Backgrounds in ILC Detectors

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ILC Physics and Detector Workshop and

Second ILC Accelerator Workshop

Snowmass, Colorado

August 14-27, 2005

OUTLINE

- IP and Beamline Backgrounds.
- Tasks Identified at RHUL Workshop.
- Results Since RHUL Workshop.
- Work to Do.

IP AND BEAMLINE BACKGROUNDS

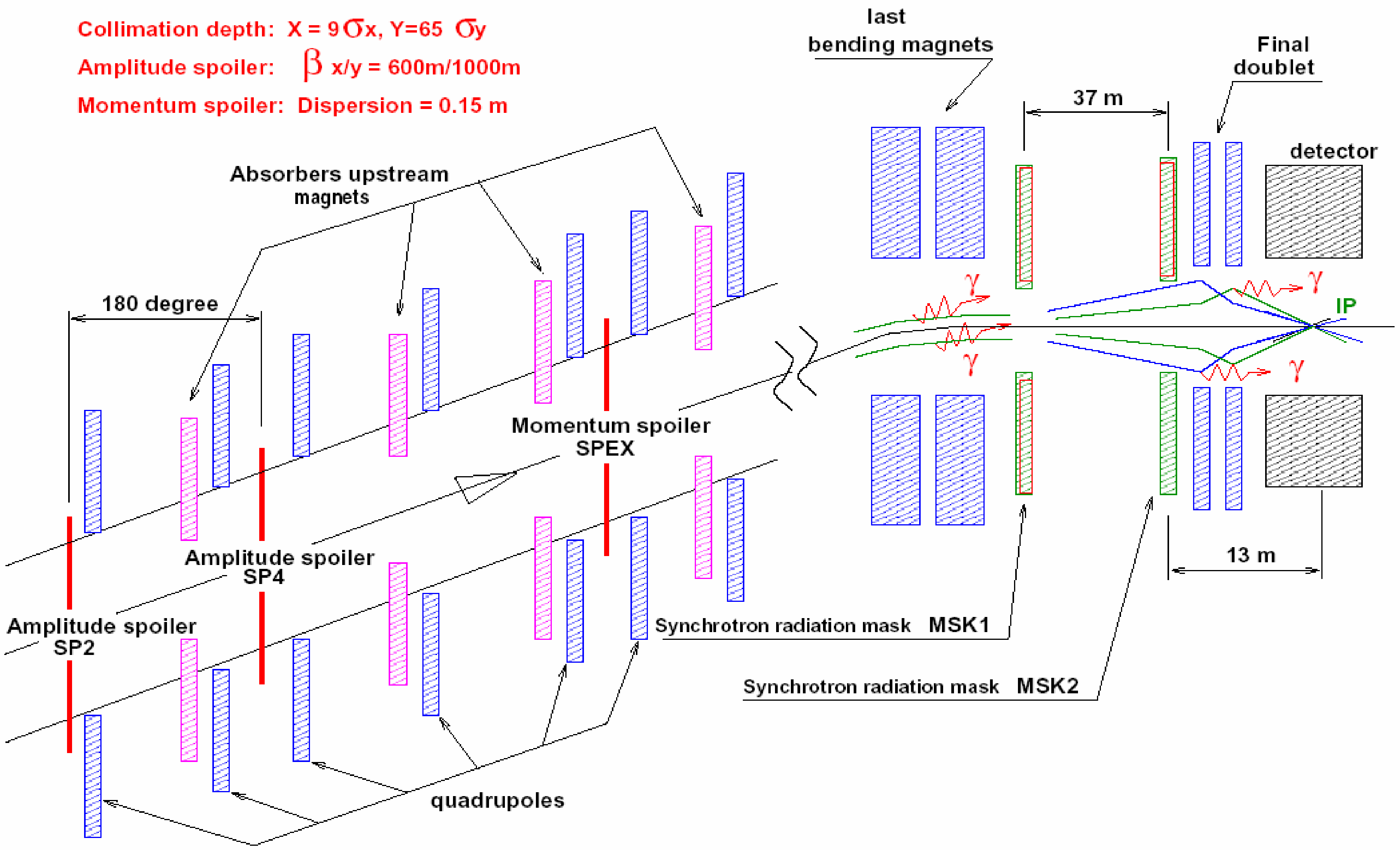
IP BG: beam-beam interactions (e^+e^- pairs, disrupted primary beam and beamstrahlung photons), hadrons from $\gamma\gamma$ interactions and radiative Bhabhas.

Average integrated hadronic fluxes produced at the IP are about six orders of magnitude lower compared to LHC. Instantaneous rates are about 1% of that at LHC for e^+e^- IP. **In general, this source is well understood and under control.**

Beamline BG: synchrotron radiation, spray from the extraction lines, beam-gas and beam halo interactions with collimators and other components in BDIR create fluxes of muons and other secondaries which can exceed the tolerable levels at a detector by a few orders of magnitude.

With a multi-stage collimation set and a system of magnetic iron tunnel fillers (or other means), **it seems that one can meet the design goal** of allowing a continuous 0.1% beam scraping rate, resulting in a tolerable muon flux at the detector.

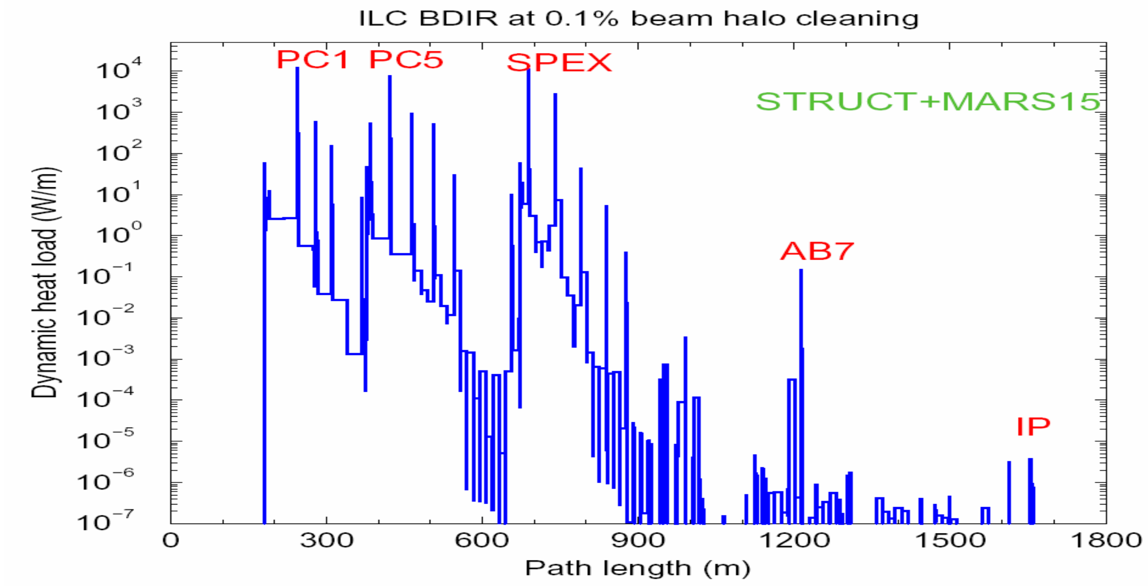
ILC COLLIMATION SYSTEM

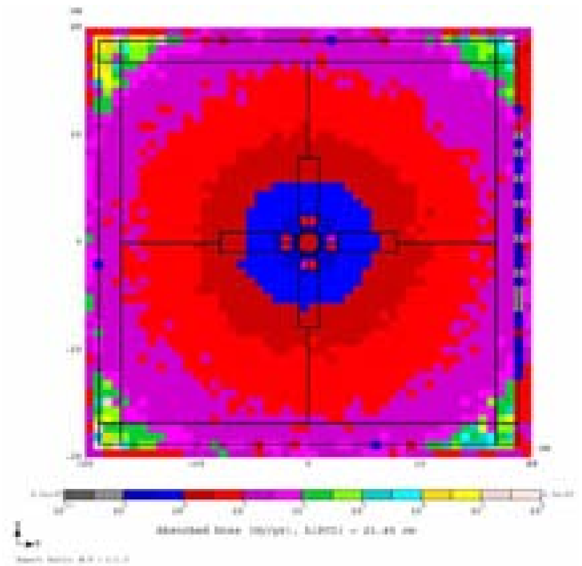


TASKS IDENTIFIED AT RHUL WORKSHOP: BDS

- 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

DYNAMIC HEAT AND RADIATION LOADS IN BDIR AS STUDIED AT FERMILAB





50 W/m for SP2, SP4 and SPEX, and 10 kW/m for PC1, PC5, PC8 and PC9

First quad downstream of protection collimator PC1: peak absorbed dose in coils ~300 MGy/yr (a few days of lifetime for epoxy), residual dose on the upstream face is 7.7 mSv/hr (should be below 1 mSv/hr). It is shown that 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.

It is shown that temperature rise and stress should not be a problem except accidental conditions. Peak heating per train: 1.4 J/g and 2 K in SP2, and 4.7 J/g and 6.6 K in PC1.

TASKS IDENTIFIED AT RHUL WORKSHOP: DETECTOR

1. 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 both for IP and beamline for μ, synchcrotron γ, neutrons, pairs
   - Mitigation methods: change VXD radius, light TPC gas, low Z mask, μ tunnel spoilers
2. From background origins to sub-detector response
3. Need consistent, detailed BDS+detector models
   - FNAL: MARS15+G4/SLIC integration for SiD
   - BDSIM+Mokka integration in progress
   - LCBDS+JUPITER in preparation
4. Complete integration as an ultimate dream

BDSIM DEVELOPMENTS AT RHUL

- Moving BDSIM to MAD-like input format
  - Read MAD decks directly - without the need to produce optics format files
  - Using MAD-like files to include process flags, geometries, bunch descriptions, etc.
- Complicated Geometries (e.g. Interaction Region) can be built using MySQL database
  - Links to detector studies that use Mokka
  - Removes need to hand code complicated geometries
  - Will be possible to apply to key/specialised components such as extraction quads
- Implement Neutron processes - we don't trust Geant4's!
- Looking to add sensible tracking cuts depending on regions of interest along the beam line
- Many other issues being looked at, such as beam gas

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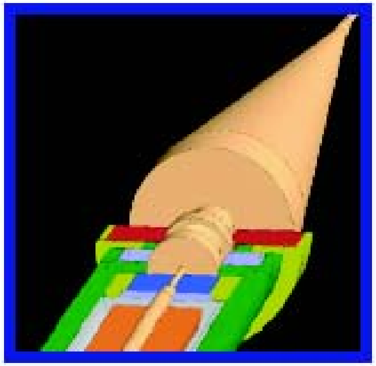
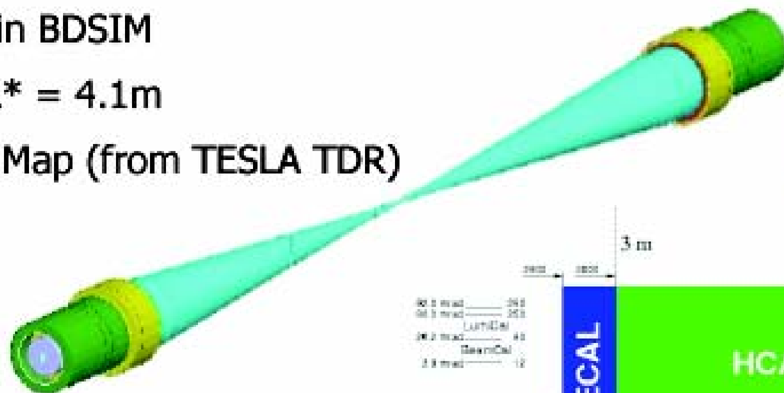
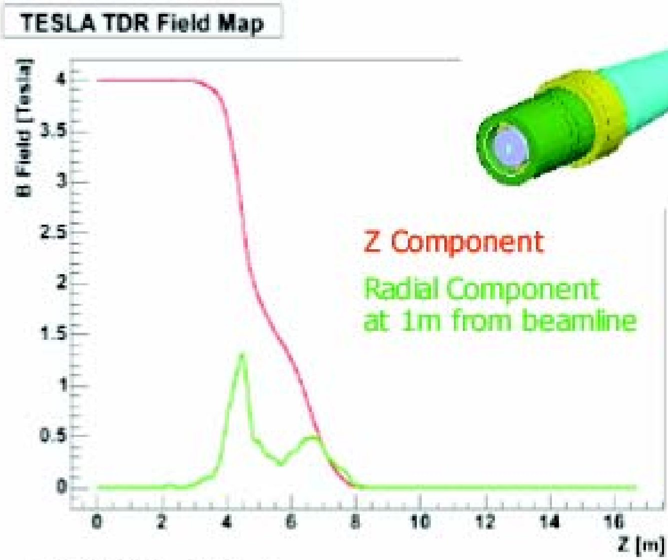
BDSIM IR SETUP

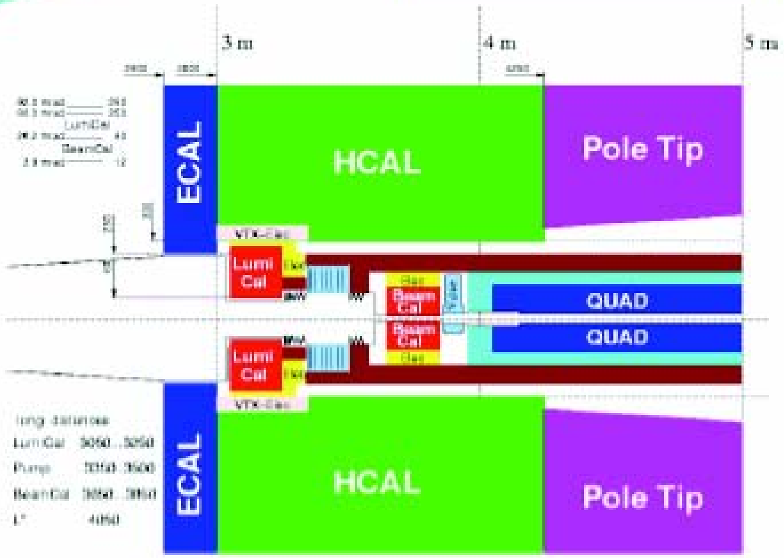
- Written a MySQL wrapper to interface to Geometry databases used by Mokka (Using OFFLINE SQL database dump file obtained from A. Vogel at DESY)
- Can also access a locally running MySQL database
- Full IR Geometry modelled in BDSIM
- Using the Stahl design for L* = 4.1m
- Including 4T Solenoid Field Map (from TESLA TDR)

A. Vogel, ILC-BDIR June 2005









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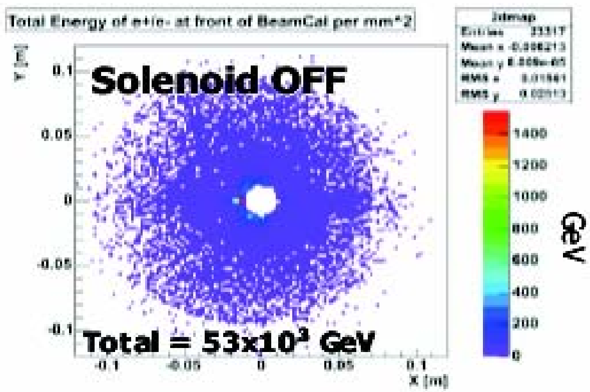
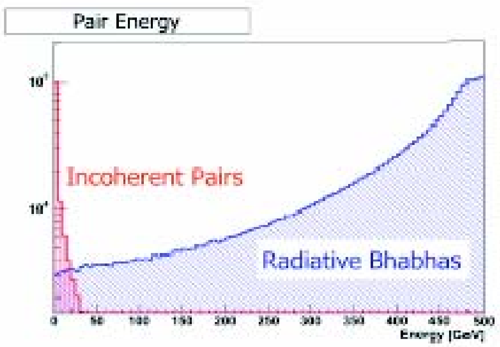
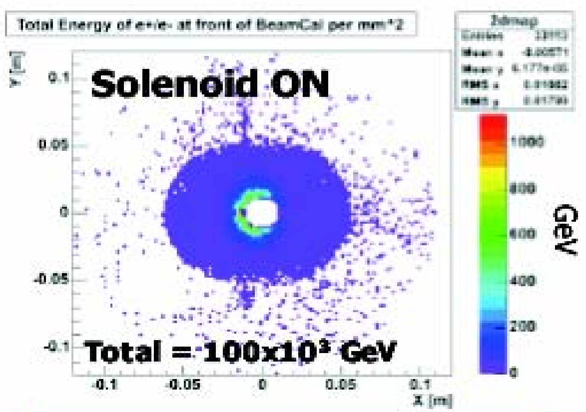
BDSIM PAIR BACKGROUNDS



- Using Guinea-Pig produced pairs based on the WG1 1TeV Nominal for 1bx
  - Incoherent Pairs
    - N = 133642
    - <E> = 6.743 GeV



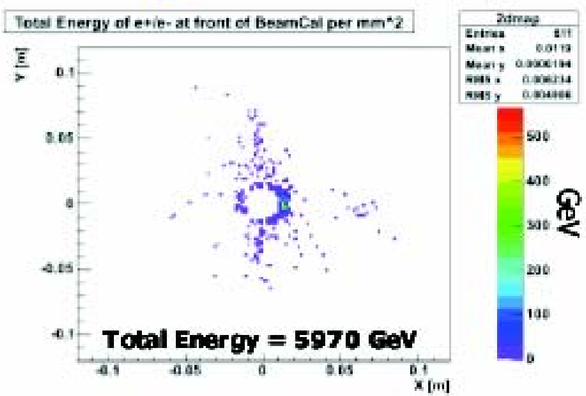


Twice as much energy than for NO solenoid!!

- Radiative Bhabhas
  - N = 1.86×10^6
  - <E> = 394.6 GeV
- Power into QD0 ~ 1.7W
- Power into SD1 ~ 6.9W

(to be checked…)

Note: No mask in place



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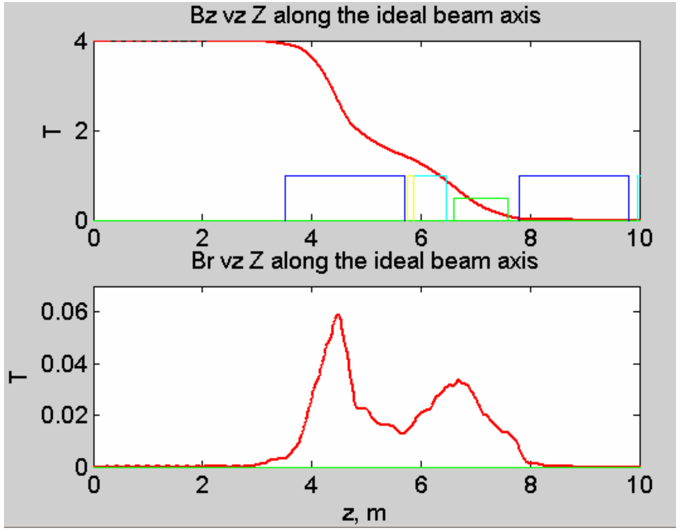
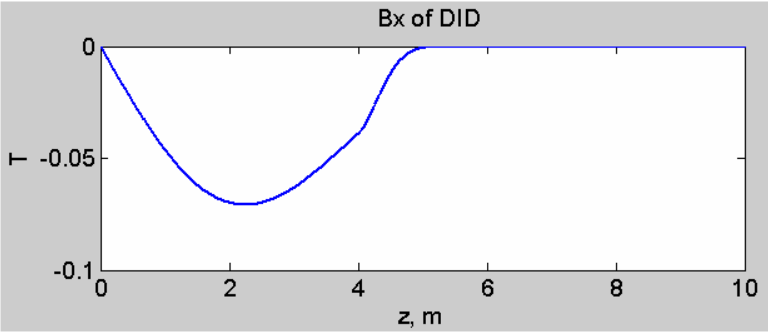
PAIR BACKGROUND STUDIES AT DESY

GUINEA-PIG GEANT3 Simulations of Pair Backgrounds in the Large Detector with realistic Solenoid and DID Fields by Karsten Büßer.

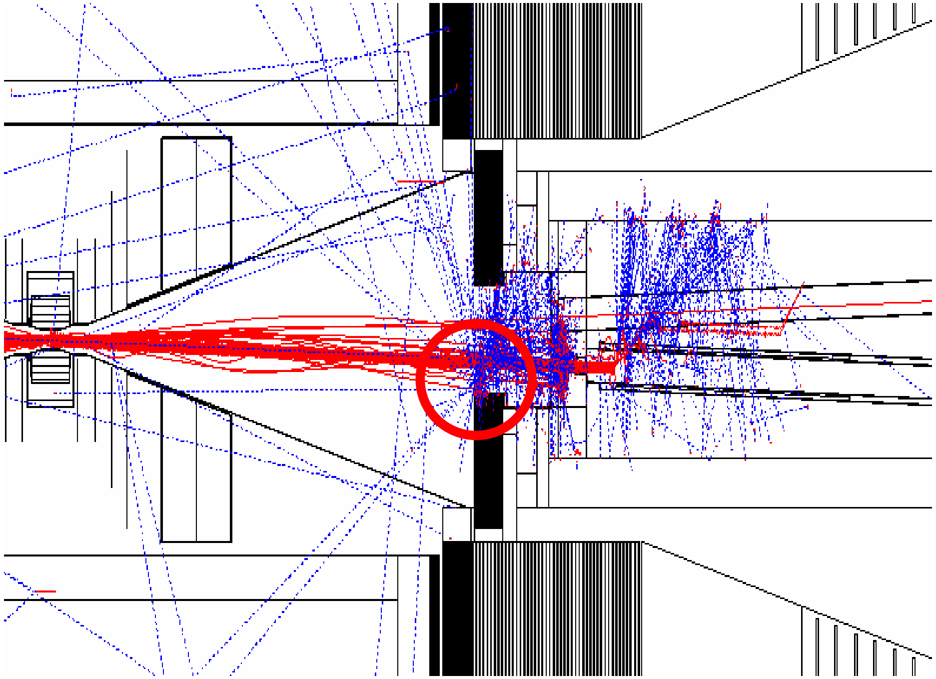
A lot of different geometries have been studied, including different crossing angles, holes for incoming/outgoing beams and magnetic field configurations. Realistic magnetic fields for TESLA solenoid (by F. Kircher et al) and Detector Integrated Dipole (by B. Parker and A. Seryi) have recently been introduced.





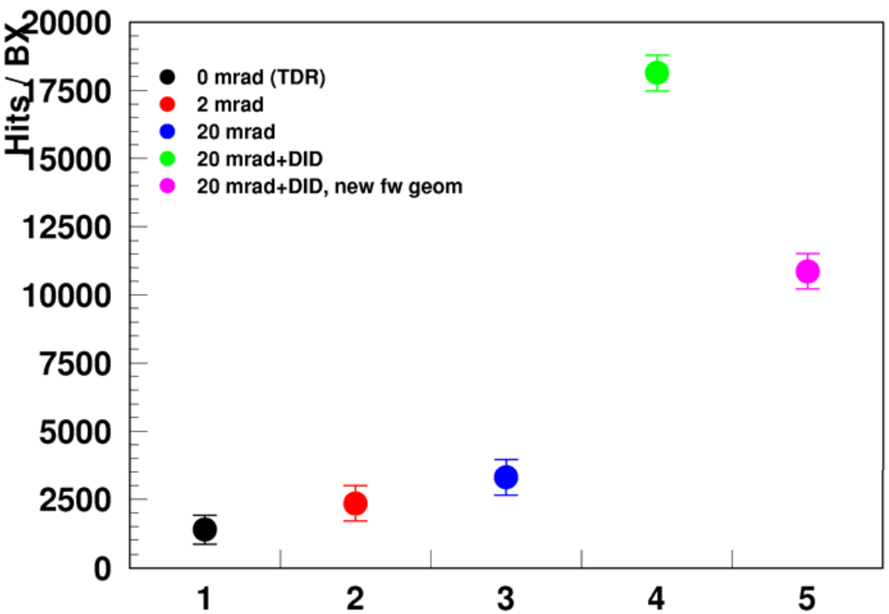
DID field combined with FD offset to zero both angle and position at the IP

Hits in the TPC with Solenoid+DID



Karsten Büßer

Comparing configurations:

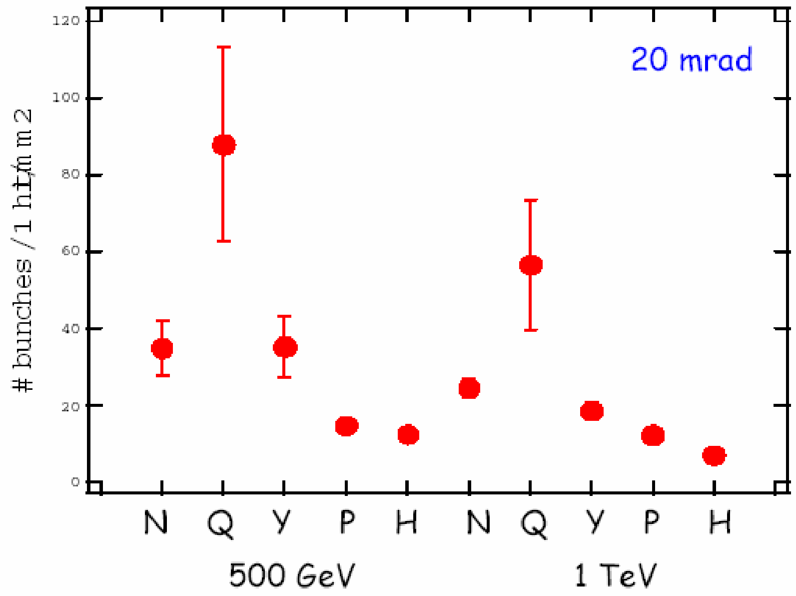


Origin of TPC photons:
pairs hit edge of LumiCal

VXD HITS FROM BEAM-BEAM PAIRS

- Readout of pixel detector is slow.
- It would be simple if one readout of whole bunch-train is sufficient.
  - GLD considers 5 μm × 5 μm fine pixel detector.
- Study VXD hits for different beam parameters.
- Use 1 hit/mm^2 as a tolerance level.
- Ask how many bunches to reach this level.

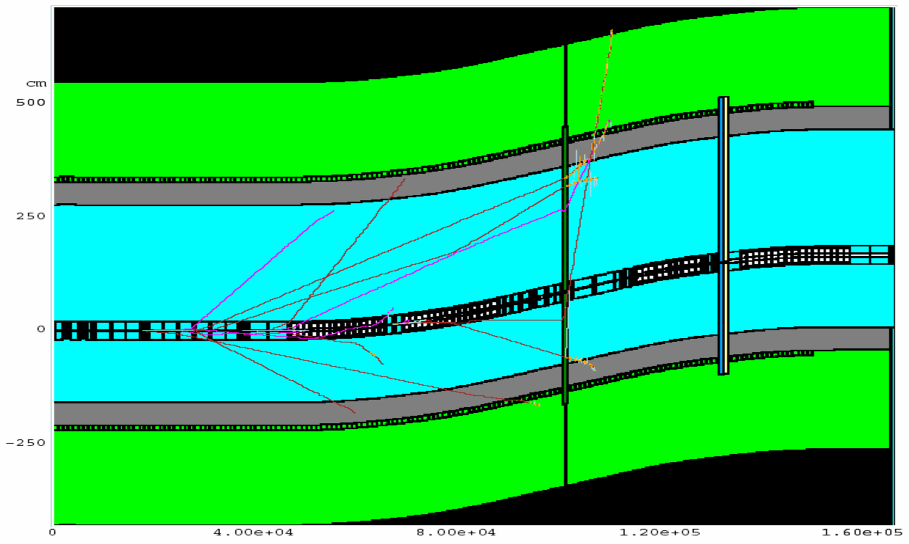
GEANT3 modeling for SiD
By Takashi Maruyama

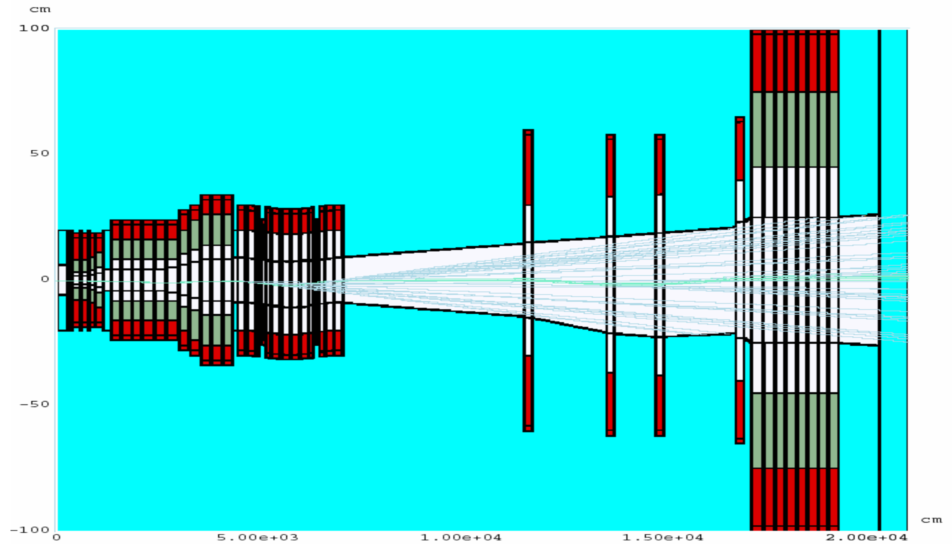


N – nominal
Q – Low Q
Y – High Y
P – Low P
H – High Lum.

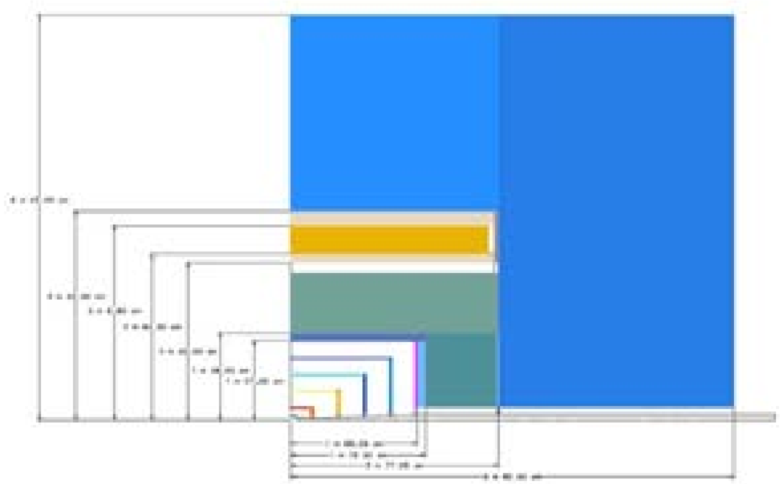
- Intra-train readout/buffering is necessary.
- # bunches to reach 1 hit/mm^2 is dependent on the beam parameters.
  - 500 GeV Low Q : 88 bunches
  - 1 TeV High Lum : 7 bunches
- One train readout using 5 μm × 5 μm fine pixel detector may work only for 500 GeV Low Q.

BDIR MARS MODEL: 1700 m BDS, SiD (GEANT4) at IP, followed by 200-m extraction line (20 mrad X)



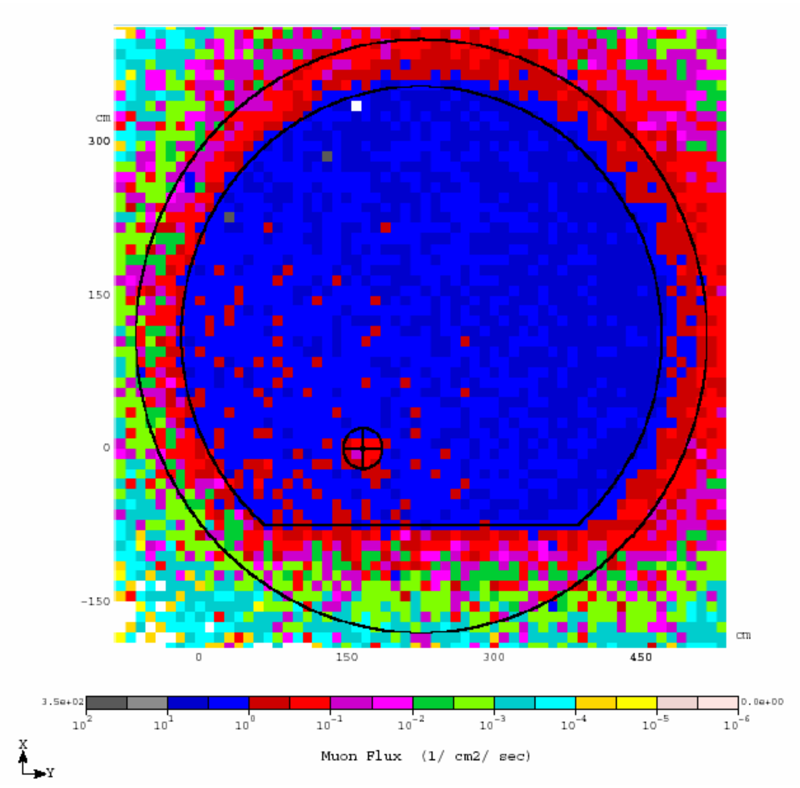


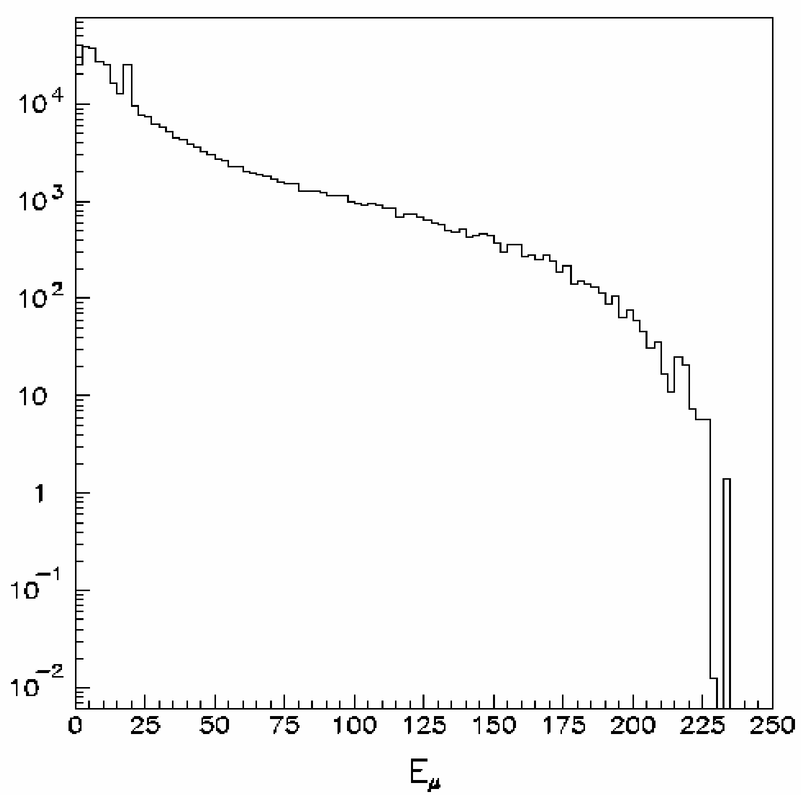
Model includes all magnets, tunnel (R=2.44 m, 0.46-m concrete walls, dirt), multi-stage collimation system (spoilers, absorbers, protection collimators, and photon masks), muon tunnel fillers, SiD, and extraction line (0 and 120-nm vertical displacement for high-lum 250-GeV beams, so far).



MUON AND OTHER PARTICLE FLUXES ON COLLIDER DETECTOR

MARS15



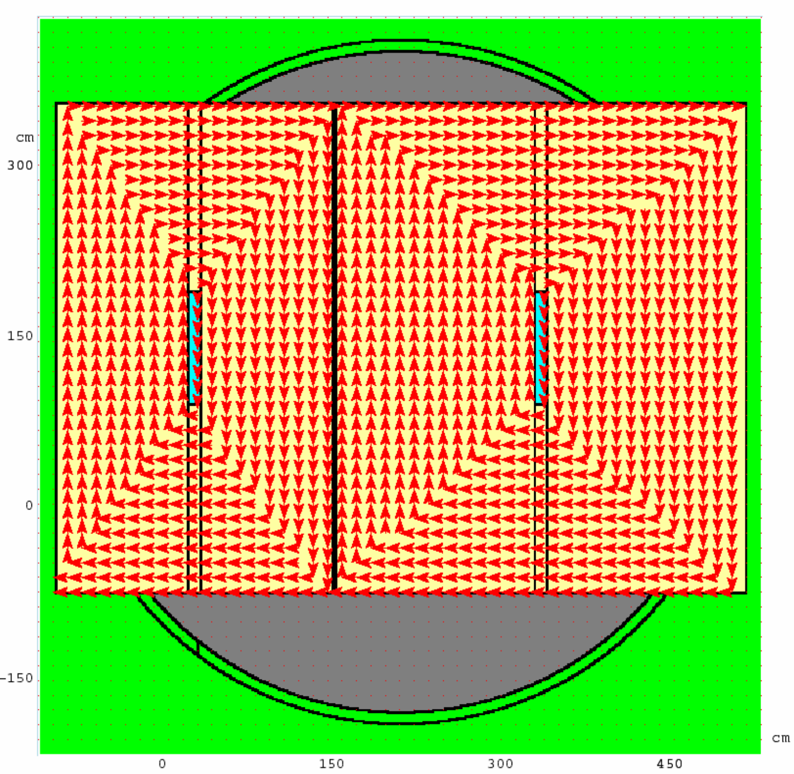


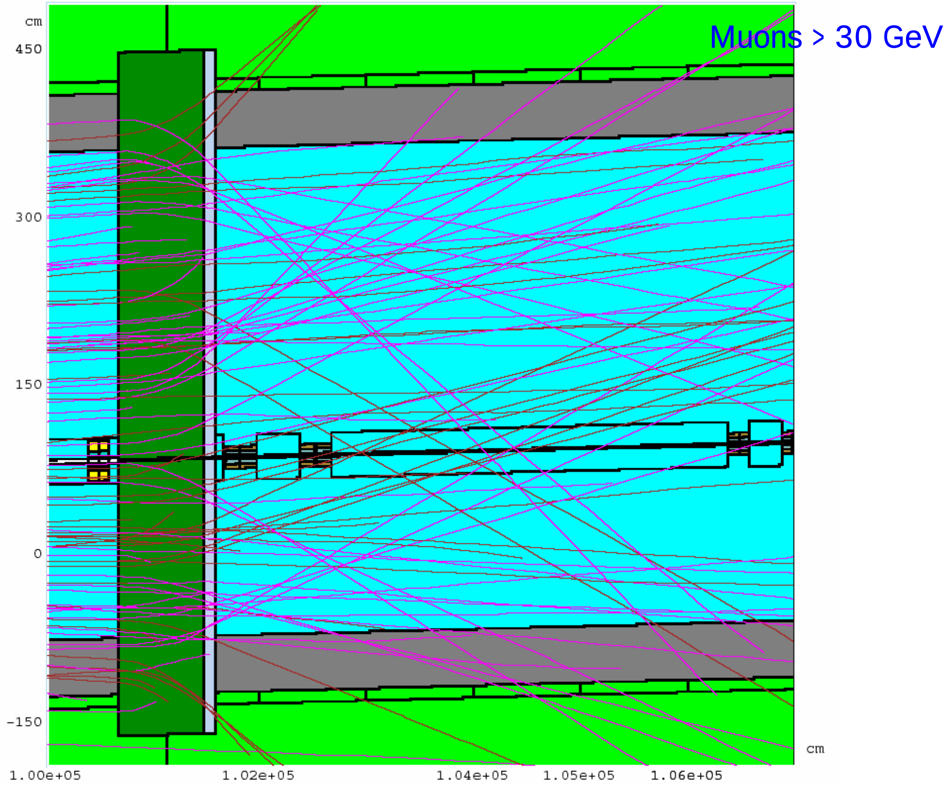
7600 muons, $7x10^5$ photons, $2x10^5$ electrons per 150 bunches

Limit: less than a few muons!

MUON SPOILERS IN BDS TUNNEL

MARS15





Two iron 9 and 18-m thick spoilers at 1.5 T sealing tunnel at 660 and 350 m from IP. Opposite field polarity in two parts. Extended 0.6 m into the tunnel walls. Central gaps are 10-cm wide and 1-m high with 0.8 T field. The gap between the parts is as beam pipe.

MUON FLUX SUPPRESSION ON DETECTOR

MARS15

Spoiler configuration	# muons in tunnel x-section per 150 bunches	Muon flux $cm^{-2}\ s^{-1}$
No spoilers	7587	4.1
Realistic	2.2	1.2×10^{-3}
Solid	0.8	4.3×10^{-4}

Consistent with Lew Keller predictions.

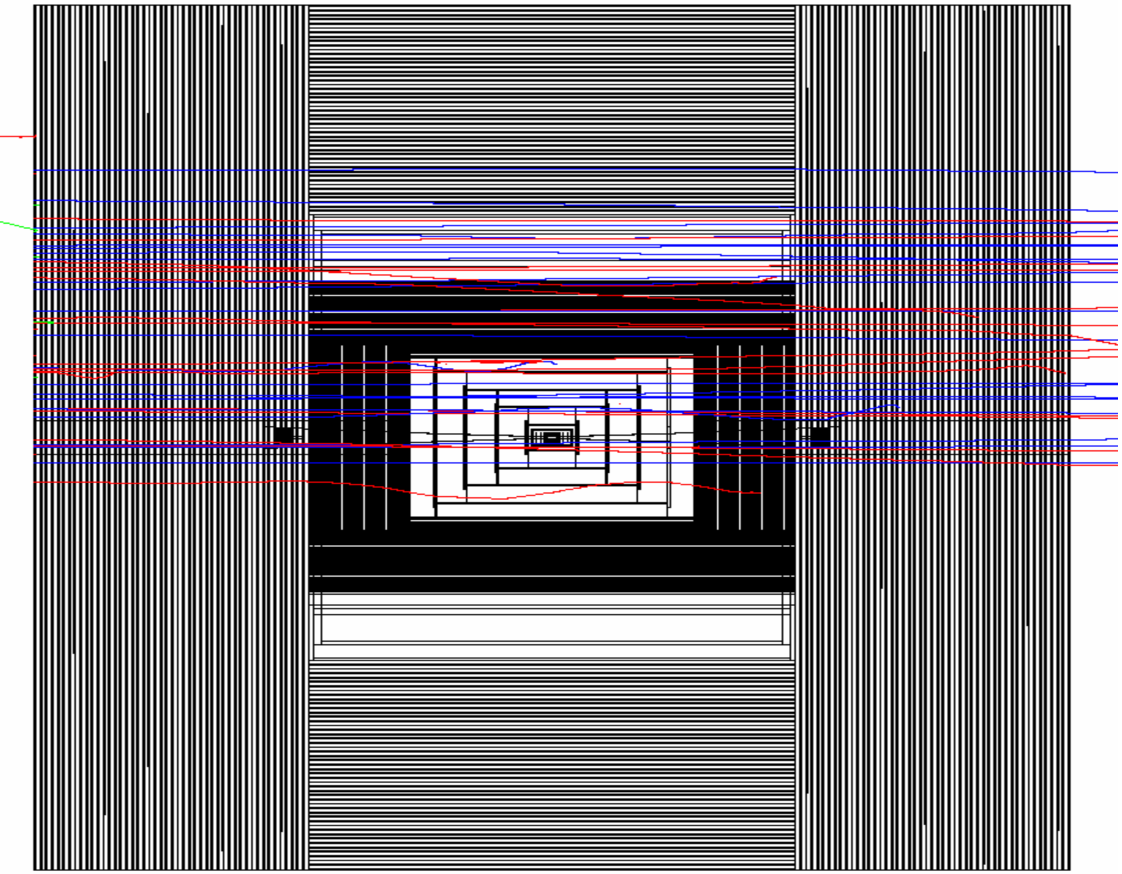
Other particle fluxes on detector for solid spoilers:
0.1 n, 400 γ, 94 e $cm^{-2}\ s^{-1}$

Exploring two alternative methods to suppress muons to mitigate engineering problems (bypass tunnels etc):

- **Muon attenuator** (colar at 1 T, 0.6-m OD, 120-m long).
- **Wide aperture magnets** (first results are quite encouraging: three to five 5-m long dipoles at 1 T give better performance than tunnel spoilers).

MARS15+GEANT4/SLIC INTEGRATION

Beamline muons on SiD: side view



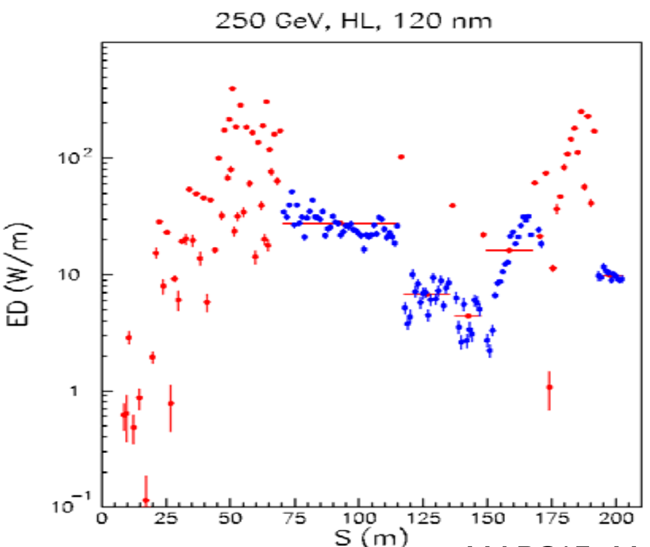
I. Tropin

SLIC and related software installed on ILCSIM farm at Fermilab. Tested with IP and MARS's event generators (sources). Work is underway on G4 physics evaluation and adding new hit collectors. **Problem: statistical weight use and propagation in GEANT4.**

Aiming at full detailed description of beamline and detector components for two-way info flow between MARS and GEANT to calculate hit rates (occupancy, with timing) and flux/dose (radiation damage and heat loads) in each sub-detector and final focus components.

EXTRACTION: BACKGROUNDS AND RAD. LOADS

Simulations (for 20 mrad) confirm that: Synchrotron photons produced from beam core and halo upstream of the IP are collimated by the photon masks and – with appropriate design – their contribution to backgrounds and radiation loads to extraction line components is negligible. Same with beamstrahlung photons which form a very narrow beam. ***e^+e^-* pairs and synchrotron photons generated by disrupted beam remain the main source of IP backgrounds and radiation loads to detector and extraction components.**



MARS15, M. Kostin

At high luminosity and 120-nm vertical offset: total radiation load in extraction beamline is 13.3 kW with 600 W/m peak. Without vertical offset, these numbers are about a factor of 10 lower.

CONCLUSIONS

Results on IP and beamline-induced backgrounds are encouraging – with considered protection and mitigation measures; there is no show stopper so far.

Work to do:

1. **Building consistent, realistic BDS+detector integrated models, with detailed magnetic field maps, tunnel and experimental halls. Add engineering realism wherever possible.**
2. **Study IP and BDS backgrounds for 3 detector concepts x 2 crossing angles**
   - **Generate/refine sub-detector tolerance tables**
     - **hit rates (occupancy): revise/extend one generated by Witold Kozanecki, sensitivity windows wrt tagged origin and bunch crossing**
     - **flux/dose (radiation damage and heat): realistic modeling**
   - **Tag origins of backgrounds for μ, synchcrotron γ, neutrons, pairs**
   - **Mitigation methods: collimation system and mask performance (e.g., low-Z mask), change VXD radius, light TPC gas, muon tunnel spoilers or muon attenuator or wide-aperture magnets.**
3. **Simulation standards, interfacing, BDIR code/model/map depository.**
4. **Code/model benchmarking.**