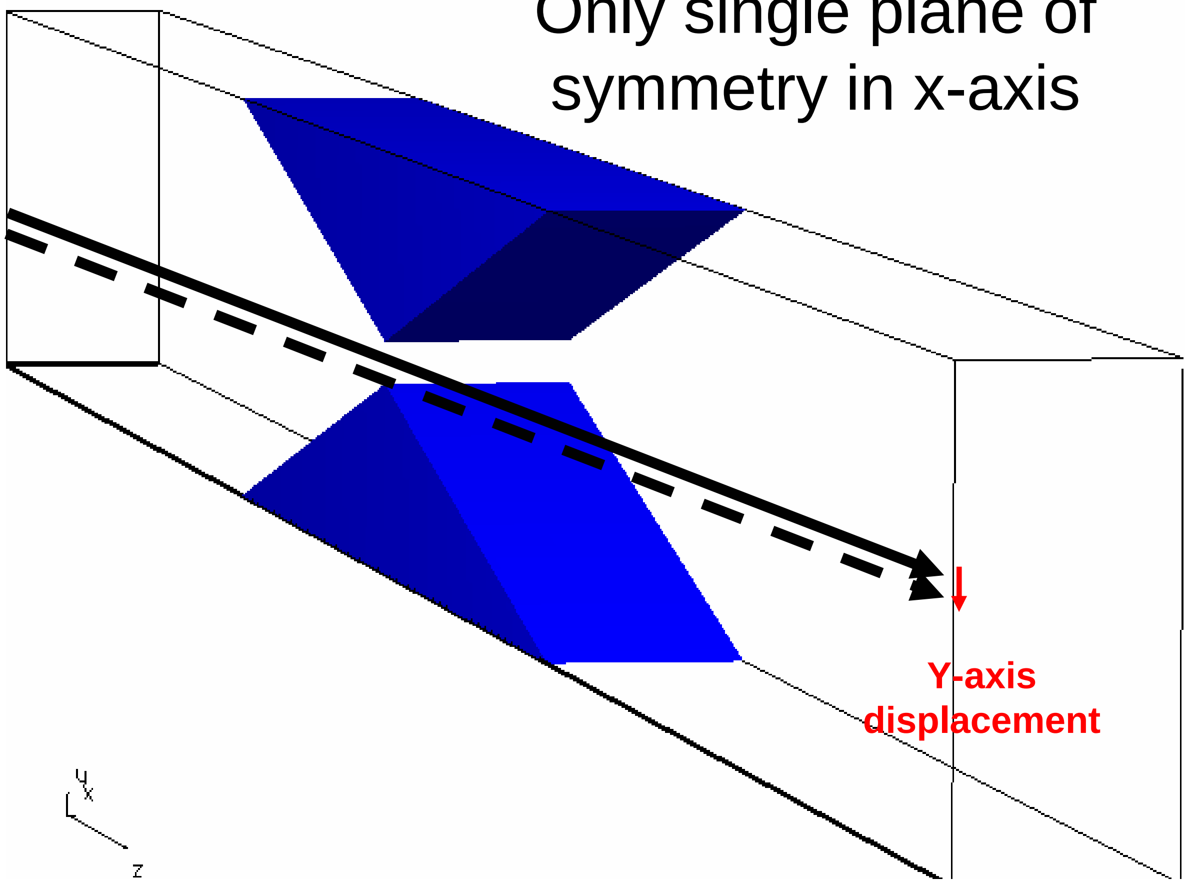


The length of the structure and the frequency make simulation time very long

Transverse Wakefield Calculations Set-up

If the structure is symmetric and the beam is on axis then the transverse components are zero

Only single plane of symmetry in x-axis



The kick factor is produced by integrating the transverse wake with the bunch shape

$$y' = \frac{N r_e}{\gamma} k_t y$$

y – beam off-set

N – Number of electrons

r_e - classical electron radius

γ - Relativistic factor

Rimbault

Main results on IPC GuineaPig/CAIN/BDK comparison

- Total IPC cross section : CAIN 12% less than GuineaPig
- VD background cross section : CAIN 40% less than GuineaPig
- LL process : GuineaPig ~ BDK ; CAIN ~ 1/3 BDK in VD
- ≠ between GP & CAIN : due to ≠ virtuality limit Q_{max}^2
- GuineaPig predictions more conservative than CAIN

Impact of beam parameter sets on VD background

Guineapig predictions

	r = 15mm	tesla	nominal	lowQ	largeY	lowP	highLum
	L_{bc} [μb^{-1}]	1.9	1.5	0.7	1.1	2.8	3.4
	L [$nb^{-1}.s^{-1}$]	27.0	20.6	20.0	16.1	18.9	48.5
3T	N_{incVD}/train[10^3]	**460**	**360**	**370**	**430**	**550**	**4800**
4T	N_{incVD}/train[10^3]	**270**	**240**	**220**	**250**	**290**	**680**
5T	N_{incVD}/train[10^3]	**160**	**160**	**120**	**170**	**190**	**390**

NB : (15mm, 3T) = (10mm, 5T)* (15mm, 4T) = (20mm, 3T) (15mm, 5T) = (20mm, 4T)

* out of inflationary cases.

(New) Web-based Guinea-Pig doc & program version mngt

Edit View Go Bookmarks Tools Help

http://flc.web.lal.in2p3.fr/mdi/BBSIM/bbsim.html

temf tud

CIO - Users manual v01-05

Beam-Beam Simulation Activities at LAL-Orsay

(these pages are under construction)

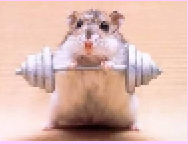
Work Plan for EuroTeV

BBSIM studies

Incoherent Pair Study

- e+e- creation processes study: first results. *Internal discussion -- LAL/Orsay -- 29.04.05*
- e+e- pairs study: Comparison GuineaPig/CAIN. *SOCLE Conference -- Grenoble -- 17.05.05*
- e+e- pairs study: Impact of Beam parameters on vertex detector background. *Internal discussion -- LAL/Orsay -- 27.05.05*

GuineaPig Support



GUINEAPIG is an e+ e- beam-beam simulation program written by Daniel Schulte.

GuineaPig user's manual

GuineaPig reference manual

GuineaPig versions manager (SVN)

References & Links

Physics of the beam-beam interaction and background study

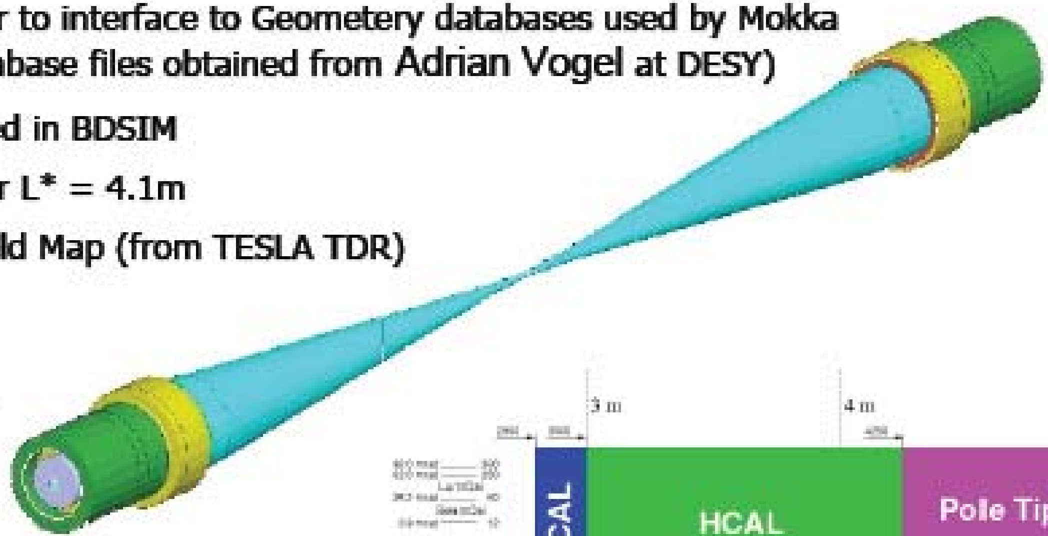
- K.Yokoya and P.Chen *Beam-beam phenomena in linear colliders*
- D. Schulte *Study of Electromagnetic and Hadronic Background in the Interaction Region of the TESLA Collider*

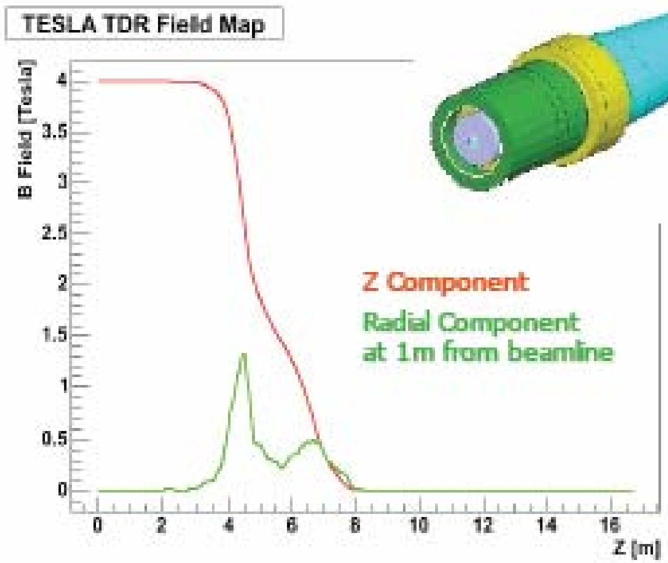
First GuineaPig documentations

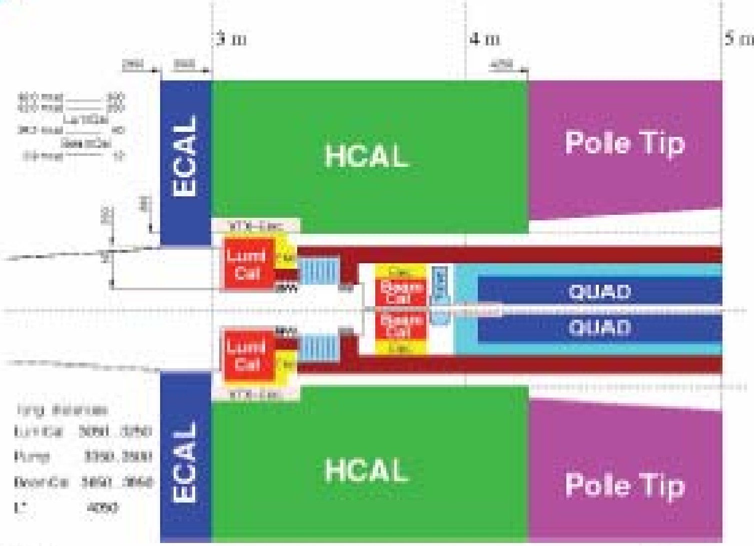
- D. Schulte *Thesis Appendix A*

IR Geometry Set Up

- Written a MySQL wrapper to interface to Geometery databases used by Mokka (Using OFFLINE SQL database files obtained from Adrian Vogel at DESY)
- Full IR Geometry modelled in BDSIM
- Using the Stahl design for L* = 4.1m
- Including 4T Solenoid Field Map (from TESLA TDR)

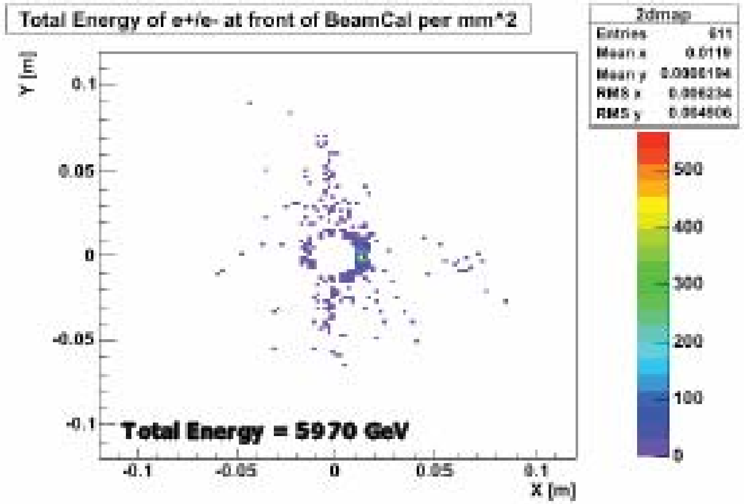






Radiative Bhabhas

- Guinea-Pig file produced for WG1 TeV nominal parameters - one bunch crossing
  - $N = 1.86 \times 10^6$ $\langle E \rangle = 394.6$ GeV
- Tracked with Solenoid Field & 1.6mrad Crossing Angle
  (solenoid 'off' to be done later - if needed)
- Energy Deposits into Components
  - QD0: 1.73W
  - SD1: 6.85W
- Comparable to other studies (T.Maruyama)
  - QD0: 1.9W
  - SD1: 0.1W



- Tracking down the extraction line proves to be difficult - due to large amount of showering when tracking down to 1keV...

Collimation Depth Calculation Issues

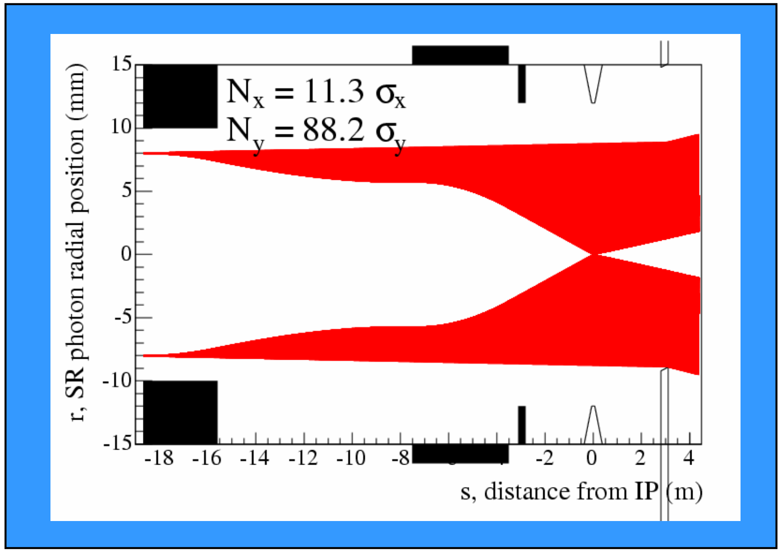
Jackson

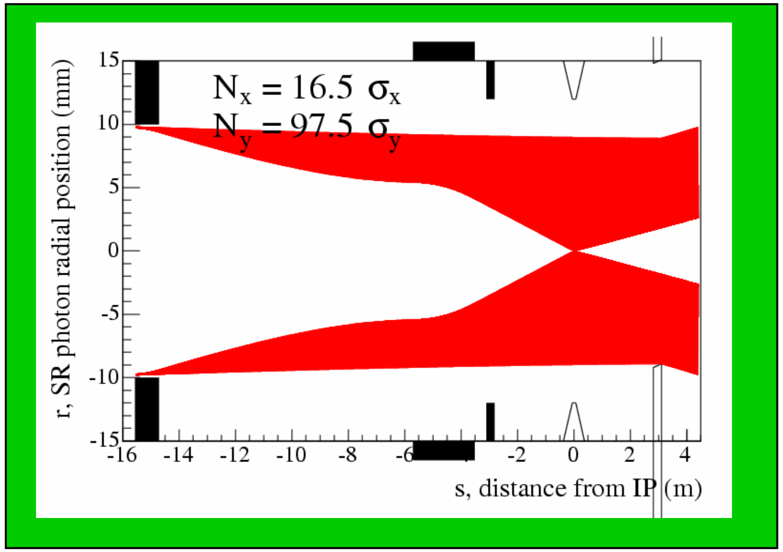
- Recent studies have highlighted some general issues
- Beam parameters
  - WG1 have published parameters table.
  - Not all FD designs use same parameters.
- Crucial apertures
  - Vtx, masks, and extraction quads
- Mask issues
  - Detector masks still to be determined
  - Some background studies suggest masks may be tightest apertures
- Crossing angle issues
  - SR fan may ‘see’ non-symmetric apertures

2mrad Results (L*=3.51 all cases)

Description	β_x/β_y (mm)	$\varepsilon_x/\varepsilon_y$ (m)	N_x/N_y
Lng doublet/TESLA/250GeV	15/0.4	1E-5/3E-8	5.7 x 83.2
Lng doublet/TESLA/400GeV	15/0.4	8E-6/1.5E-8	8.1 x 148.8
Lng doublet/NOM/250GeV	21/0.4	1E-5/4E-8	6.7 x 72.0
Lng doublet/NOM/500GeV	30/0.3	1E-5/4E-8	11.3 x 88.2
Shrt doublet/TESLA/250GeV	15/0.4	1E-5/3E-8	9.5 x 104.0
Shrt doublet/TESLA/400GeV	15/0.4	8E-6/1.5E-8	NO DESIGN
Shrt doublet/NOM/250GeV	21/0.4	1E-5/4E-8	11.2 x 90.1
Shrt doublet/NOM/500GeV	30/0.3	1E-5/4E-8	16.5 x 97.5

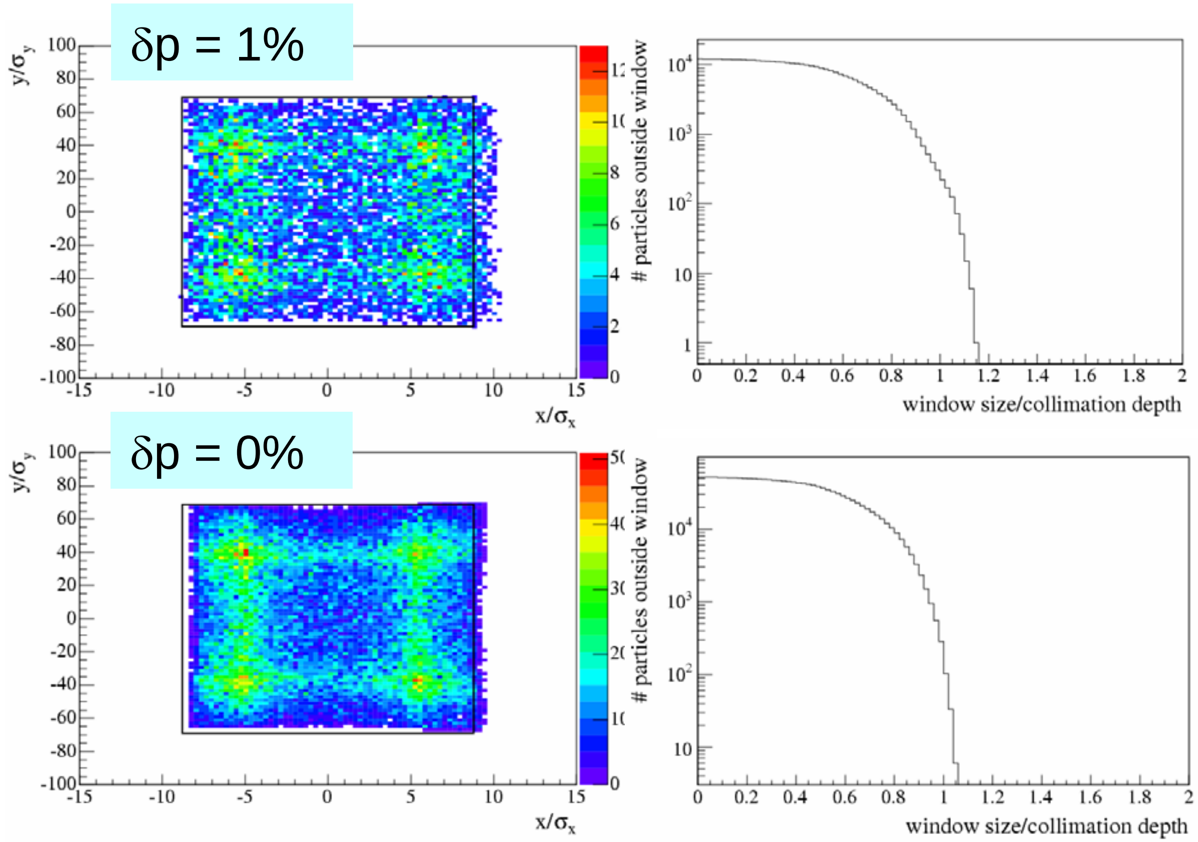
- In each case can trade N_x for N_y and vice-versa
- Short doublet seems more relaxed coll. depths
- QF aperture may limit halo as well as SR fan





20 mrad Collimation Performance

- 100 K particles, 1/r halo extending to $13\sigma_x$, $93\sigma_y$
- Halo intercepted by SP2, SP4, SPEX and secondaries are absorbed before FD
- 0.1% of initial halo population escapes $8.8\sigma_x$, $68.9\sigma_y$ depth



Summary

- Backgrounds x 3 detector concepts x 2 crossing angles
  - Sub-detector tolerance tables, separate origin of backgrounds, mitigation methods
- Collimation efficiency
- Muon spoilers
- Protection: machine + detector components
- Extraction beamline, including failsafe design
- Introduce engineering realism