PARTICLE COLLIDER INTERACTION REGIONS

Backgrounds and Machine-Detector Interface

Lecture 1: e^+e^- Colliders

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BMDI Lectures

1. e^+e^- (ILC)
2. pp (LHC)
3. $\mu^+\mu^-$
4. Collimation
5. Computing

Acknowledgments

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Lecture 1

e^+e^- Collider Backgrounds and MDI

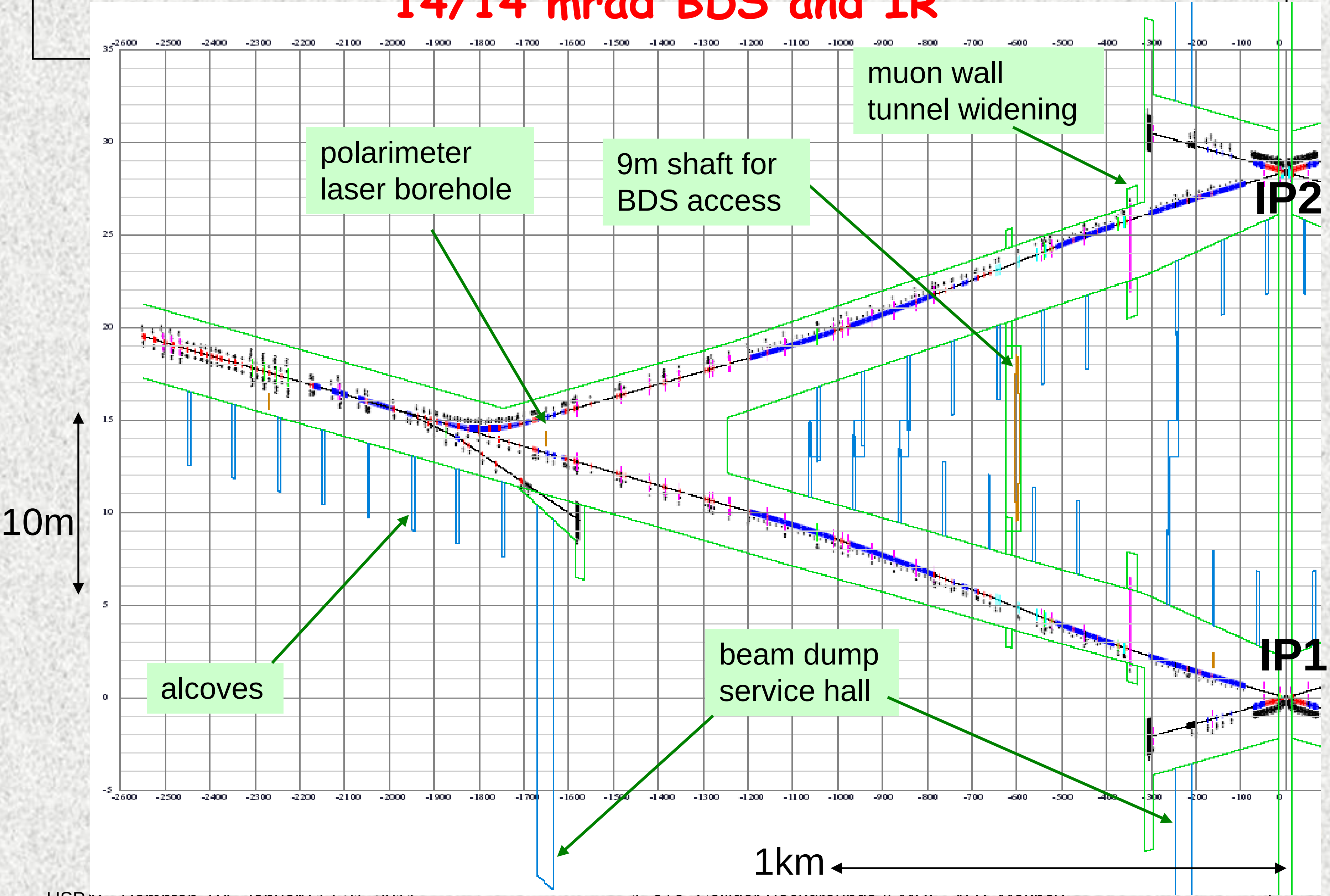
OUTLINE

1. Beam-Beam and Machine-Related Backgrounds
   Detector and Radiation Tolerable Limits
2. Synchrotron Radiation
   Electromagnetic Showers, Muon/Hadron Production in Beam Delivery System
3. Dealing with Muon Spray
   Particle Flux, Hit Rate and Occupancy in Detector
4. Radiation Loads in BDS, IR and Extraction Line
   Machine and Environment Protection

BACKGROUNDS, RADIATION AND IR/DETECTOR DESIGN

The high physics potential of the ILC is reached only if a high luminosity of e^+e^- collisions in the TeV range is achieved (say, 2×10^{34} cm^{-2} s^{-1}). The overall detector performance in this domain is strongly dependent on the background particle rates in various sub-detectors. The deleterious effects of the background and radiation environment produced by the accelerator and experiments have become one of the key issues in the Beam Delivery System (BDS), Interaction Region (IR) and detector design and development.

14/14 mrad BDS and IR



polarimeter laser borehole

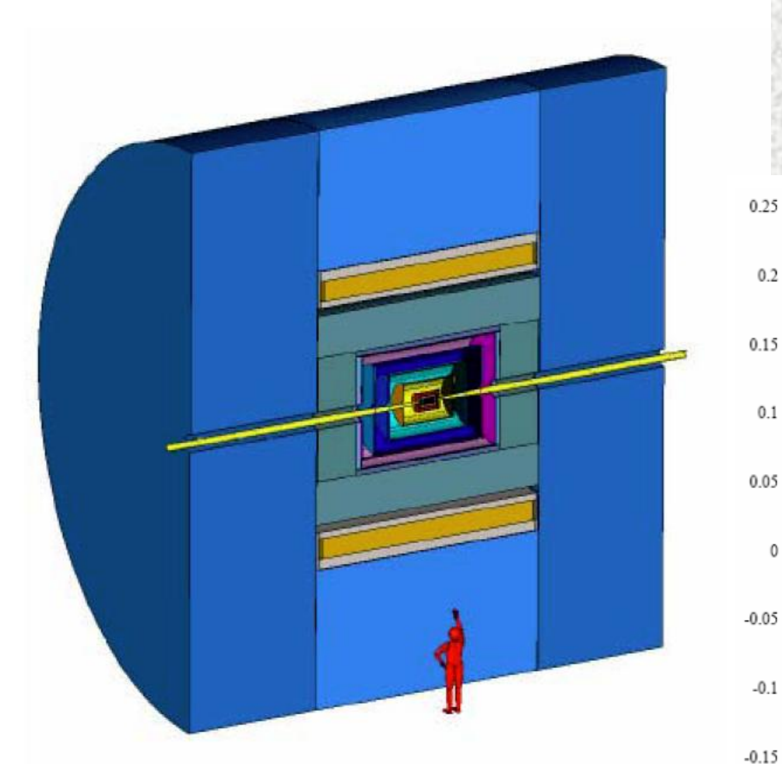
9m shaft for BDS access

muon wall tunnel widening

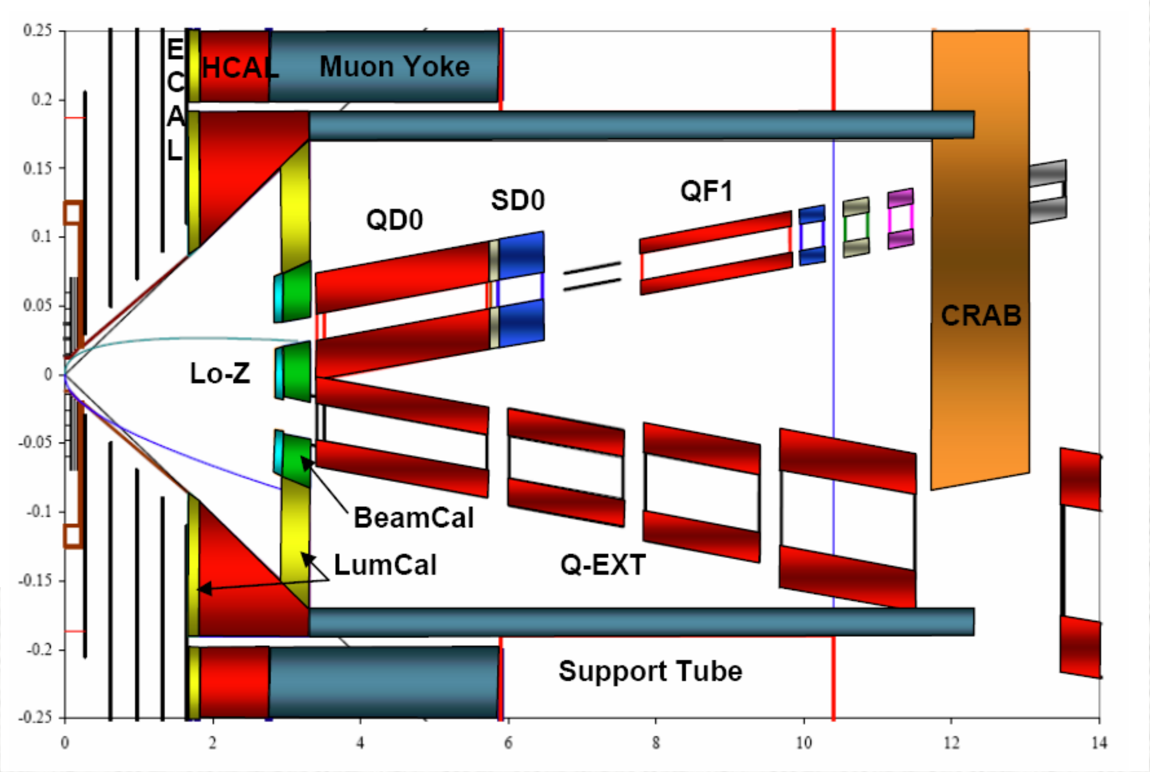
alcoves

beam dump service hall

ILC MACHINE-DETECTOR INTERFACE



ILC “compact” detector SiD with 5-Tesla solenoidal field



L* ≈ 3.5 m, compare to L* = 23 m at LHC !

BACKGROUNDS AND DETECTOR PERFORMANCE

Two sources

1. **IP backgrounds:** Particles originated from the interaction point (IP) – beam-beam interaction products and collision remnants.
2. **Machine backgrounds:** Unavoidable bilateral irradiation by particle fluxes from the beamline components and accelerator tunnel.

Backgrounds affect ILC detector performance in three major ways:

- Detector component radiation aging and damage.
- Reconstruction of background objects (e.g., tracks) not related to products of e^+e^- collisions !!!
- Deterioration of detector resolution (e.g., jets energy resolution due to extra energy from background hits).

IP BACKGROUNDS

Source:

Beam-beam interactions (disrupted primary beam, beamstrahlung photons, e^+e^- and $\mu^+\mu^-$ pairs and hadrons from beamstrahlung and $\gamma\gamma$ interactions, and extraction line losses) and **radiative Bhabhas** ($e^+e^- \longrightarrow e^+e^-\gamma$).

From the standpoint of integrated background, e^+e^- linear colliders are relatively 'clean' machines. Average integrated hadronic fluxes produced at the IP are about six orders of magnitude lower compared to LHC.

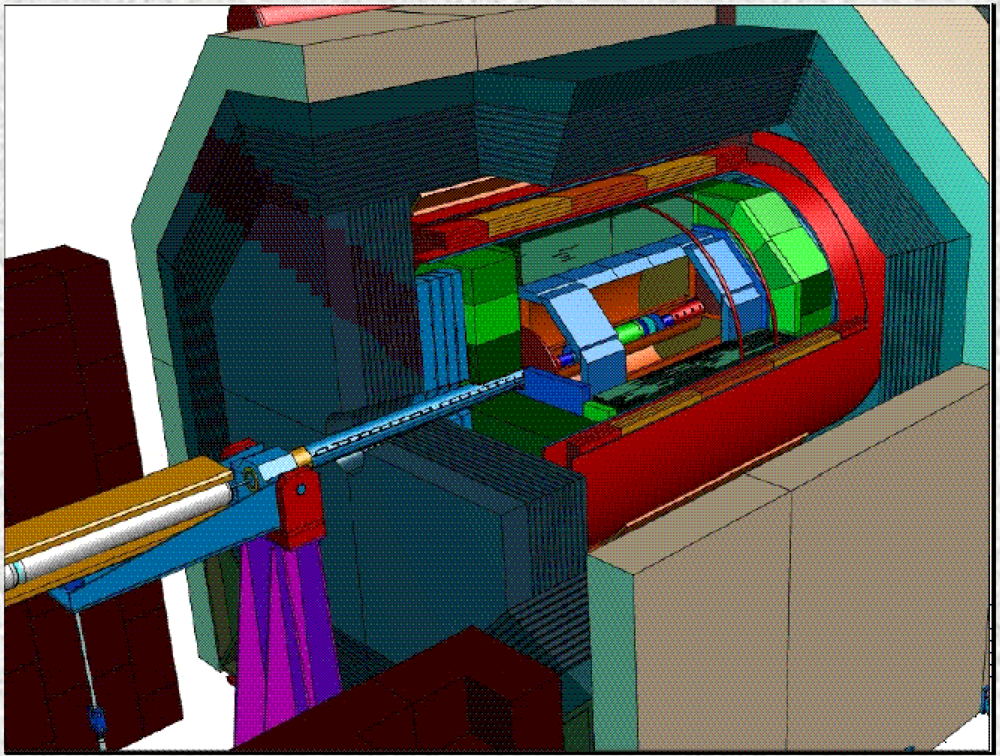
However, the instantaneous rates are not so drastically different. Say, for the $\gamma\gamma$ option, a peak radiation field is about 10% of that at LHC. The e^+e^- option is 10 times better.

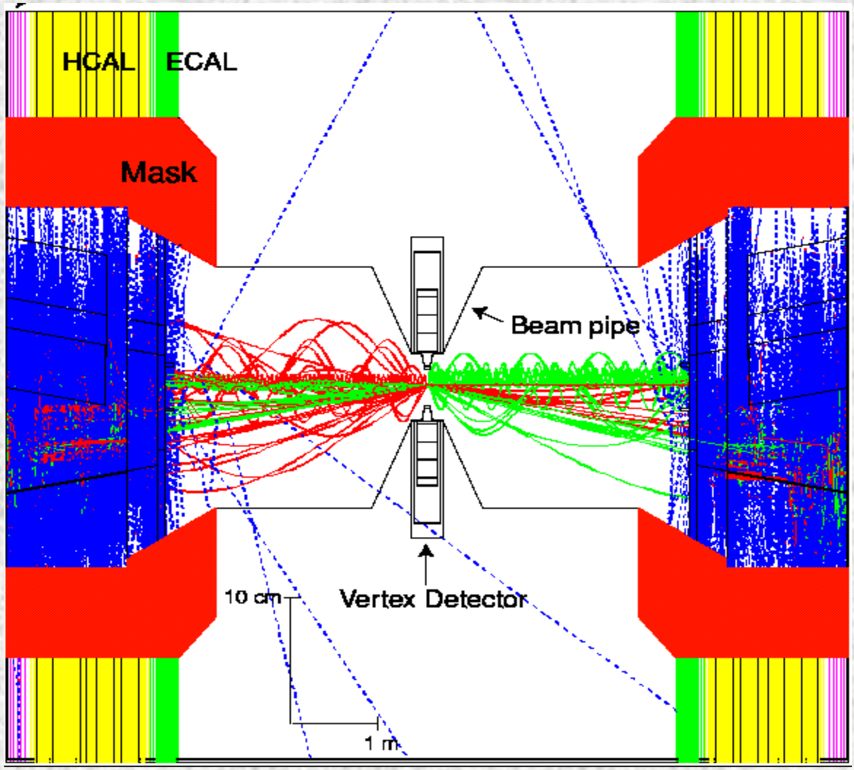
In general, this source is well understood and under control: it scales with luminosity, one should transport interaction products away from IP and shield/mask sensitive detectors, and exploit detector timing.

THREE DETECTOR CONCEPTS

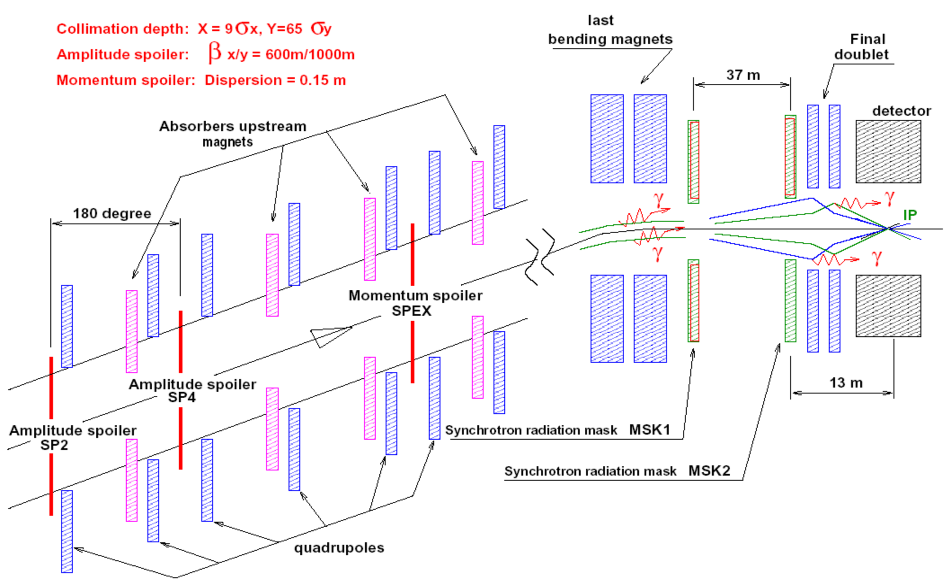
Subdetector	GLD	LDC	SiD
Vertex detector	Si pixel r1= 2.0 cm	Si pixel r1= 1.5 cm	Si pixel r1 = 1.4 cm
Tracker	TPC	TPC	Si strips
EM CAL	Scintillator-W	Si-W	Si-W
HAD CAL	Scintillator-Pb	Scintillator-Fe RPC/GEM-Fe	Si-W
Muon system	Scintillator	RPC (resistive plate counter)	RPC
Solenoid	3 Tesla R = 3.5 – 4.5 m L = 8.9 m	4 Tesla R = 3 – 4.45 m L = 9.2 m	5 Tesla R = 2.5 – 3.3 m L = 5.4 m

DEALING WITH SYNCHROTRON RADIATION AT IP



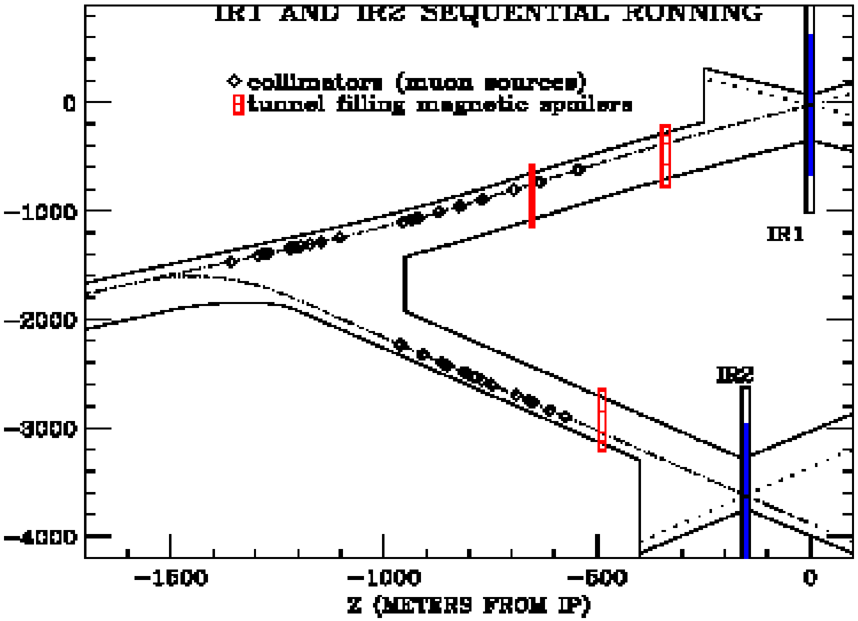


COLLIMATION SYSTEM AND MAGNETIC SPOILERS IN BDS


Collimation depth: $X = 9\sigma_x$, $Y=65\ \sigma_y$

Amplitude spoiler: β x/y = 600m/1000m

Momentum spoiler: Dispersion = 0.15 m



TEMPORAL ASPECTS

Temporal considerations in the IP and machine background analysis are of a primary importance. Integrated levels determine radiation damage, aging and radio-activation of detector components as well as the radiation environment in the experimental hall, accelerator tunnel and their surroundings. High instantaneous particle fluxes complicate track reconstruction, cause increased trigger rates and affect detector occupancy.

One can define the ***instantaneous*** or ***effective*** luminosity - which determines the detector performance – for the amount of radiation in the detector active element over the drifting/integration time Δt_d ("sensitivity window") or the bunch train length, whichever is smaller. For detector elements most susceptible to occupancy problem Δt_d is 40 - 300 ns.

BEAM PARAMETERS

- 250-GeV
- 5 trains per second
- 2820 bunches in each train
- 300 ns between bunches
- 199 ms between trains
- Train length 868 μs
- 2×10^{10} positrons/electrons per bunch
- Luminosity 2×10^{34} cm^{-2} s^{-1}

DETECTOR TOLERANCES

Subdetector	Tolerance criterion
Vertex detector and/or Silicon Tracker	Rad. damage (worst-case: CCD's) : ∫ < 3-10 x 10^9 n cm^{-2} Occupancy (pattern recognition): < 1% (2-d hit density) Occupancy (pile-up): ≤ 1 hit / channel ("buffered")
Time Projection Chamber	Occupancy (pattern recognition): < 1% (3-d density) ? *Experts disagree on impact on reconstruction + space charge*

Subdetector	Granularity	Sensitivity window	Fract'l sensitivity
Vertex detector (Layer 1)	20 μ x 20 μ pixels = 2500 pixels/mm^2	50 μs (~ 150 bunches)	Chgd trks: ε = 1.0 (4 pixls) γ: ε = 0.02 (4 pixels)
TPC	1.5 10^6 pads x 10^3 time buckets = 1.5 10^9 voxels		Chgd trks: ε = 1.0 γ: ε = 0.02 n: ε = 0.01 μ: ε = 1.0

1% generic occupancy limit (per train or per SW) implying x10 safety factor

Background tolerance levels

(*) *As per R. Settles et. al., TESLA St Malo workshop Detector-specific data from T. Maruyama + detector response to MDI questions, Aug 05.*

Limits are expressed in # particles either per sensitivity window [SW] (typically 50 μs ≈ 150 bunches in VXD/TPC), or per bunch train [tr]

Subdetector	Charged hits	γ	n (~ 1 MeV)	Model
Vtx detector (L1)	6 mm^{-2} / SW 100 mm^{-2} tr^{-1}	300 mm^{-2} /SW	3 x 10^{7} mm^{-2} 10^{8} mm^{-2}	1 % generic GLD
Si tracker	Pile-up: 0.2 / 1.0 mm^{-2} tr^{-1}	Pile-up: 10/50 mm^{-2} tr^{-1}		SiD: analog/digital
TPC (/SW)	1.5 x 10^{7} voxels ≈ 2.5 - 5 10^{3} tracks	1.25 x 10^{6} γ	2.5 x 10^{7} n	1 % generic

Notes

1. No generic answers – depend strongly on subdetector technology
2. Need to clarify impact of TPC occupancy on track reco efficiency & space charge
3. Only rough estimates so far. Real answer needs detailed simulations, pattern recognition studies, space charge, understanding of background distribution....
4. 1% may sound overconservative...but we need ~ x 10 safety factor!

BACKGROUND TOLERABLE LIMITS SUMMARY

Calorimeter, tracker and vertex detectors: in smallest element, ***occupancy*** $\leq$ 1%.

To avoid ***pattern recognition*** problem in tracker, hit density from charged particles should be $\leq$ 0.2 hit/cm^2/bunch.

To avoid ***pile-up*** problem (from previous BX !) in tracker, hit density from charged particles should be $\leq$ 0.2 hit/mm^2/train.

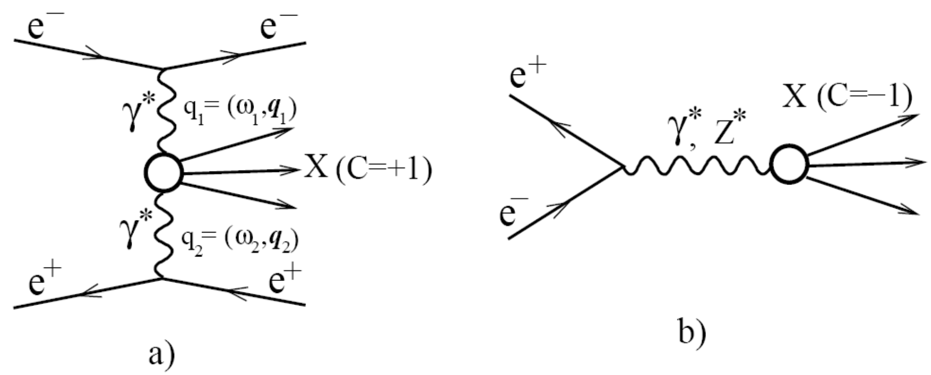
Muon system: the RPCs (sensitive media) need 1 ms to re-charge a 1 cm^2 area around the avalanche, therefore, the hit rate in excess of 100 Hz/cm^2 would result in an unmanageable dead time. With typical 80 sensitive layers in a Muon Endcap, it corresponds to a muon flux at its entrance of about 1 μ/cm^2/s.

RADIATION LIMITS AND DESIGN CONSTRAINTS

Site/Lab/Country-specific. For Fermilab as an example:

- Peak residual dose rate P_γ < 100 mrem/hr = 1 mSv/hr at 1-ft in tunnel (30 days / 1 day) – hands-on maintenance (~1 W/m)
- Prompt dose equivalent in non-controlled areas is *DE* < 0.05 mrem/hr at normal operation and < 1 mrem/hr for the worst case due to accidents; it is *DE* < 5 mrem/hr = 0.05 mSv/hr for limited access areas
- Ground-water activation: do not exceed radionuclide concentration limits of 20 pCi/ml for ^{3}H and 0.4 pCi/ml for ^{22}Na in any nearby drinking water supply
- Peak energy deposition and absorbed dose in beamline and detector components below temperature rise, material integrity and radiation damage limits
- Air activation: do not exceed radionuclide concentration limits

IP BACKGROUNDS: *e^+e^-* and $\mu^+\mu^-$ pairs and hadrons

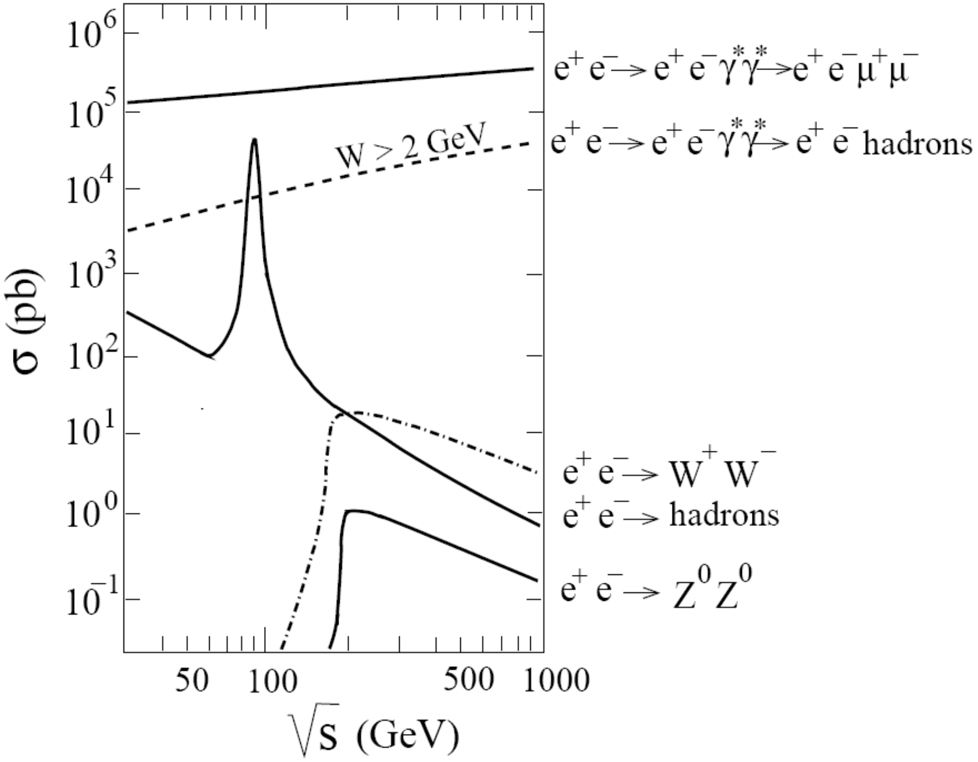


At 500 GeV, "backgrounds" x-section is orders of magnitude larger than the "physics" one

Production of system X:

a) by two equivalent photons emitted by e^+ and e^-

b) in e^+e^- annihilation



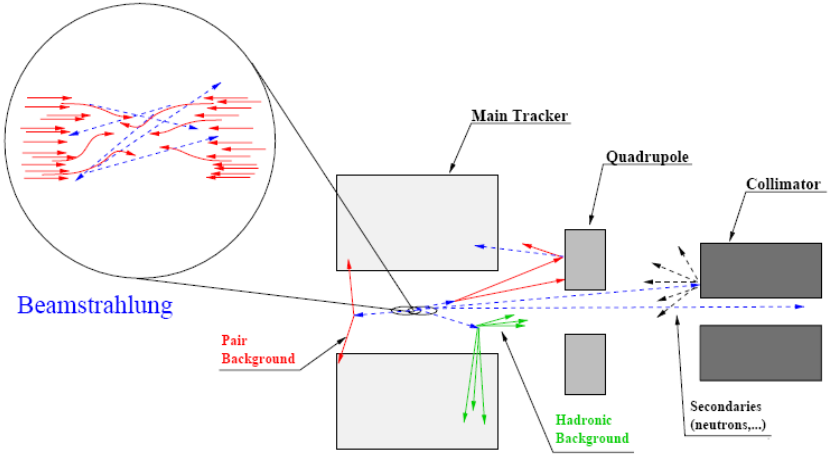
BEAMSTRAHLUNG

Beams are extremely collimated with large bunch charge

$\rightarrow$ electrons of one bunch radiate against the coherent field of the other bunch

$$dE \sim \frac{N^2}{\sigma_x^2 \sigma_z}$$

$\rightarrow$ average energy loss 1.5% for electrons/positrons at 500 GeV

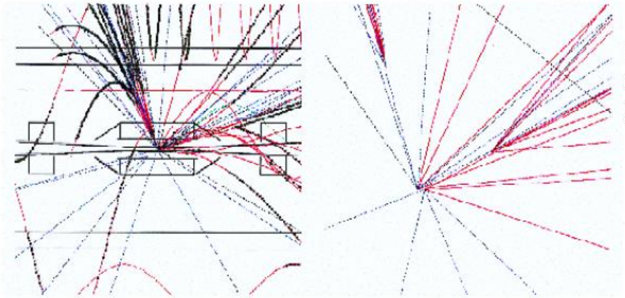


photons are very collimated around beampipe, but

- $\approx 0.6 \times 10^5 e^+e^-$-pairs per bunch crossing
- $\approx$ 1 hadronic event ($\gamma\gamma \rightarrow$ hadrons) per 10 bunches
- secondaries (neutrons, ...)

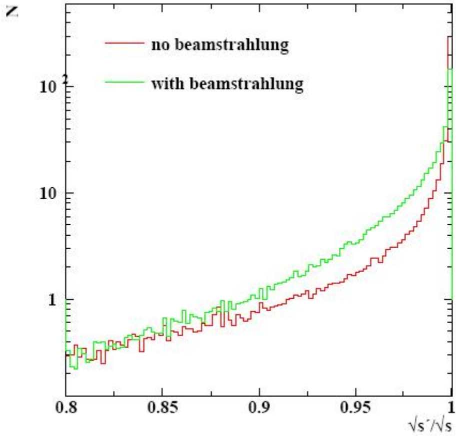
Consequences:

1. Shield Detector against low-angle e^+e^-–pairs and secondaries $\Rightarrow$ Mask
2. Hadronic $\gamma\gamma$–events might overlay real physics events: recognize them!



Battaglia
Schulte
(2000)

3. Beam particles lose energy before interaction (similar to ISR)



Mönig
Ohl
(1999)

IP BACKGROUNDS IN SiD

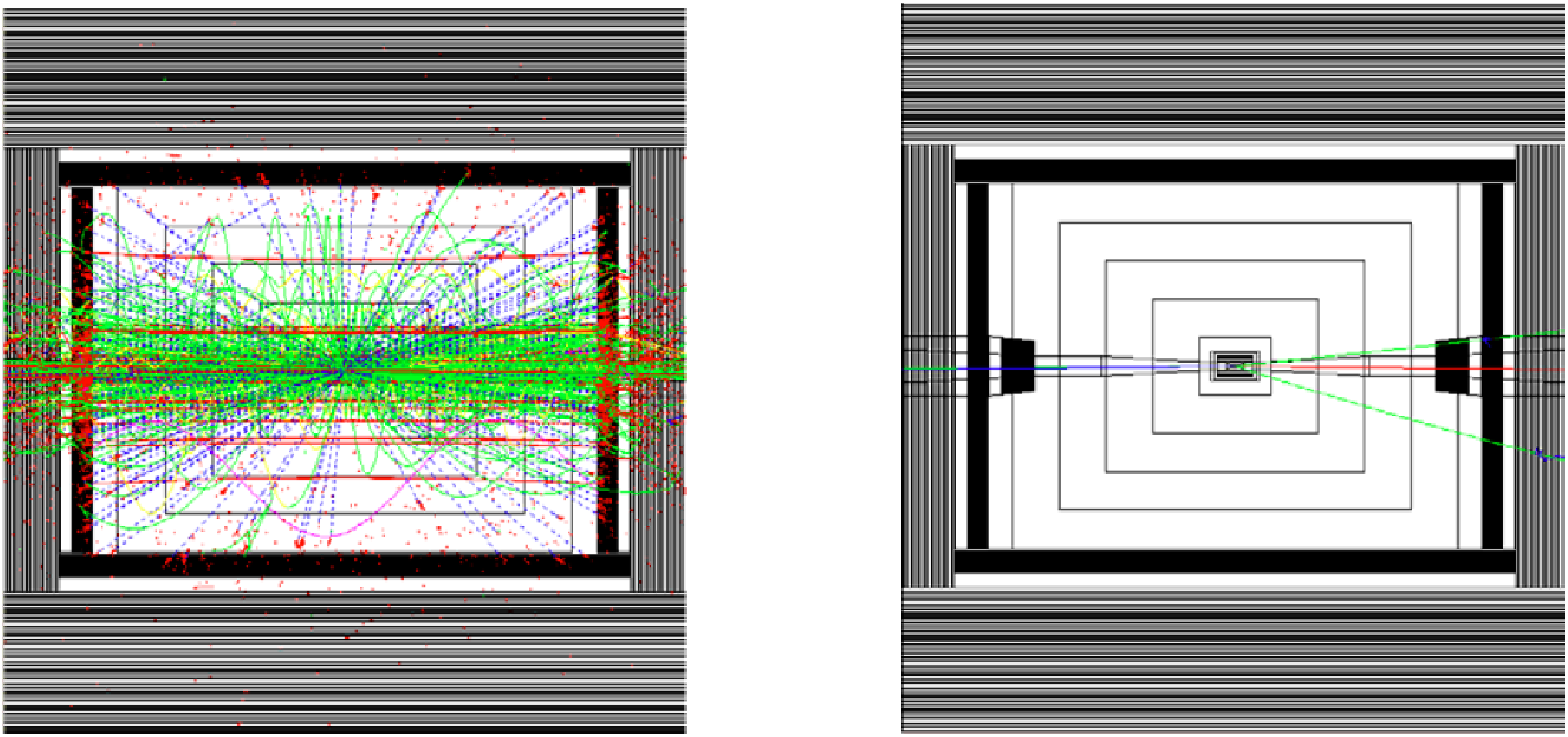
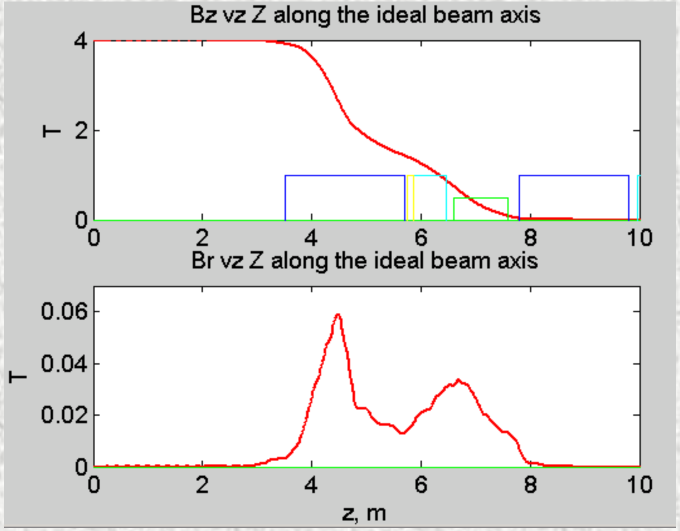


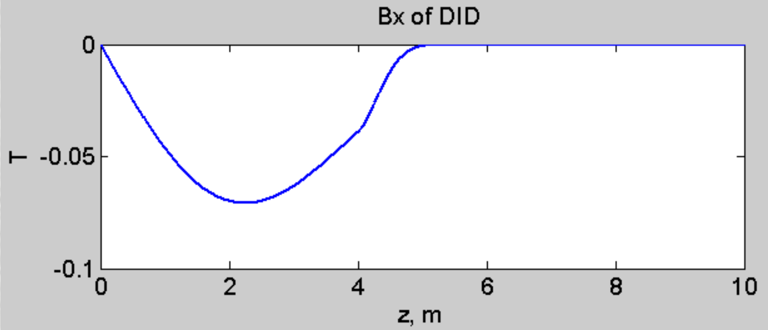
Figure 8 Physics backgrounds from gamma-gamma produced e^+e^- pairs, muon pairs, and hadronic events integrated over 150 bunch crossings (left) and a single bunch crossing (right).

PAIR BACKGROUND STUDIES

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 been introduced.





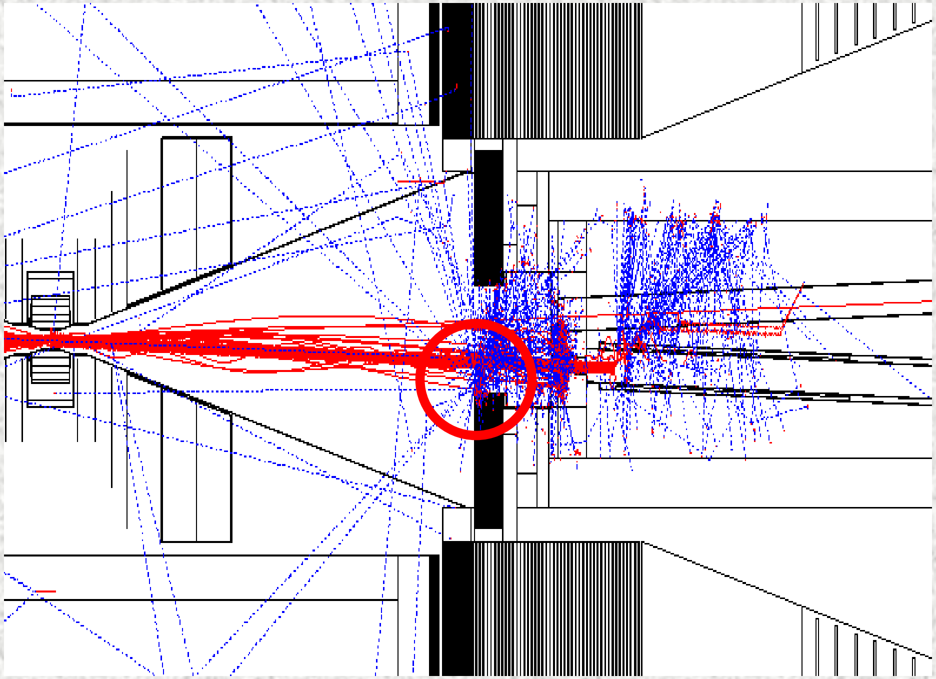
DID field combined with FD offset to zero both angle and position at the IP

PAIRS AS A DOMINANT SOURCE

- Dominant background
- Very dependent on Beam parameters
- Solenoid field strength
  - Solenoid compensation for 20 mrad
- VXD layer radius
- Far forward geometry

	Beam	# e+/e- /BX	Total energy
500 GeV	Nominal (N)	98 K	197 TeV
	Low Q (Q)	38	86
	High Y (Y)	104	191
	Low P (P)	232	709
	High Lum (H)	268	944
1 TeV	Nominal	174	1042
	Low Q	73	486
	High Y	229	1356
	Low P	458	4596
	High Lum	620	7367

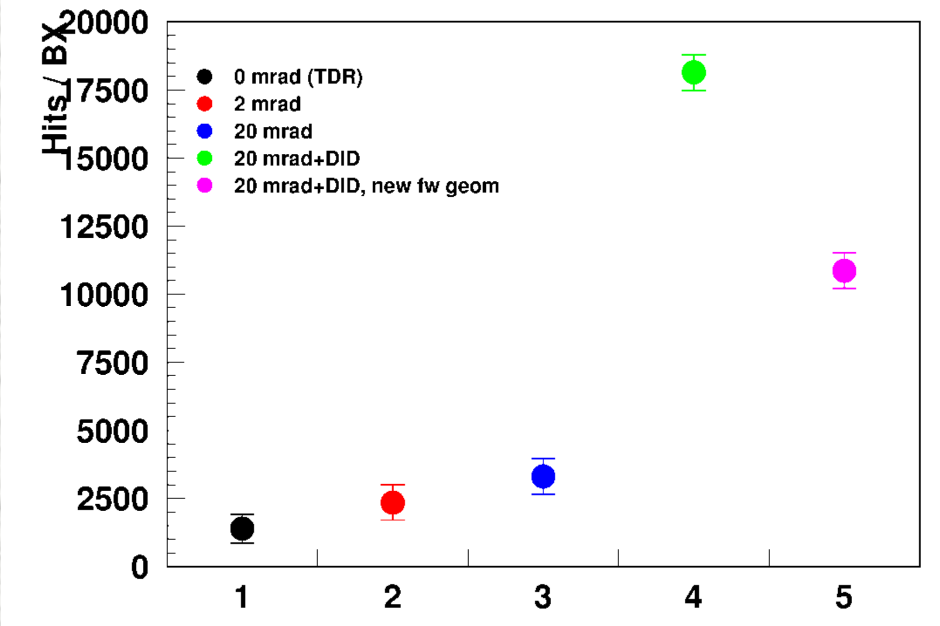
Hits in the TPC with Solenoid+DID



Karsten Büßer

Origin of TPC photons:
pairs hit edge of LumiCal

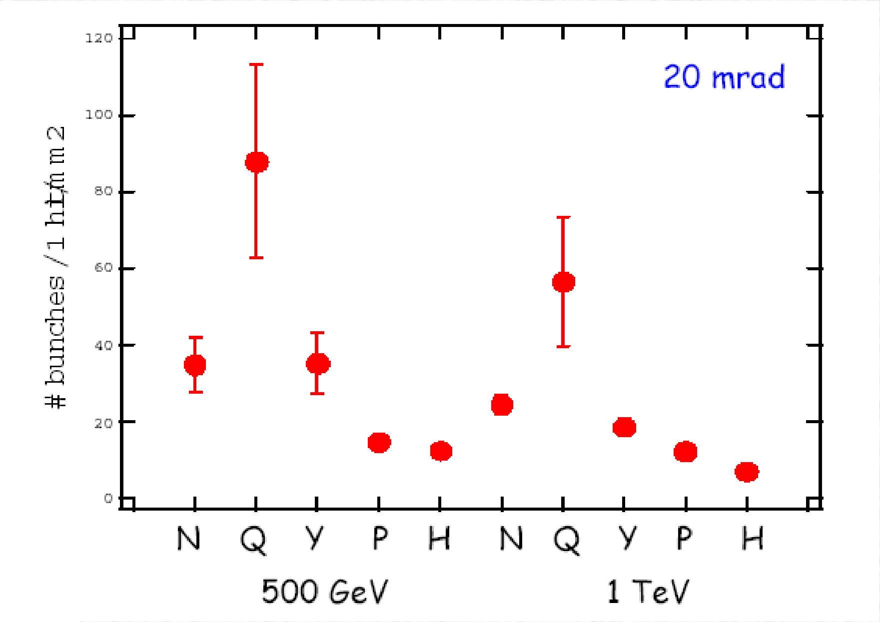
Comparing configurations:



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

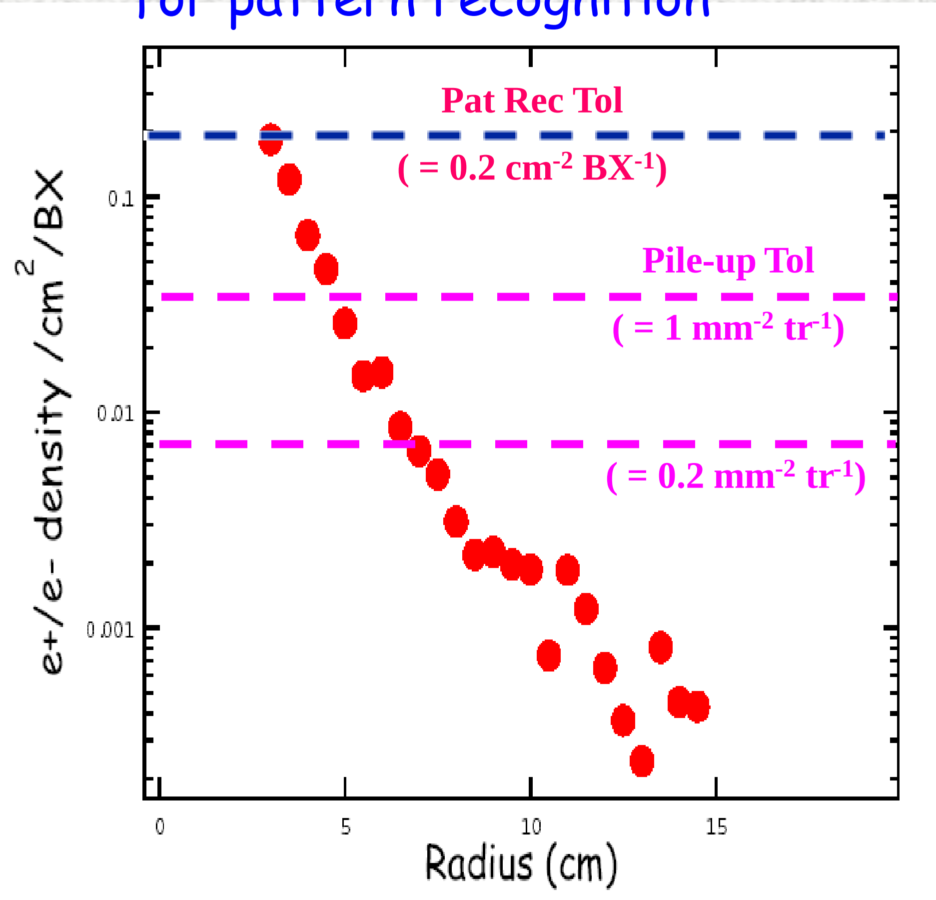


N – nominal
Q – Low Q
Y – High Y
P – Low P
H – High Lum.

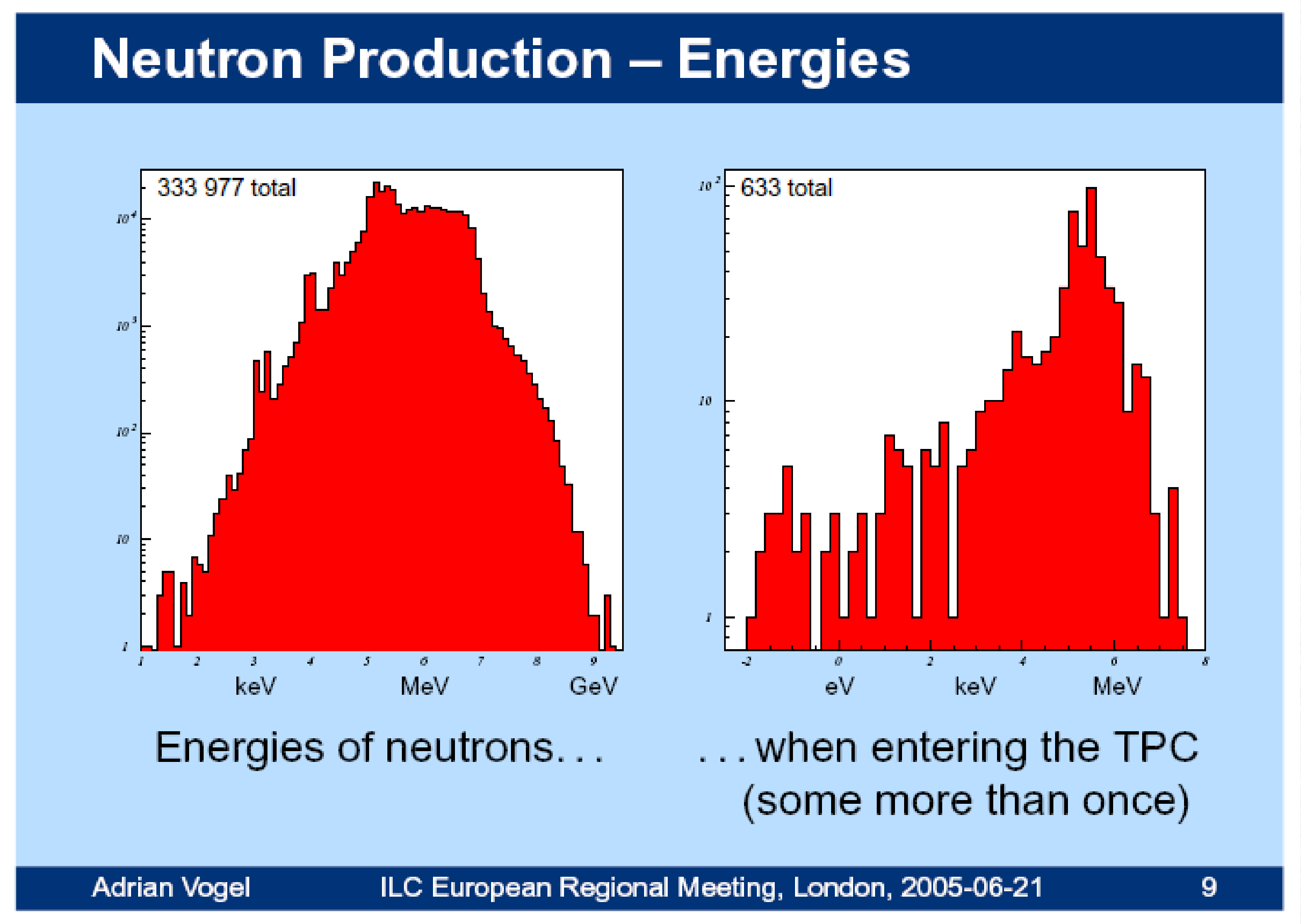
- Intra-train readout/buffering is necessary.
- # bunches to reach 1 hit/mm^2 is dependent on the beam parameters.
  - 500 GeV Low Q : 88 bunches
  - 1 TeV High Lum : 7 bunches
- One train readout using 5 μm × 5 μm fine pixel detector may work only for 500 GeV Low Q.

e+/e- Flux in SiD Tracker

Forward Tracker Layer #1 hits: innermost region is at the limit for pattern recognition



NEUTRONS IN DETECTOR



Neutron Production – Energies

Energies of neutrons. . .

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

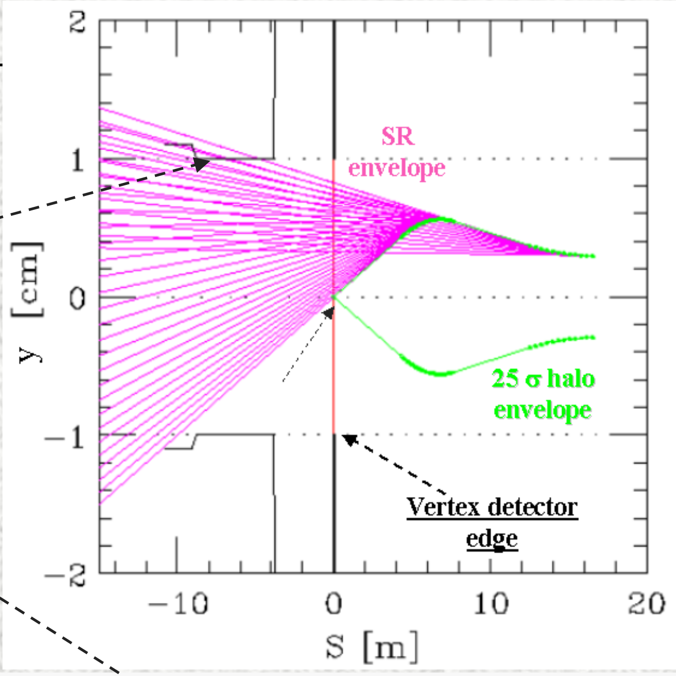
Adrian Vogel ILC European Regional Meeting, London, 2005-06-21 9

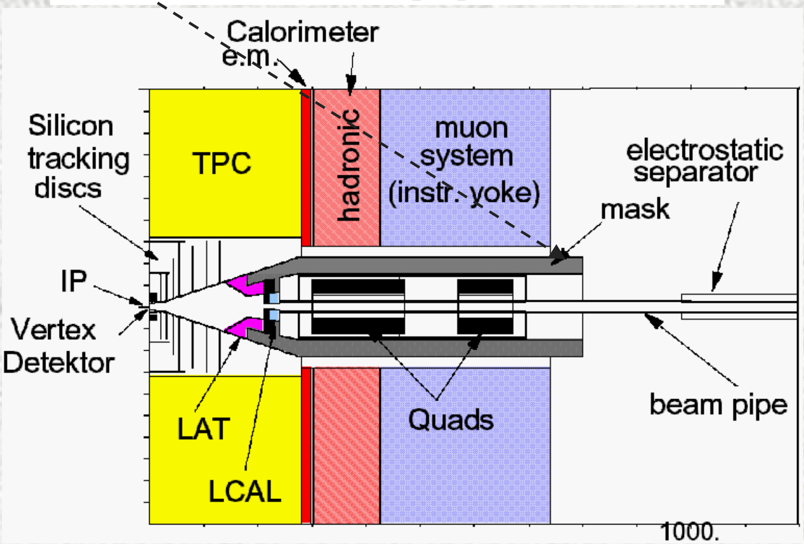
SYNCHROTRON RADIATION

See SR theory in A. Seryi's lecture

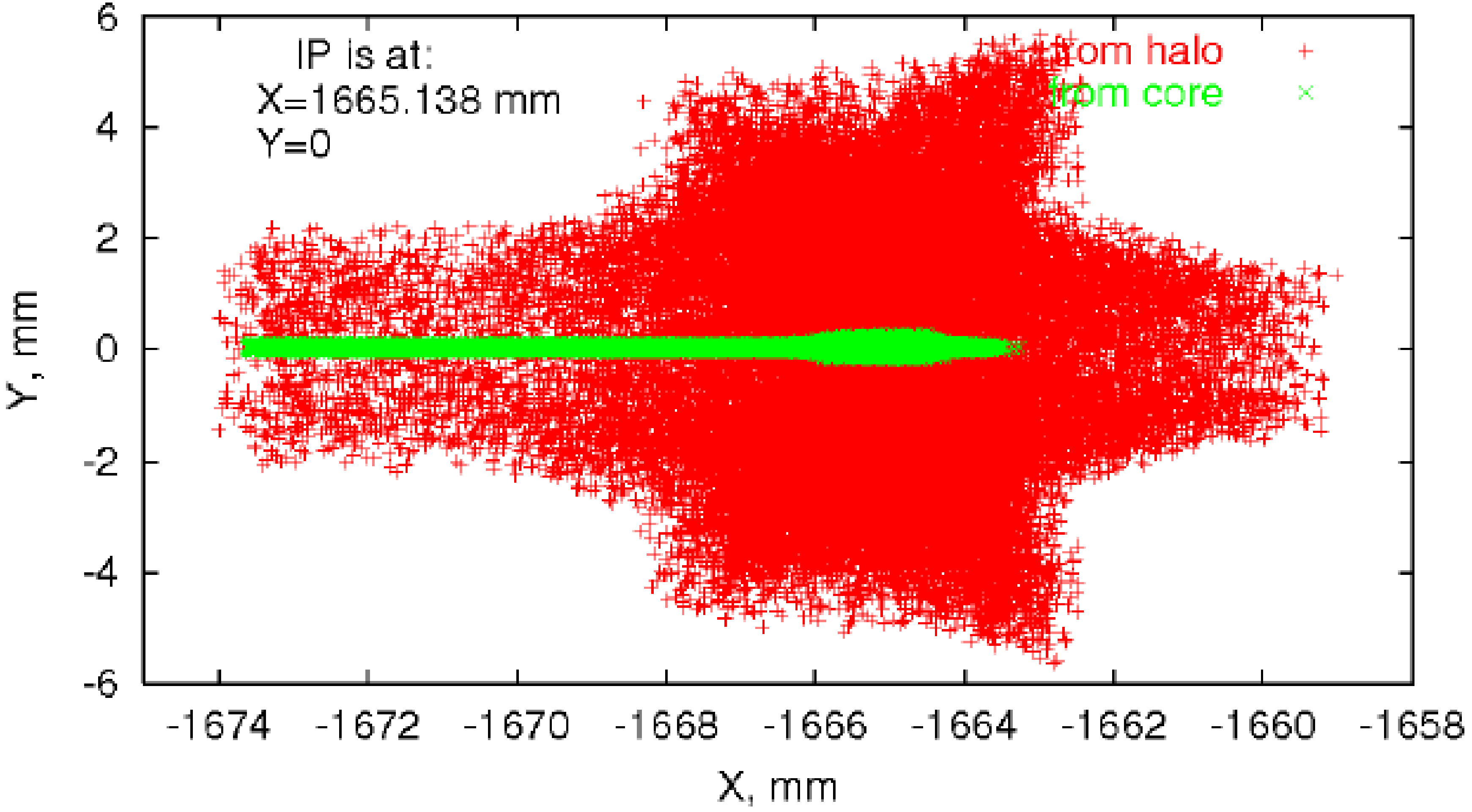
Concerns

- backscattering from downstream aperture limitations
- edge- & tip- scattering from upstream SR masks
- impact of a partially-shared beam line on SR masking (2mr):
  - compatibility of stay-clear apertures (spent beam, pairs, beamstrahlung γ) with effective masking of incoming SR

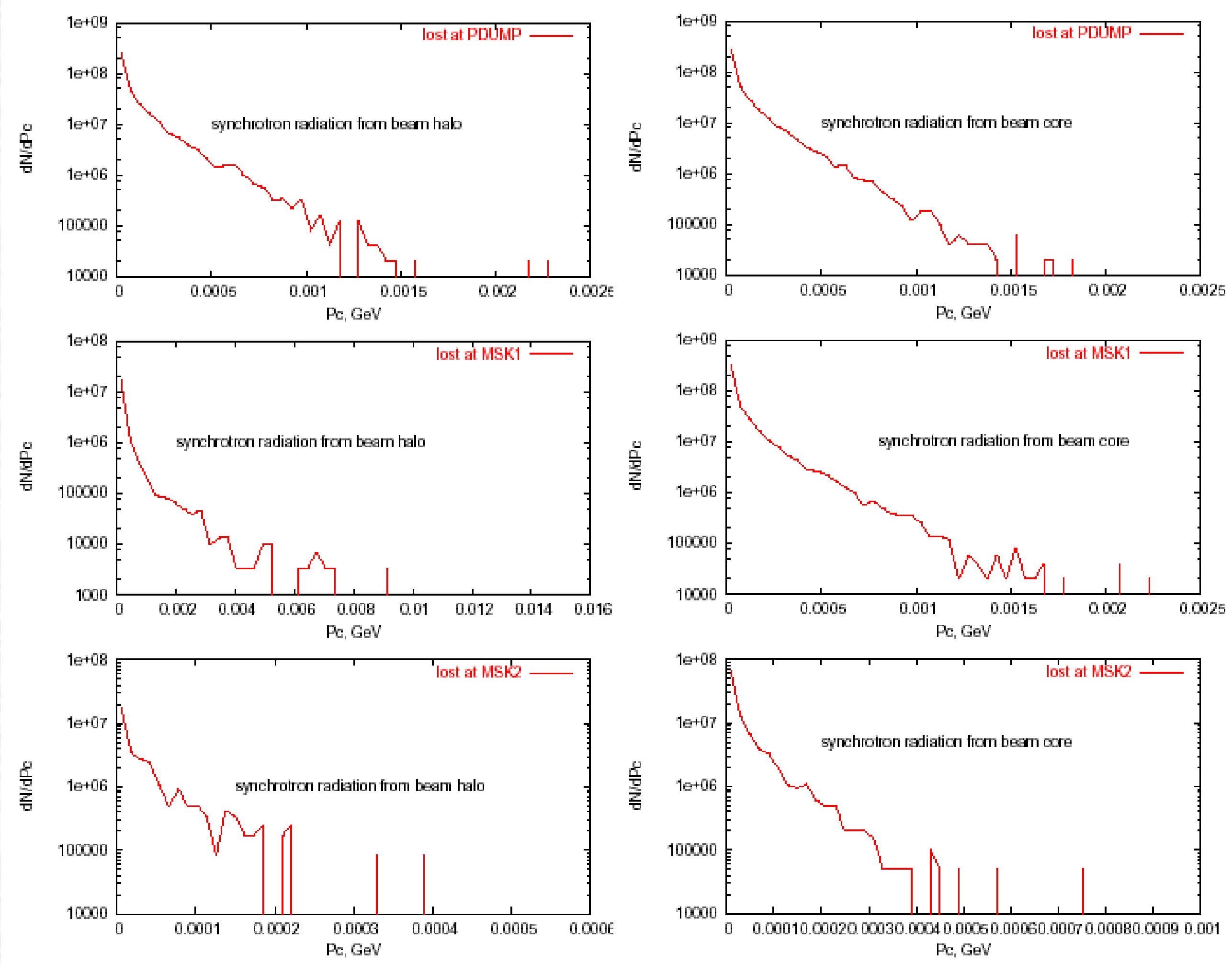


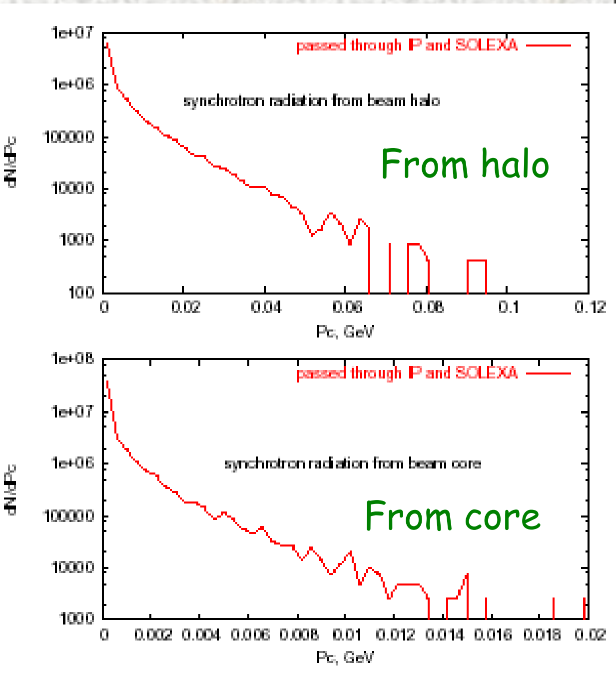


Beam Core and Halo Synch Photons at IP



SYNCH PHOTON ENERGY SPECTRA AT MASKS





Passed through IP

From beam halo

From beam core

Electromagnetic Shower Basics

Intense electromagnetic showers (EMS) are generated when electrons hit material of beam-line components. At high energies, the dominant processes are bremsstrahlung for electrons and e^+e^- pair product for γ.

At high energies, properties of EMS are conveniently described using

Radiation length X_0: electron loses all but 1/e of its energy by brems, and 7/9 of the mean free path for pair production by photons.
Critical energy E_c = 800 MeV/(Z+1.2): $(dE/dx)_{ion} = (dE/dx)_{brems}$.
Scale energy $E_s = m_e c^2 (4\pi/\alpha)^{1/2}$ = 21.2 MeV.
Molier radius $R_M = X_0 \times E_s/E_c$.

Multiple Coulomb scattering: $\langle\theta\rangle = E_s/p\, (x/X_0)^{1/2} (1 + 0.038 \ln x/X_0)$
$\langle\theta_{x,y}\rangle = \langle\theta\rangle /\sqrt{2}$
EMS length: 20-30 X_0. (X_0 = 0.35, 1.43, 1.77 and 35cm for W, Cu, Fe and Be, respectively).
EMS radius: 2-3 R_M

Bethe-Heitler Muons, Hadrons etc.

About 10^{-4} muons are generated per 250-GeV electron hitting material (limiting apertures, residual gas) which – being accompanied by other particles – can reach the IP and create background levels well above the tolerable limits. These are mainly energetic muons from Bethe-Heitler process $\gamma Z \longrightarrow \mu^+\mu^- Z$.
Also, muon pairs from e^+e^- annihilation, hadrons from photo- and electro-nuclear inelastic interactions, and decay products of all unstable particles.

Make these limiting apertures (collimators) as far from IP as possible. Suppress muon flux far from IP by thick magnetic walls or doughnuts.
Studied in very complex realistic BDS modeling.

BEAM HALO

From beam loss point of view, beam halo can be defined as a number of particles of any origin which lie in the low-density region of beam distribution far away from the dense core.

At ILC, as at any other accelerator, the creation of beam halo is unavoidable. This happens because of numerous reasons (next page). As a result of halo interactions with limiting apertures, electromagnetic showers are induced in accelerator and detector components causing numerous deleterious effects ranging from minor to severe.

An accidental loss of a small fraction of the beam can cause catastrophic damage to the collider and detector equipment.

BEAM HALO ORIGIN

Particle processes:

- Beam-gas scattering (elastic, inelastic, bremsstrahlung)
- Ion or electron cloud effects
- Intrabeam scattering (including large-angle Touschek)
- Synchrotron radiation
- Scattering off thermal photons

Optic related:

- Mismatch, coupling, dispersion
- Non-linearities

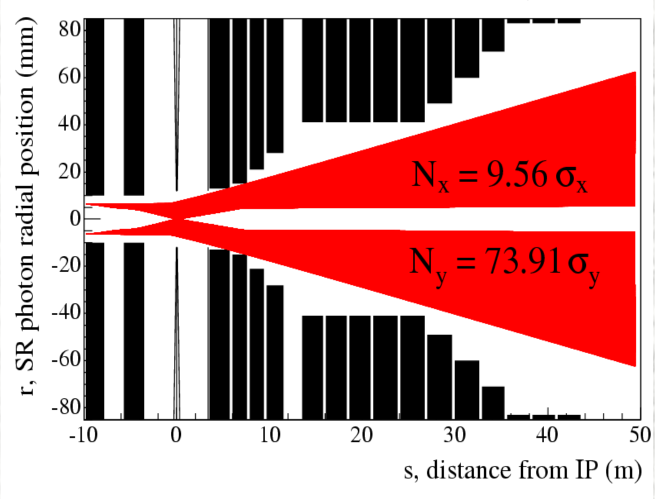
Collective & Equipment related:

- Noise and vibration
- Dark currents
- Space-charge effects close to source
- Wake-fields
- Beam loading

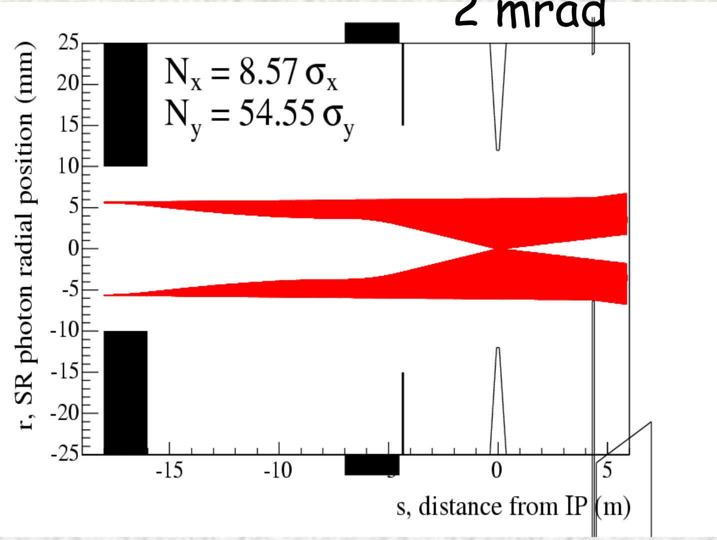
COLLIMATION DEPTH ($\theta_{halo}/\theta_{beam}$)

It is primarily determined by clearance of final doublet sync radiation through the IR. All collimation tracking simulations are done for beam halo falling off as $1/R^2$ in phase space.

20 mrad



2 mrad

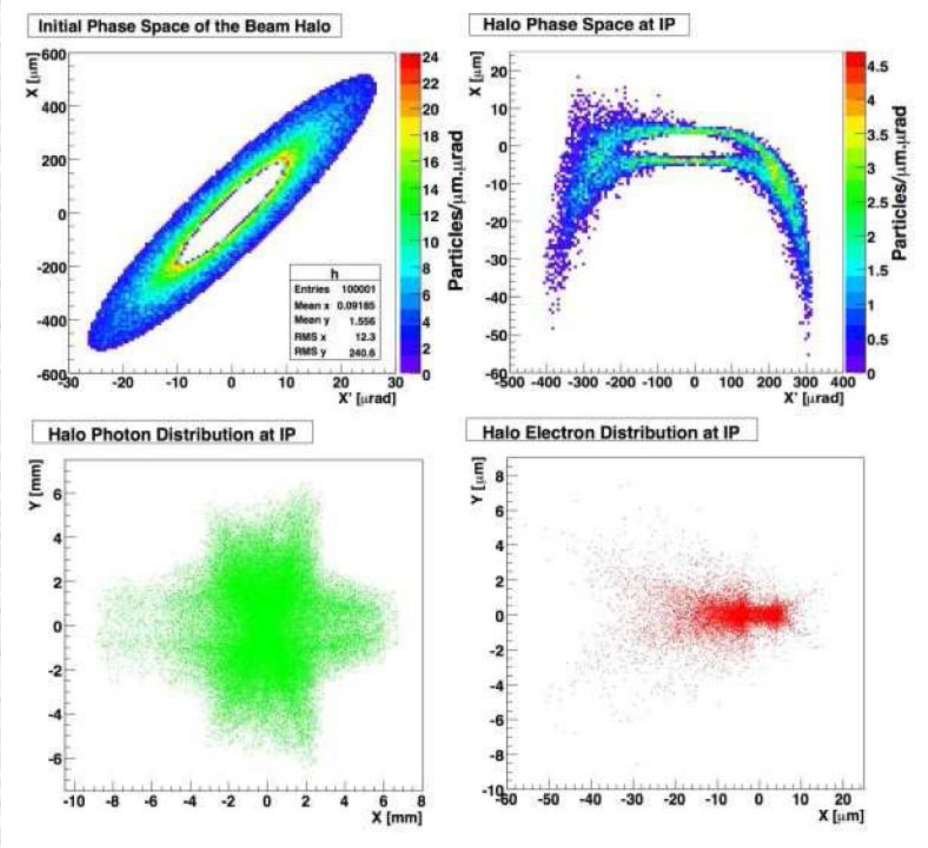


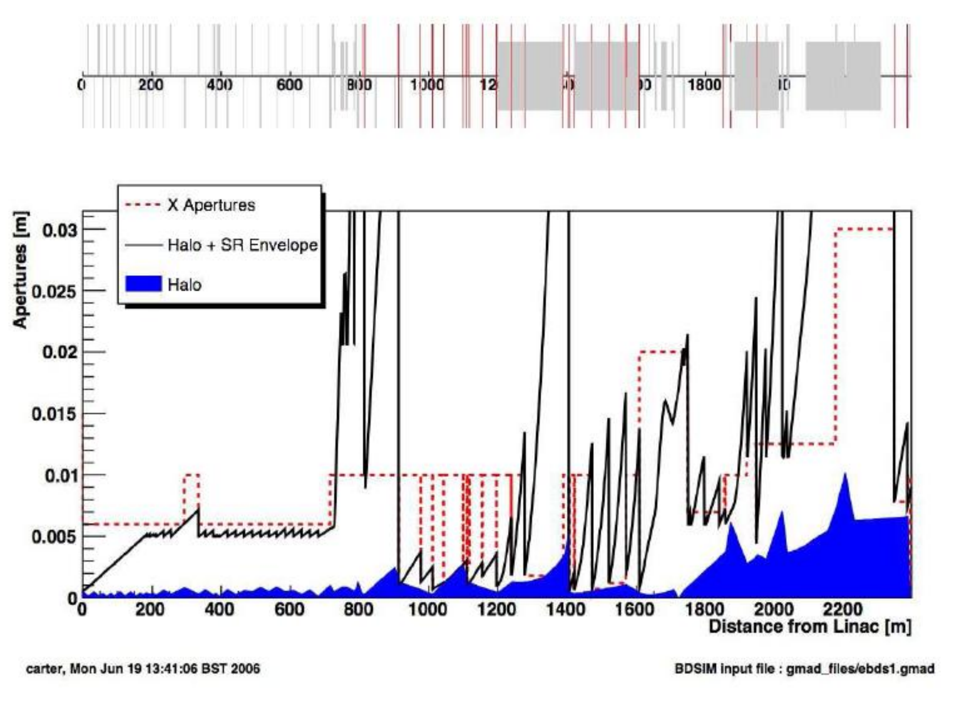
Limiting aperture: r =12 mm (20 mrad), 15 mm (2 mrad)

Spoiler gaps a_x = 1mm, a_y = 0.5 mm

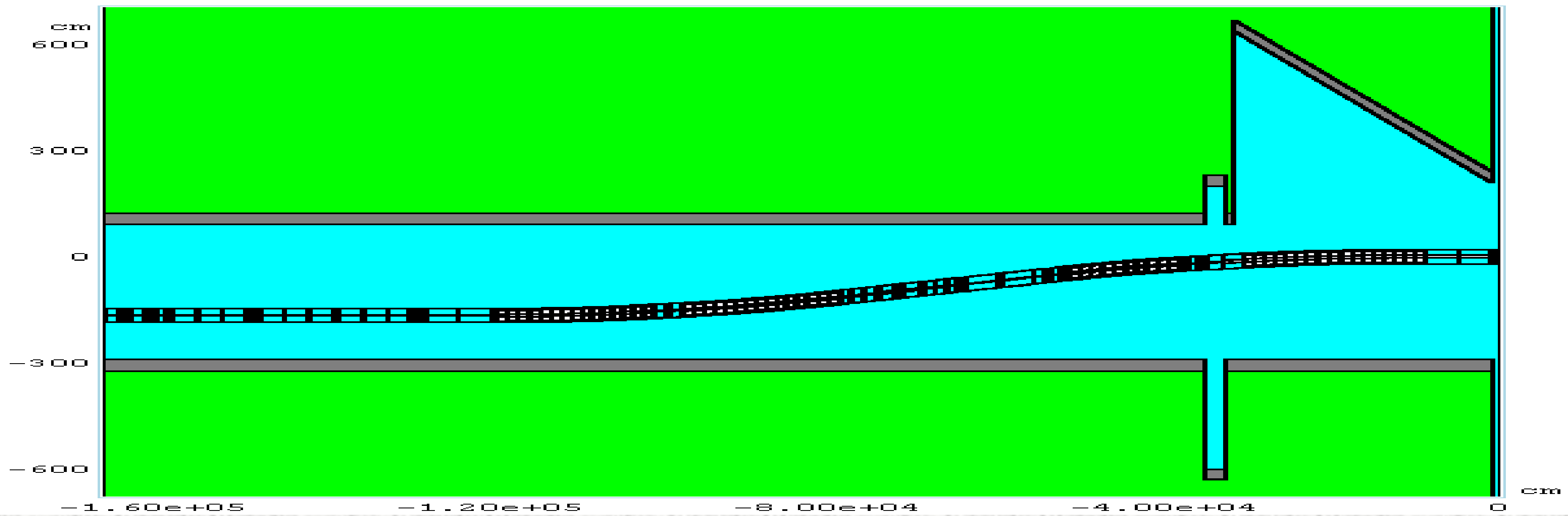
Tighter collimation for 2 mrad

BEAM HALO AND SR DISTRIBUTIONS & ENVELOPE

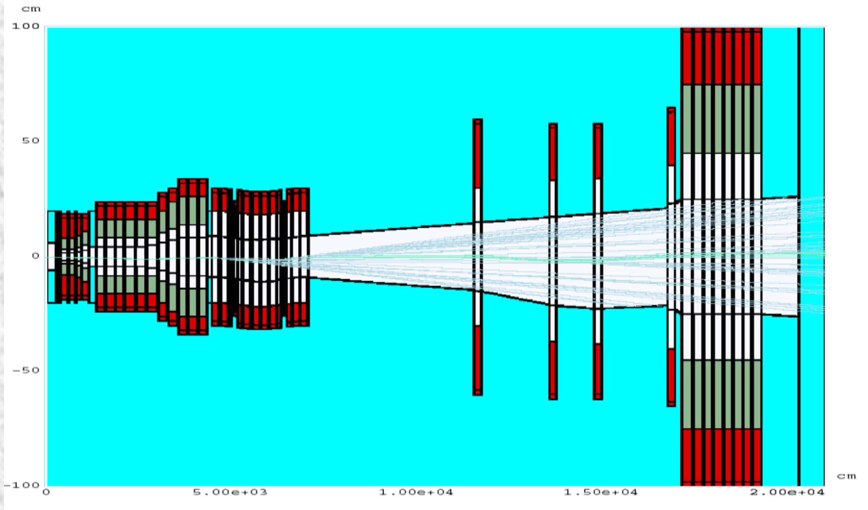




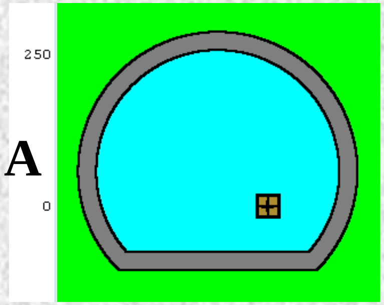
BDIR MARS MODEL: 1700 m BDS, SiD (GEANT4) at IP, followed by 200-m extraction line

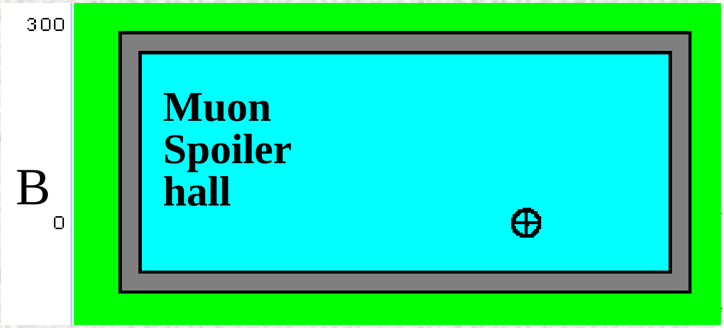


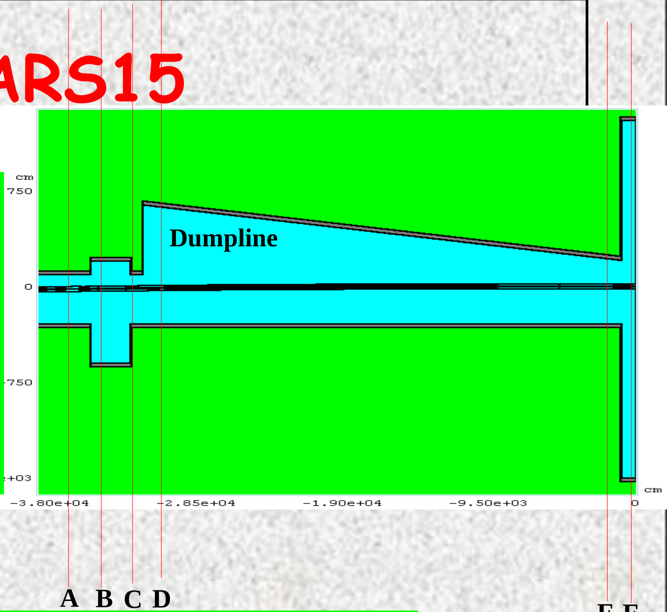
Model includes all magnets, tunnel, concrete walls, dirt, multi-stage collimation system (spoilers, absorbers, protection collimators, and photon masks), muon tunnel spoilers, SiD detector, and extraction line (for high-lum 250-GeV beams).

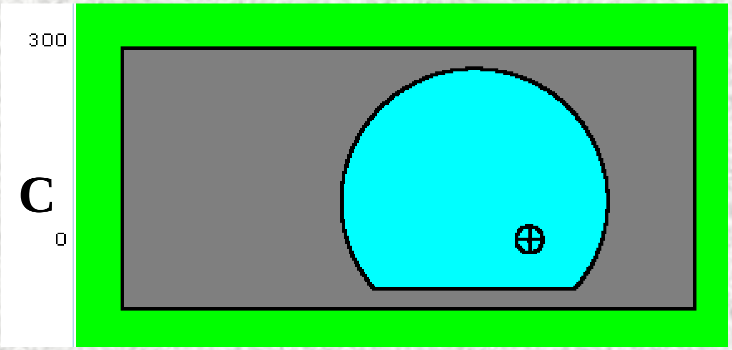


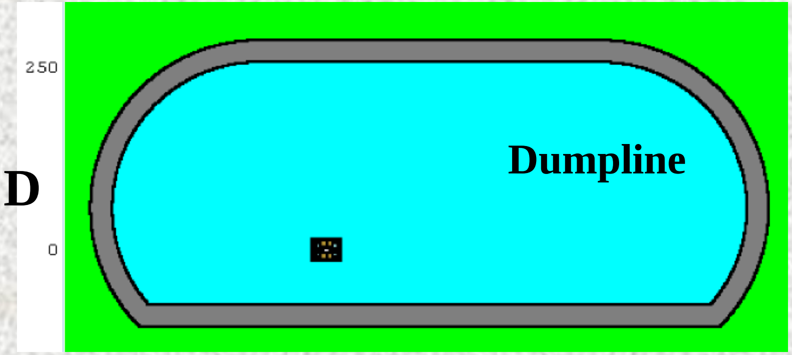
BDS MODEL X-SECTIONS IN MARS15

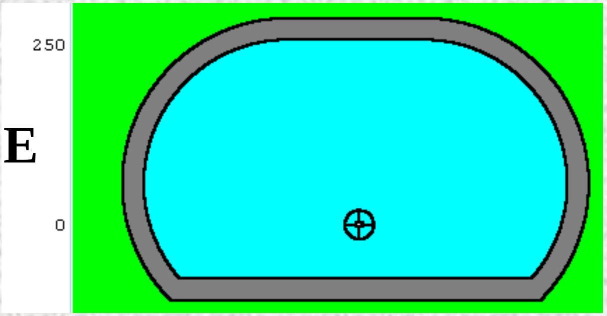


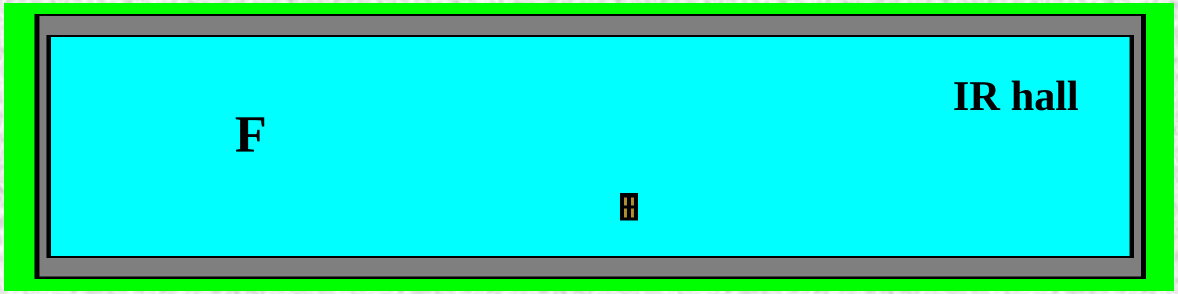




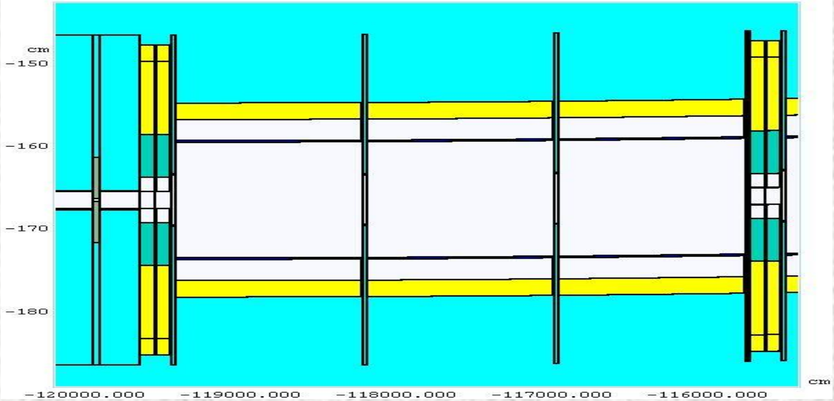


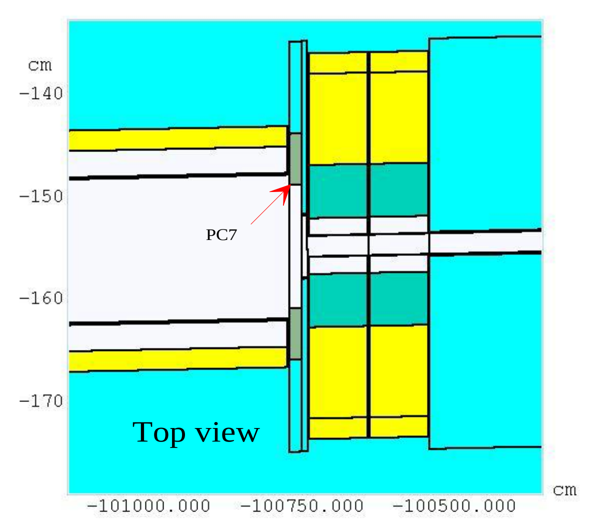




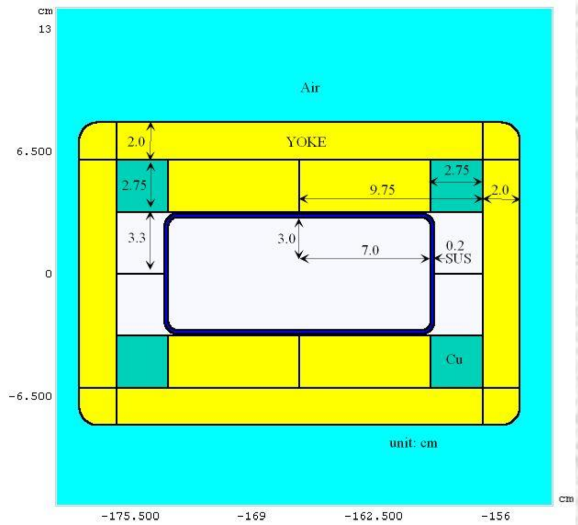


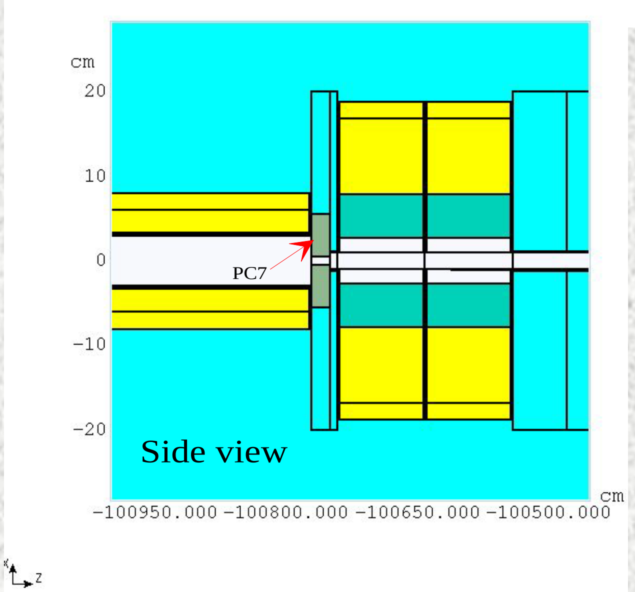
MARS Magnet and PC Geometries





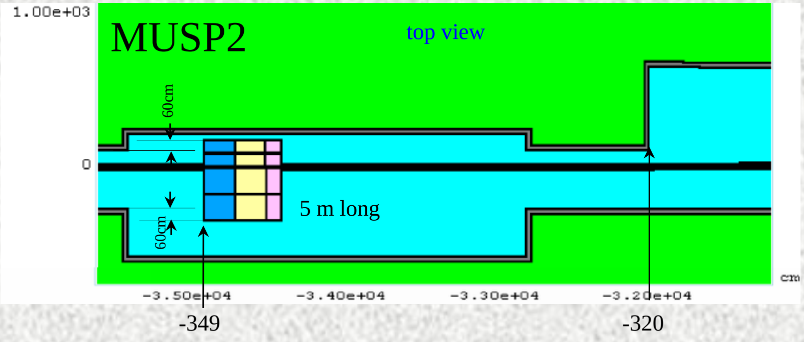
Top view

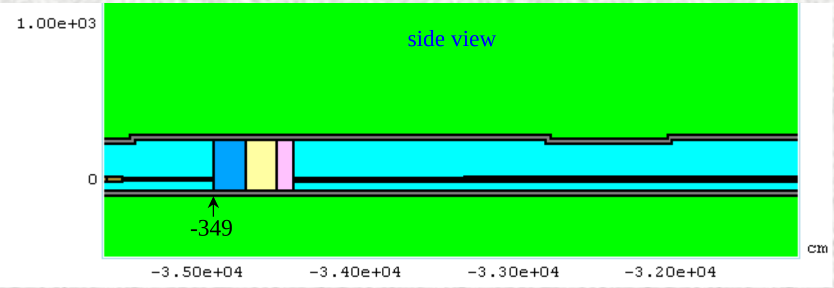




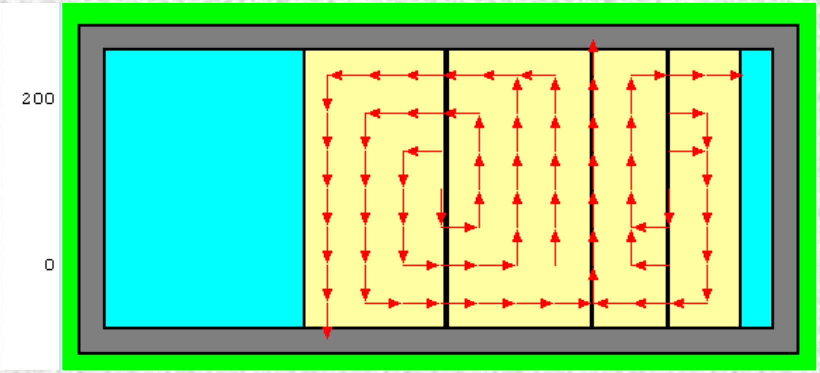
Side view

MUON SPOILER

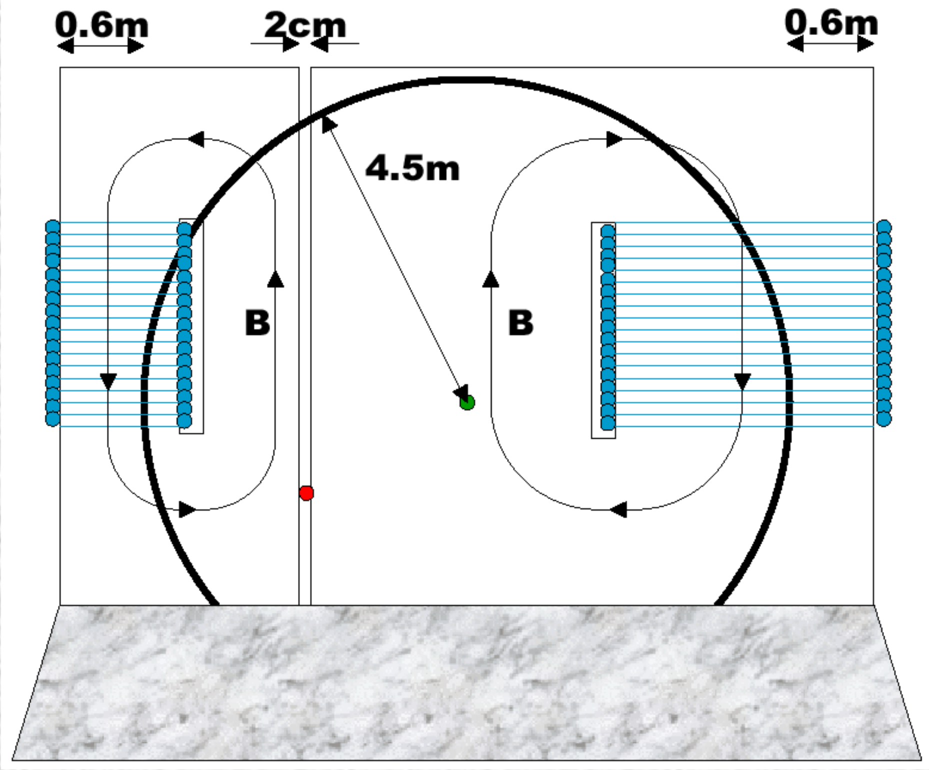




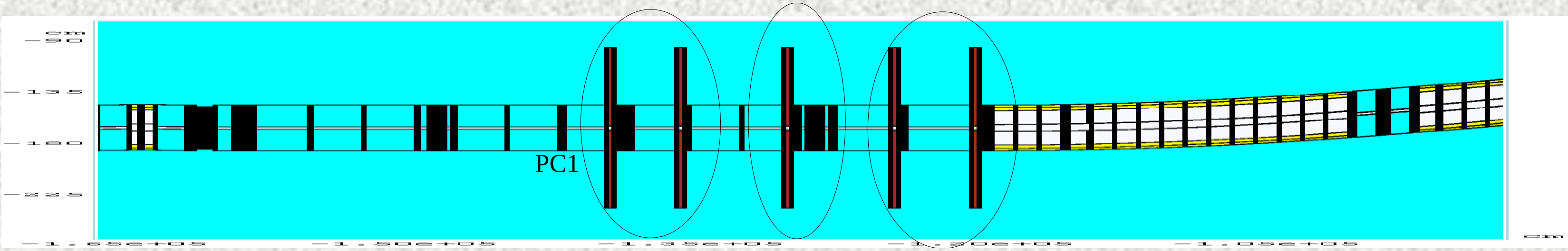
Cross sectional view (looking toward downstream)

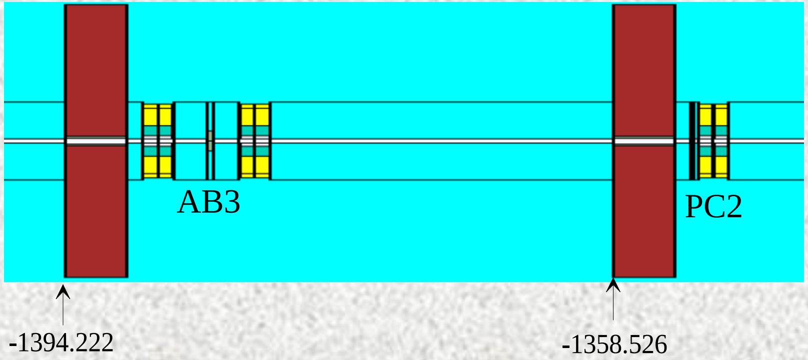


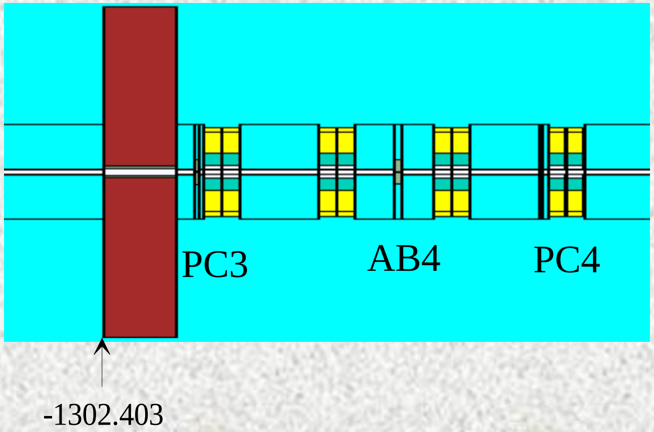
Thick steel 1.5-T magnetic wall sealing tunnel x-section, to spray the muons out of the tunnel

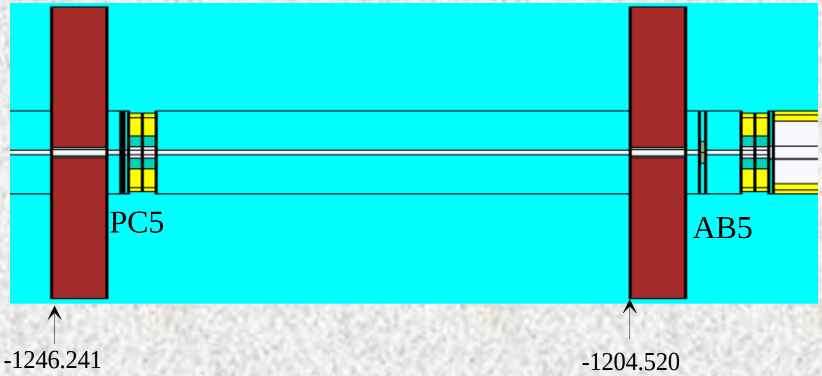


Five 4-m Thick Doughnut Scheme

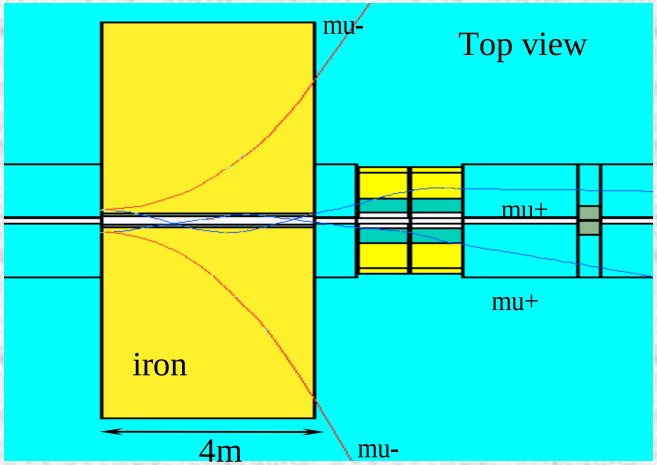


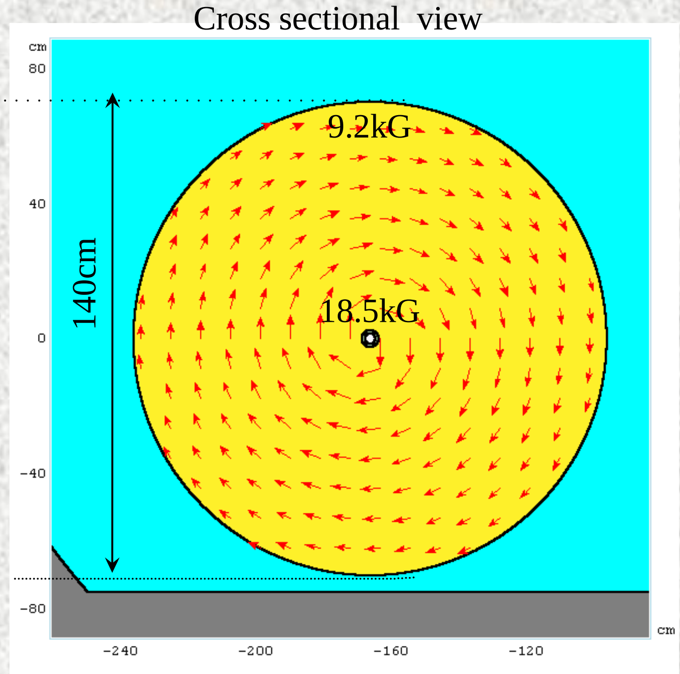


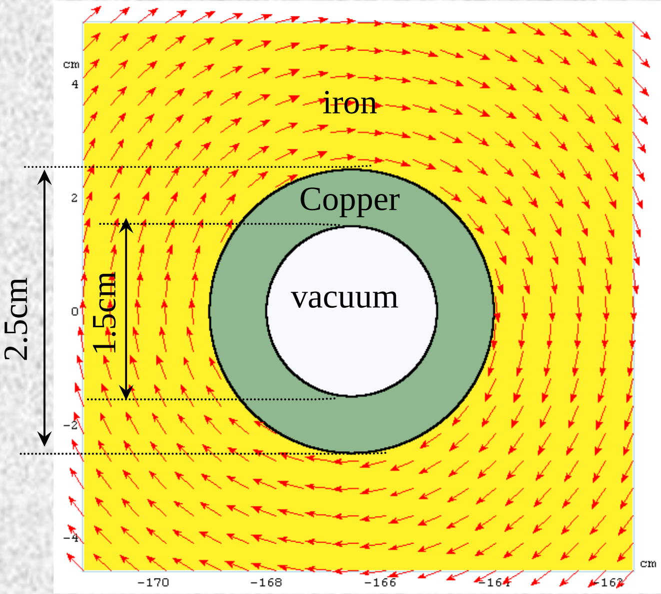




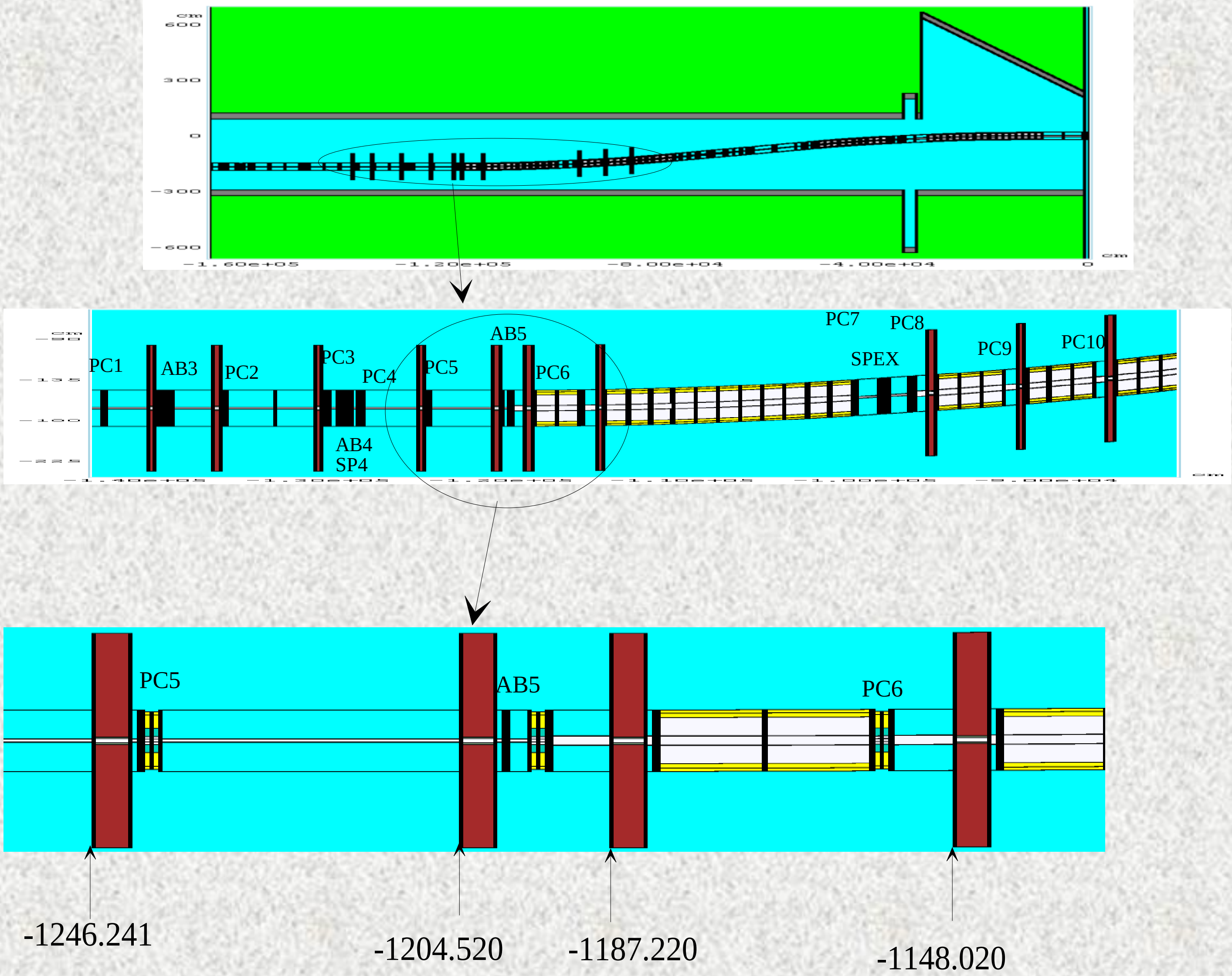
Magnetic Doughnuts



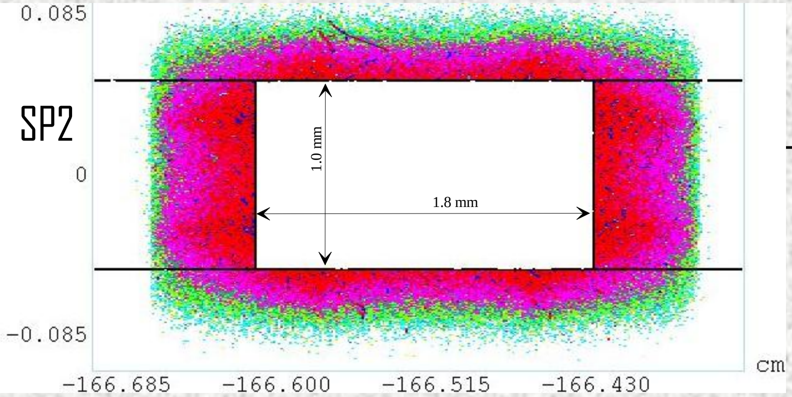


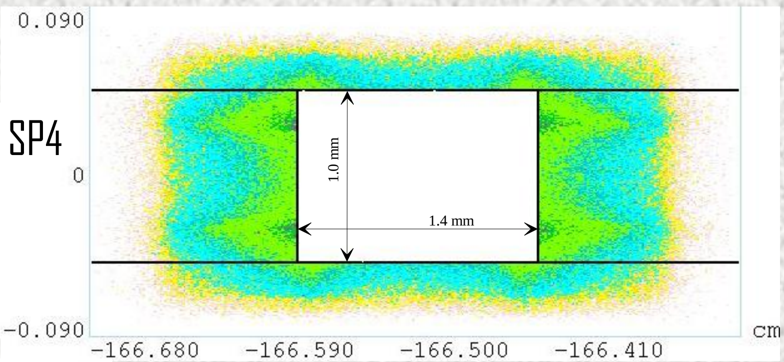


“Ultimate” Doughnut Scheme

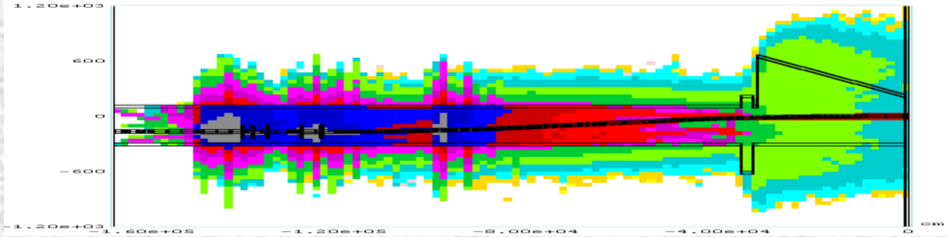


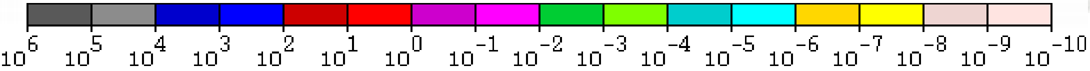
HALO ON SPOILERS



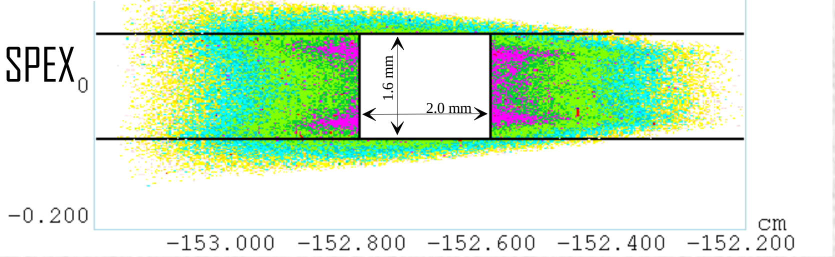


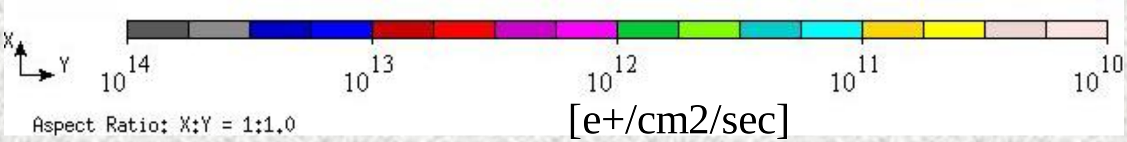
and dose isocontours with
5-m steel magnetic wall





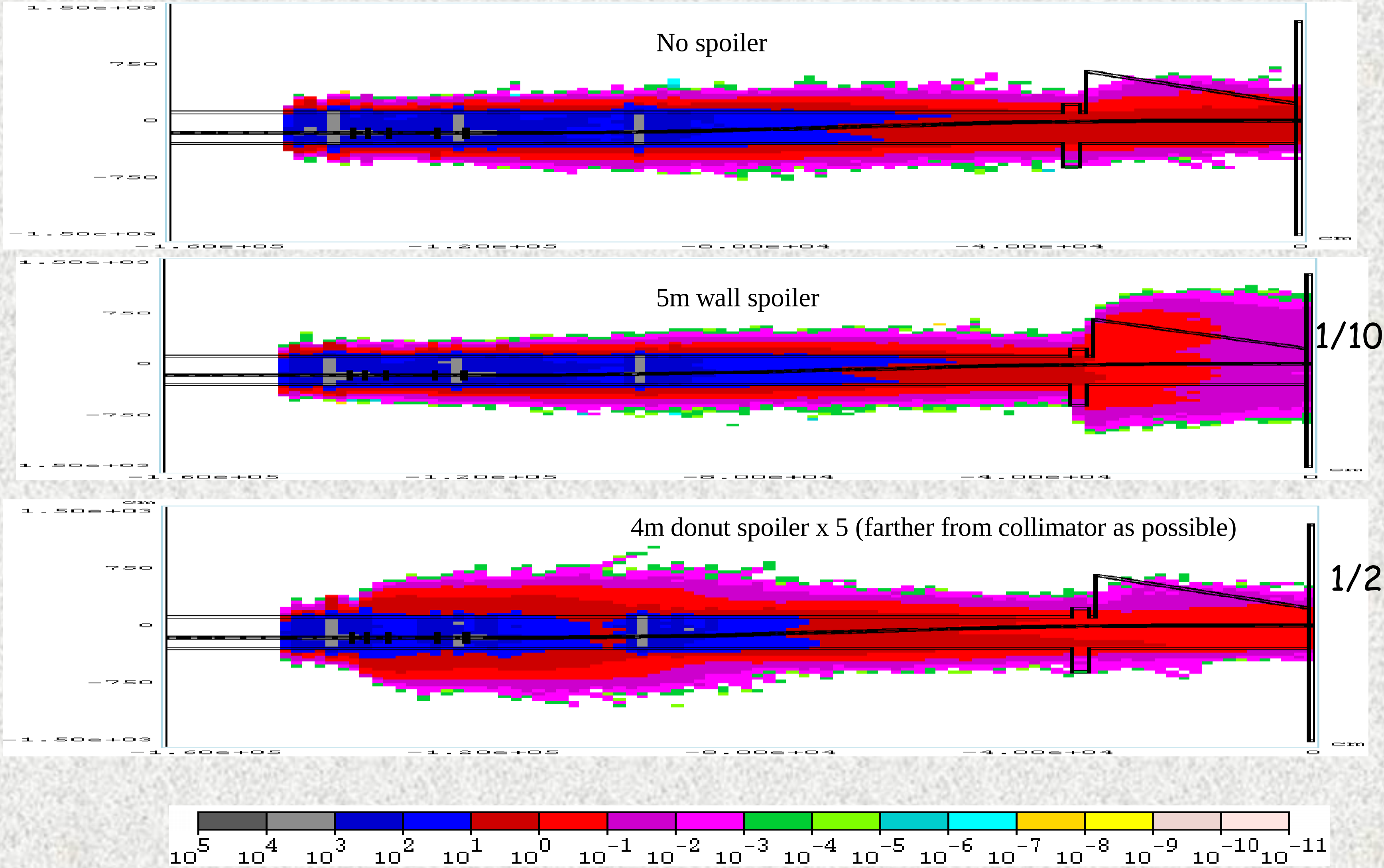
mSv/hr





[e+/cm2/sec]

Muon Flux Isocontours

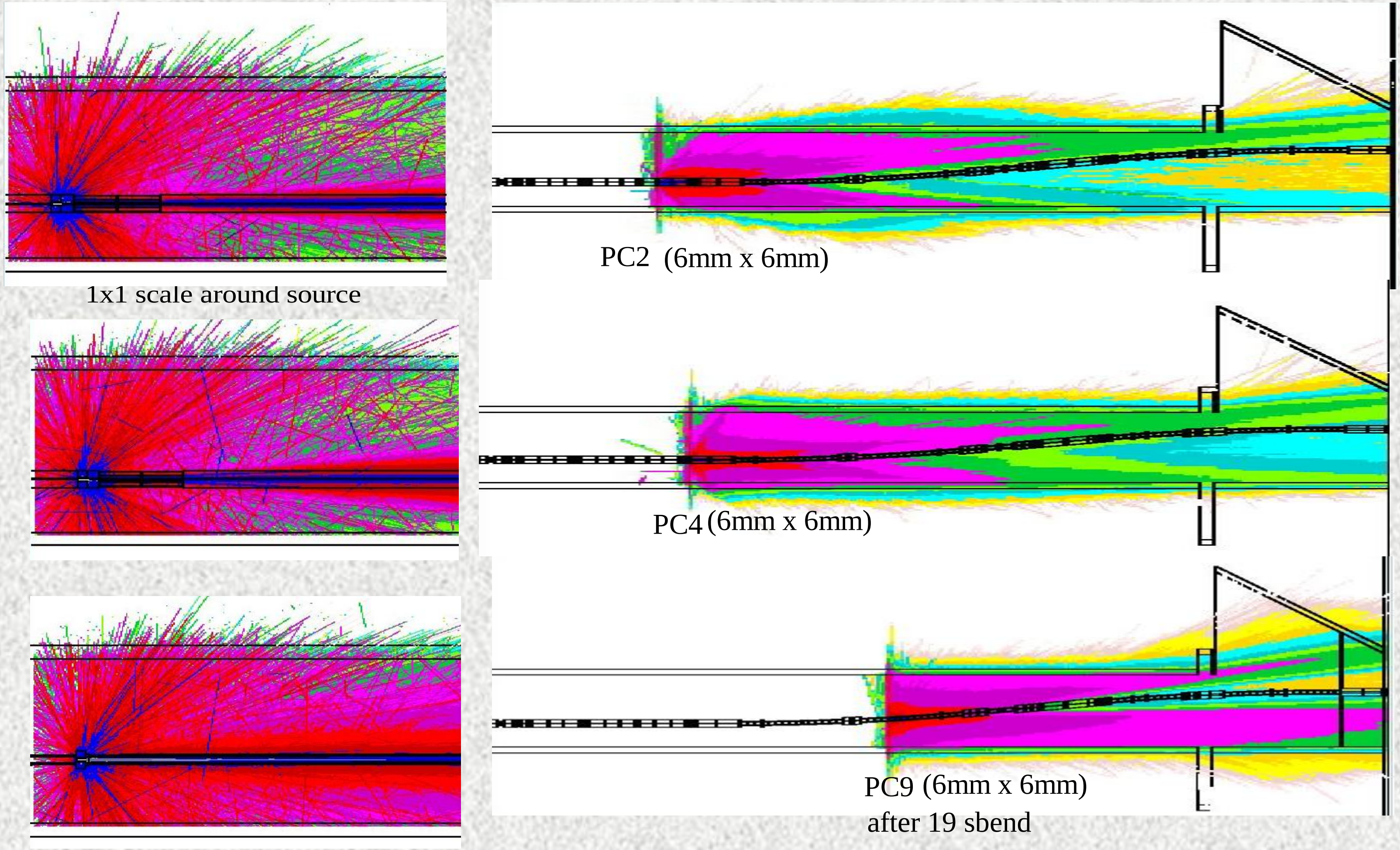


1/100

1/20

Muon flux [1/cm2/e+] $cm^{-2}\ s^{-1}$

Muon Fluxes from Hottest PCs



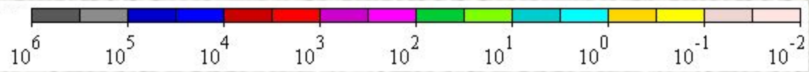
1x1 scale around source

PC2 (6mm x 6mm)

PC4 (6mm x 6mm)

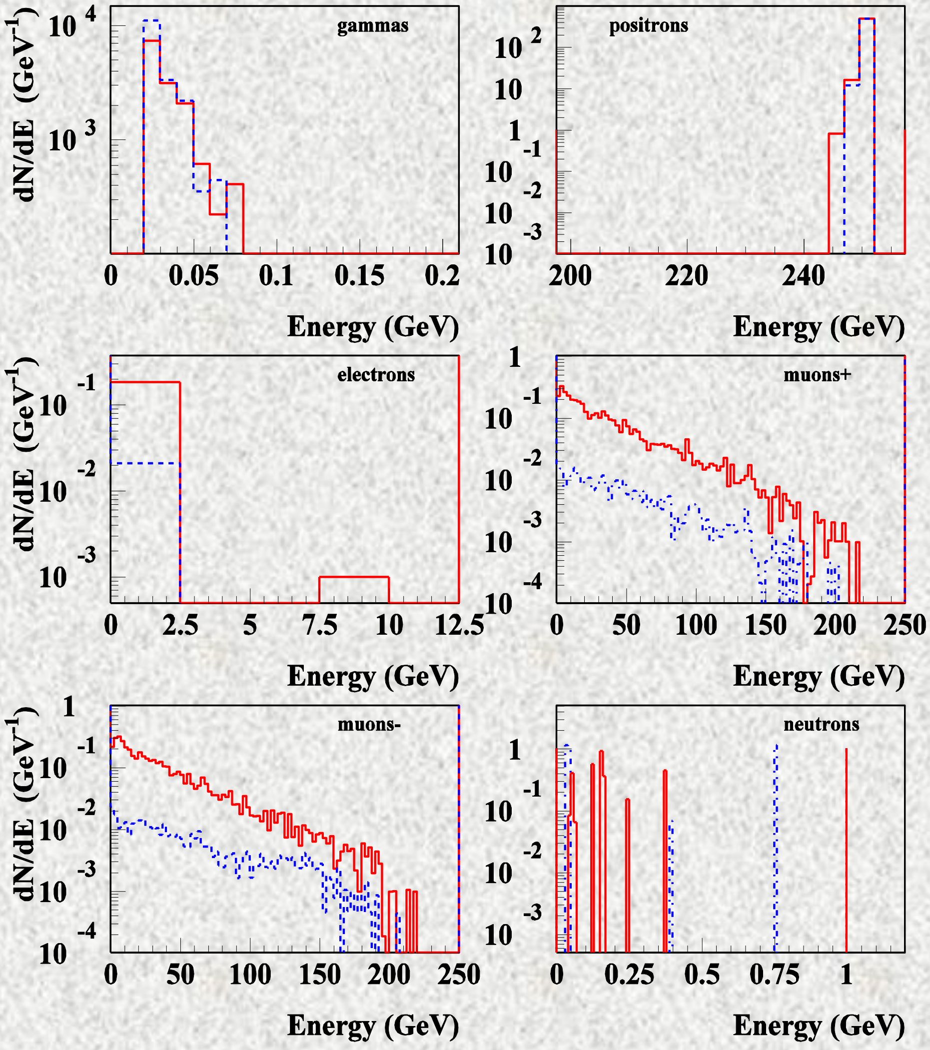
PC9 (6mm x 6mm)
after 19 sbend

Muon flux
[mu/cm2/sec]



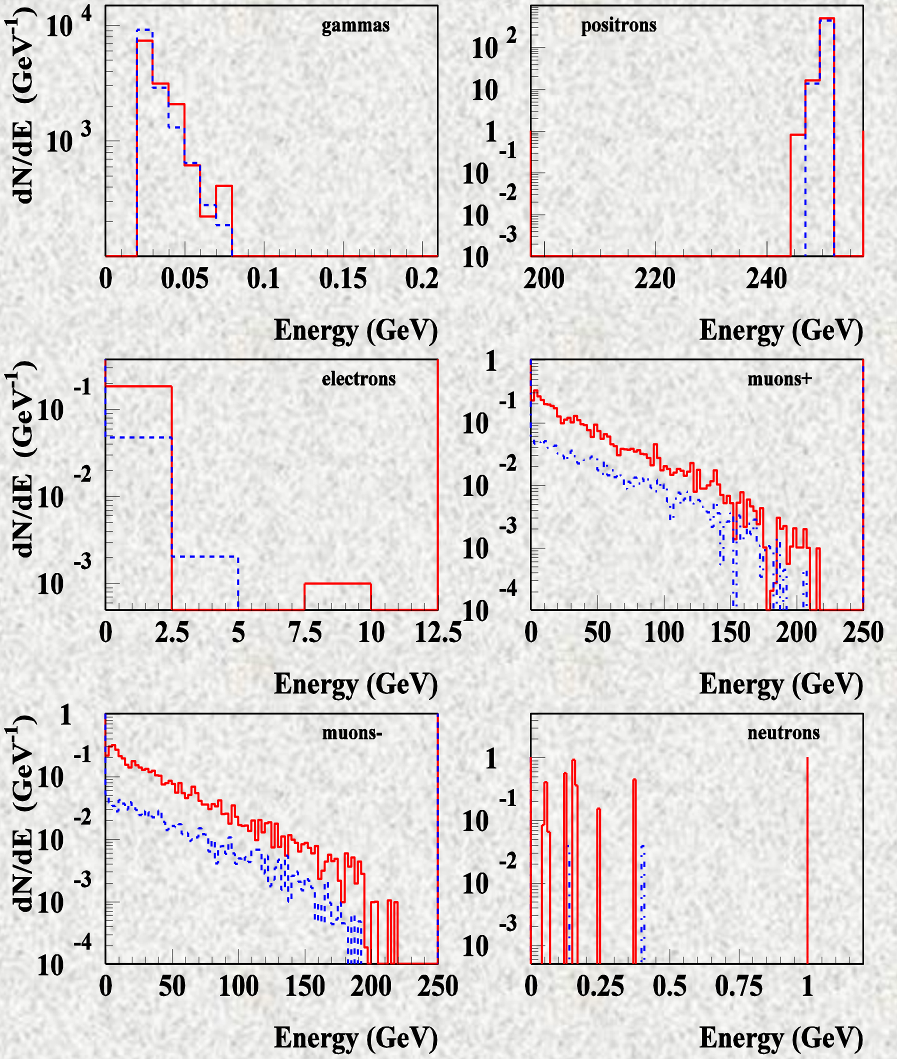
Energy Spectra at Detector

Red lines – no spoilers, blue – 5m wall



no spoiler/musp2

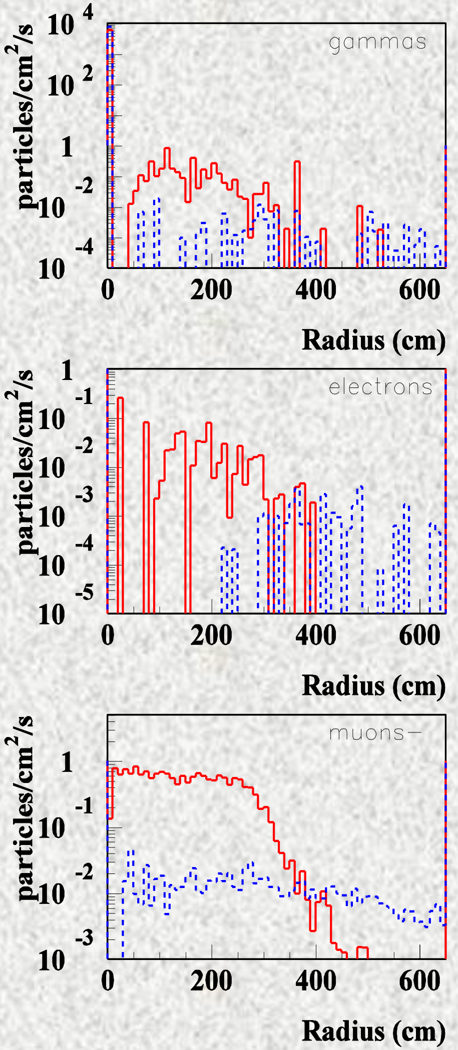
Red lines – no spoilers, blue – 5 donuts



no spoiler/5 donuts, 4m x 0.7m, LK

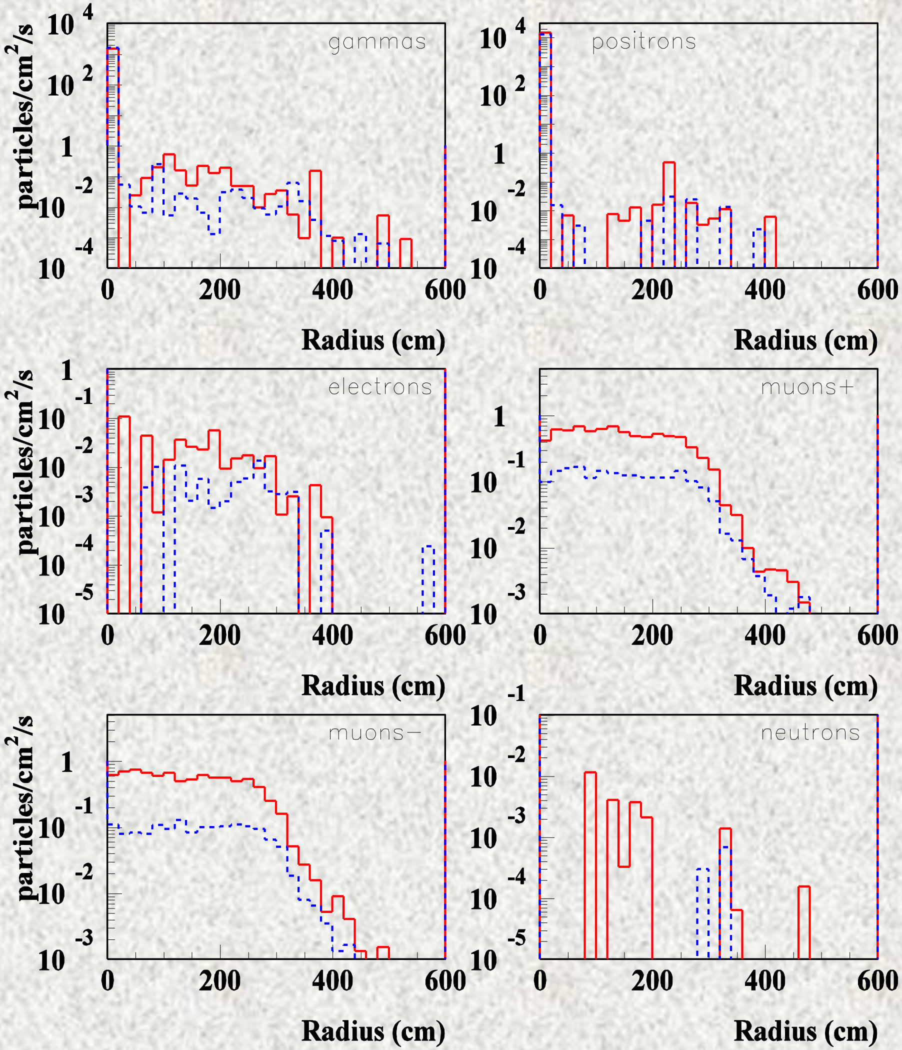
Radial Distributions of Backgrounds at Detector

Red lines – no spoilers, blue – 5m wall



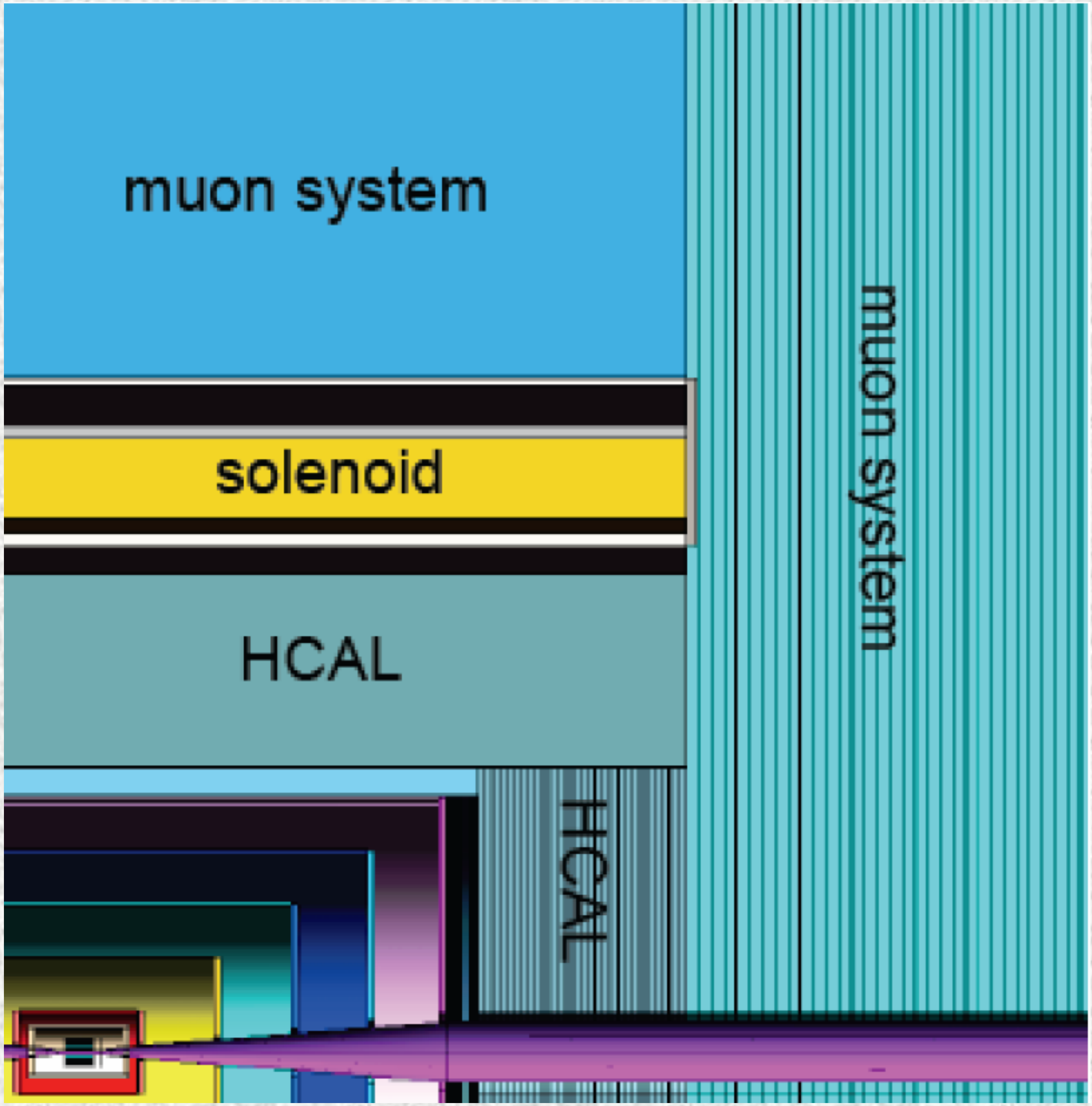
no spoiler/musp2

Red lines – no spoilers, blue – 5 donuts



no spoiler/5 donuts, 4m x 0.7m, LK

SiD SUB-DETECTORS (one quadrant)



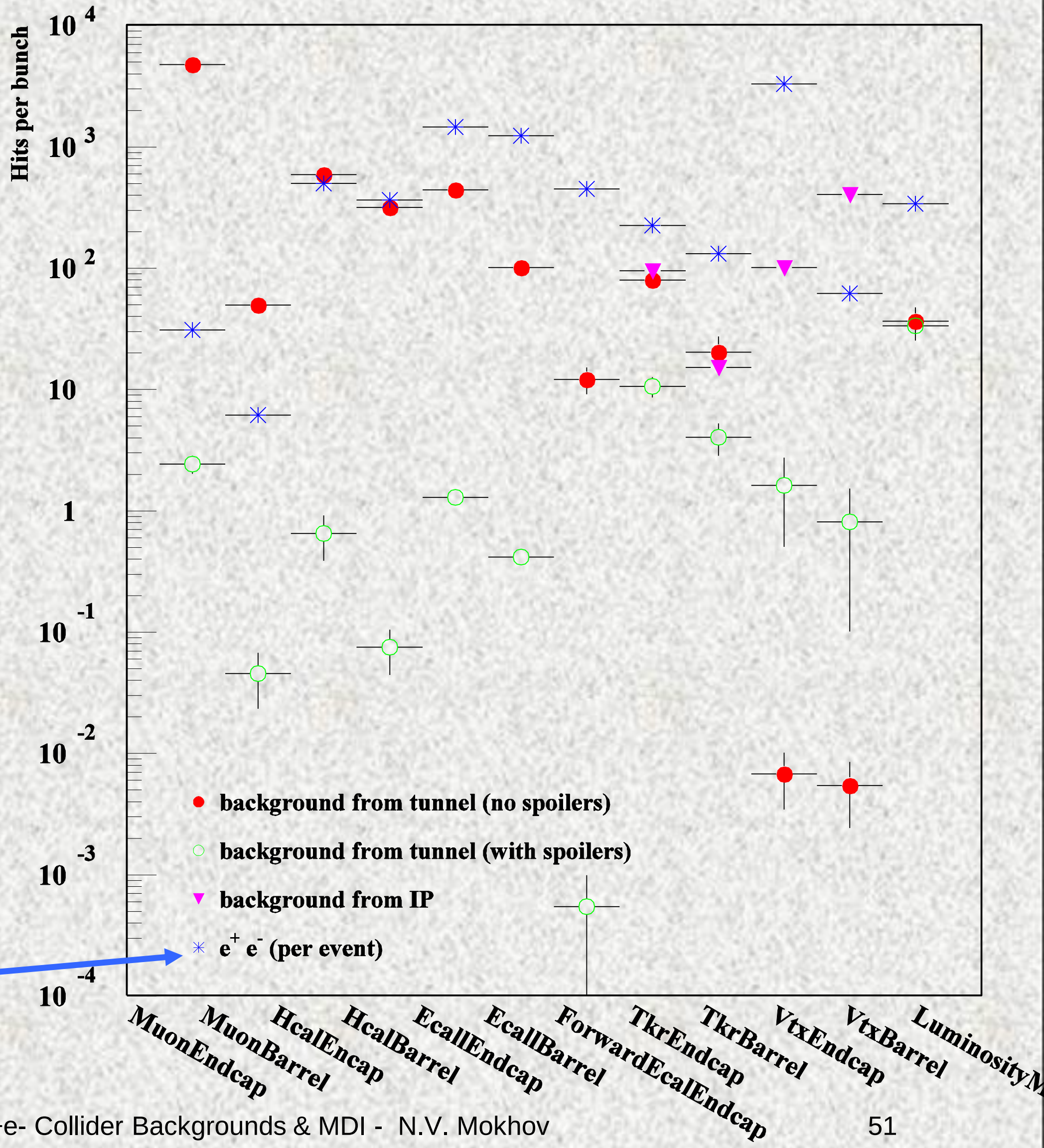
Hit Rates in Detector Subsystems

1. Machine-related background with and without spoilers – STRUCT+MARS15 + SLIC.

   <u>Here – only from e^+ beam.</u>

2. IP-related background – radiative Bhabas from beam-beam interaction and synchrotron radiation from beam. Guineapig + GEANT3

3. *e+e-* events at 500 GeV- PYTHIA + SLIC



Per e^+e^- event

Tracker

Tolerable limits

pattern recognition:

0.2 hits/cm^2/bunch

pile-up problems:

0.2 hits/mm^2/train

Machine bckgrs in Tracker Endcap:

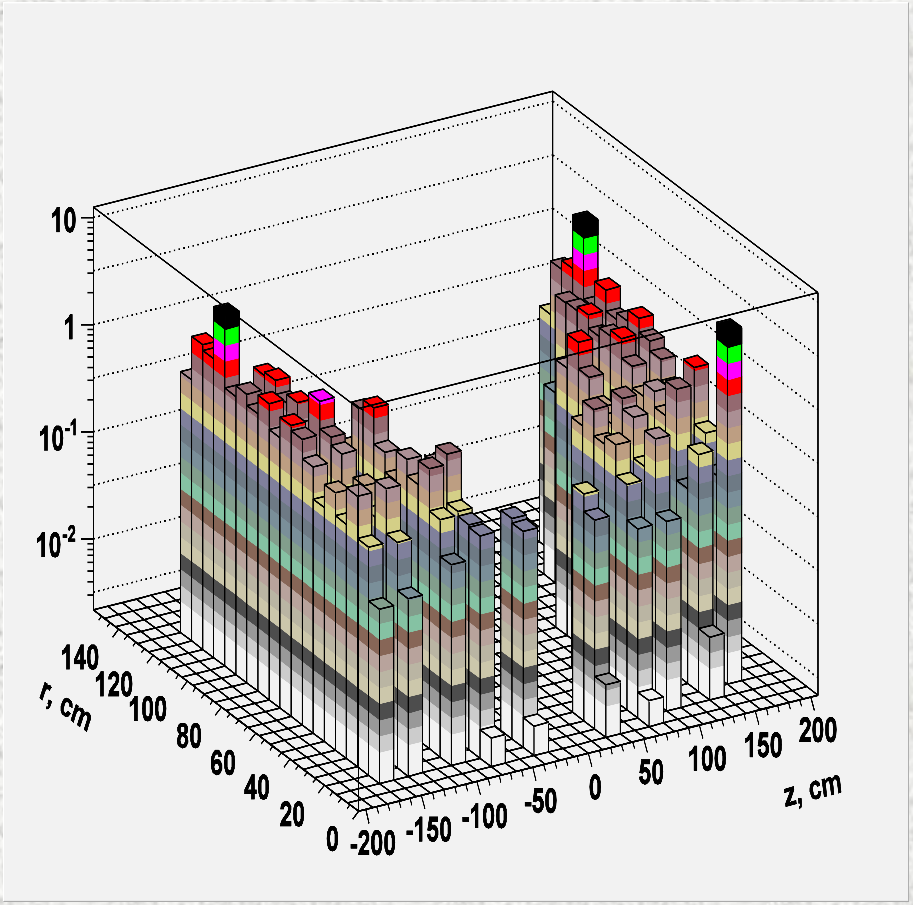
7 10^{-4} hits/cm^2/bunch

0.02 hits/mm^2/train

Machine bckgrs in Tracker Barrel

4 10^{-5} hits/cm^2/bunch

0.001 hits/mm^2/train



Tracker Endcap

No spoilers

BDS Background Occupancy

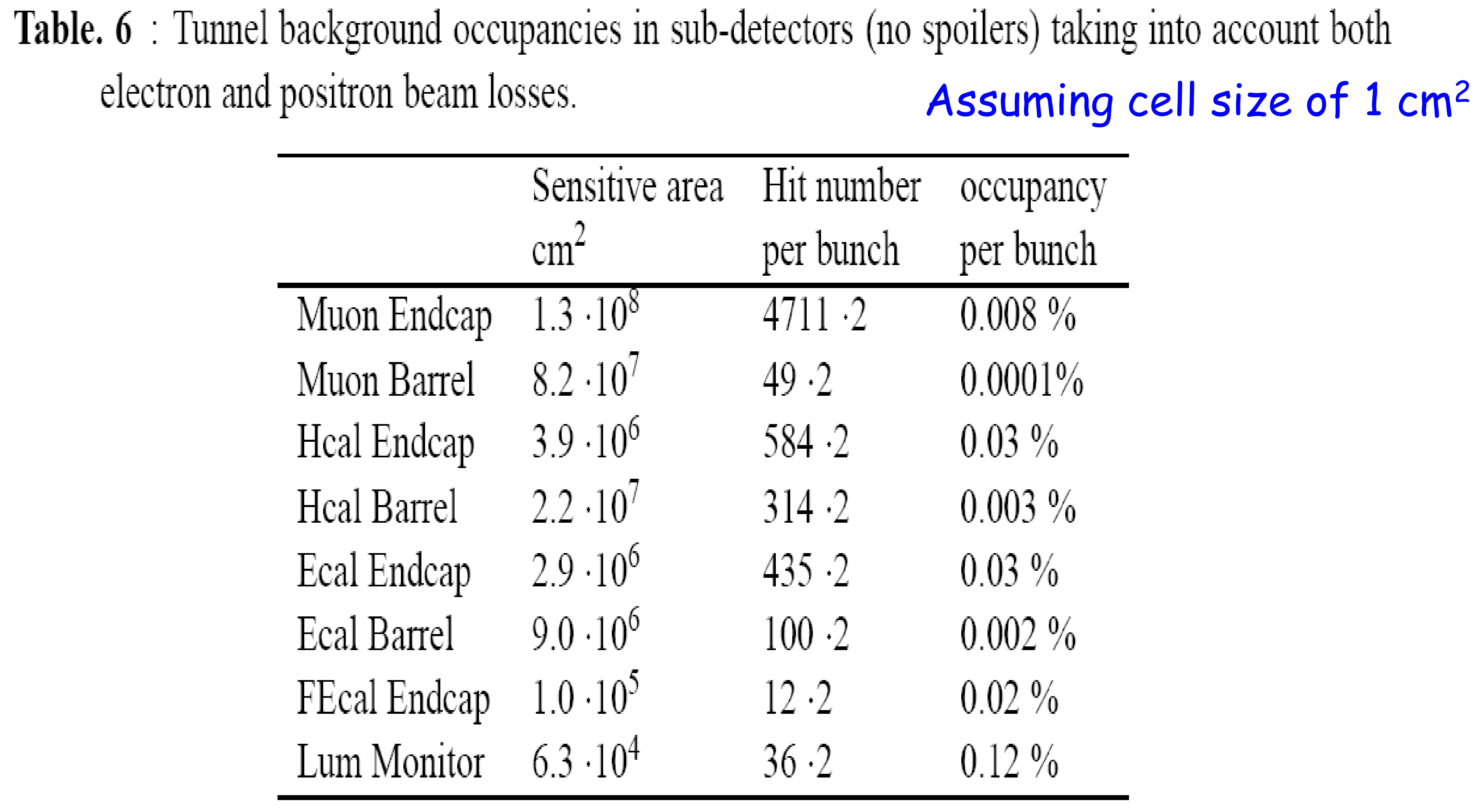


Table. 6 : Tunnel background occupancies in sub-detectors (no spoilers) taking into account both electron and positron beam losses.

	Sensitive area cm^2	Hit number per bunch	occupancy per bunch
Muon Endcap	$1.3 \cdot 10^8$	$4711 \cdot 2$	0.008 %
Muon Barrel	$8.2 \cdot 10^7$	$49 \cdot 2$	0.0001%
Hcal Endcap	$3.9 \cdot 10^6$	$584 \cdot 2$	0.03 %
Hcal Barrel	$2.2 \cdot 10^7$	$314 \cdot 2$	0.003 %
Ecal Endcap	$2.9 \cdot 10^6$	$435 \cdot 2$	0.03 %
Ecal Barrel	$9.0 \cdot 10^6$	$100 \cdot 2$	0.002 %
FEcal Endcap	$1.0 \cdot 10^5$	$12 \cdot 2$	0.02 %
Lum Monitor	$6.3 \cdot 10^4$	$36 \cdot 2$	0.12 %

Assuming cell size of 1 cm^2

Should be < 1% / SW, a problem with 50 μs (150 bunch) SW (VTX, TPC)

Hits in Muon Endcap

RPCs need 1ms to recharge 1 cm^2 area around the avalanche.

Background rate should be

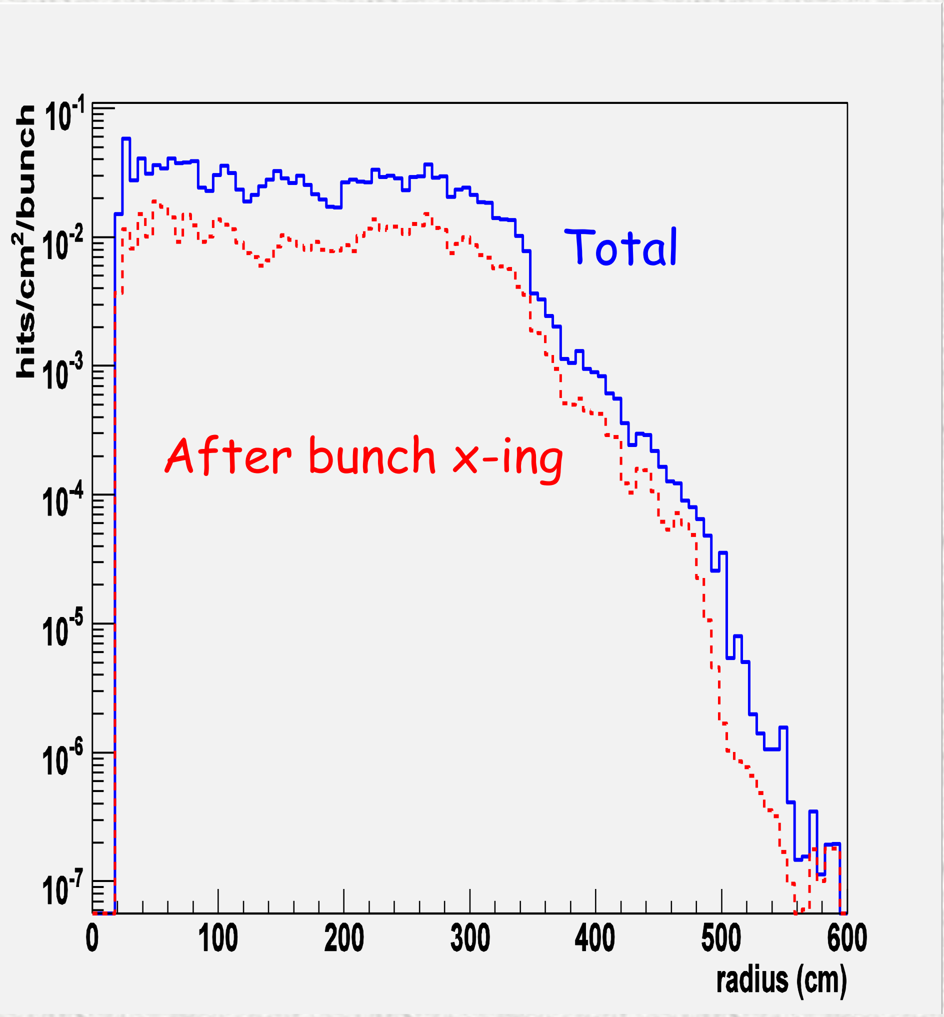
< 100 Hz/cm^2

Otherwise, an unmanageable dead time.

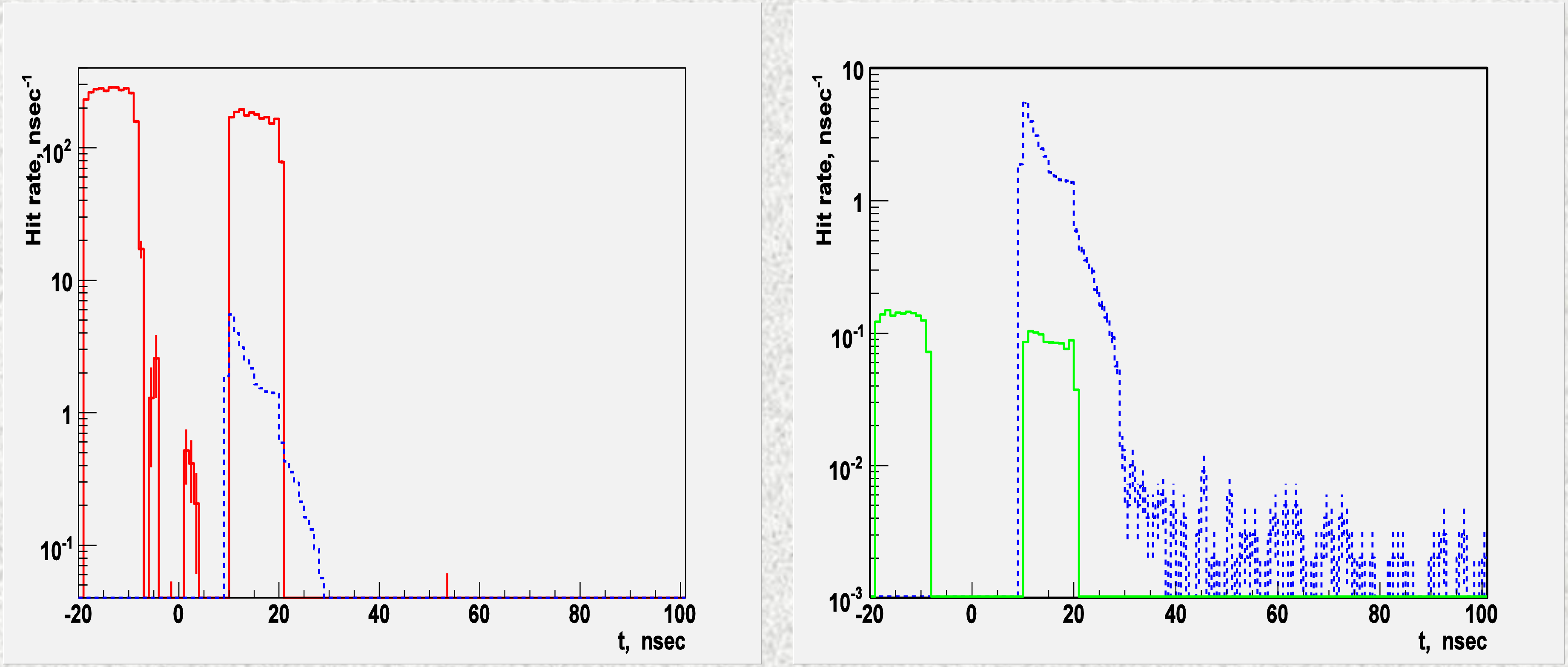
There are 14100 bunches per second

Tunnel background is about:

400 Hz/cm^2 without spoilers



Hit Time Distribution in Muon Endcap



Red: machine background (no spoilers)

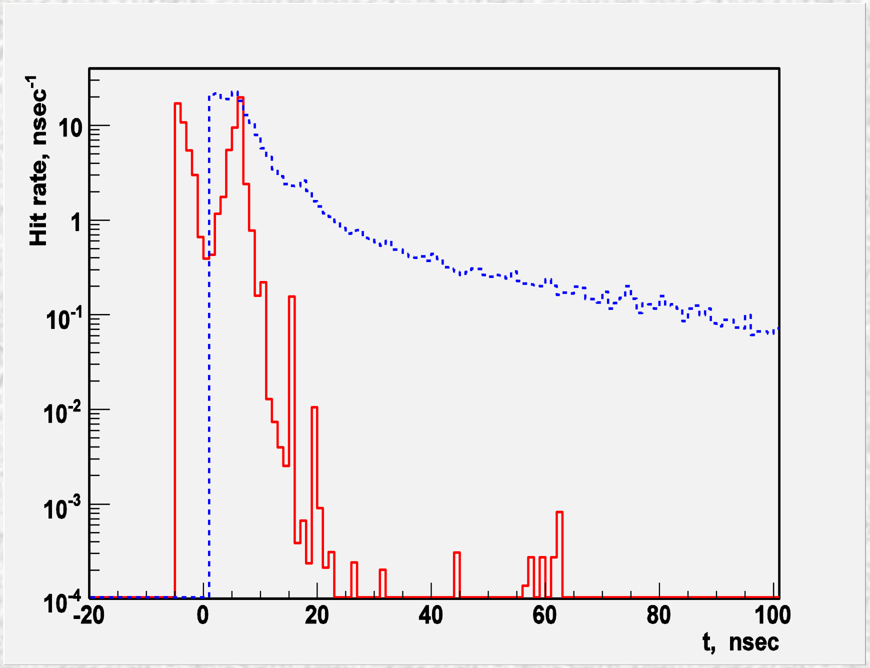
Green: machine background (with 9 & 18-m walls)

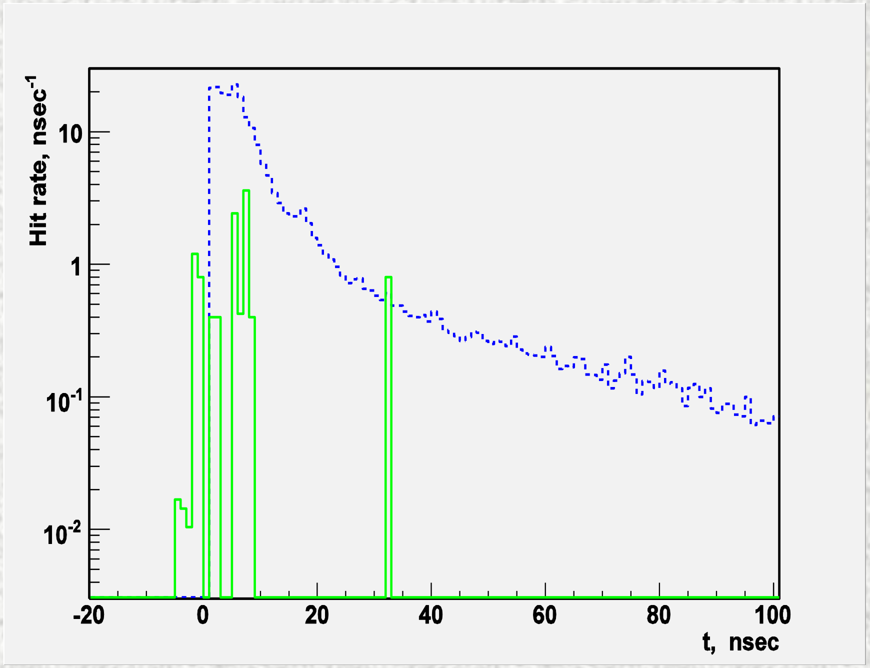
Blue: e+e- events

t=0 is bunch crossing.

BDS background
from e^+ tunnel only

Hit Time Distribution in Tracker Endcap

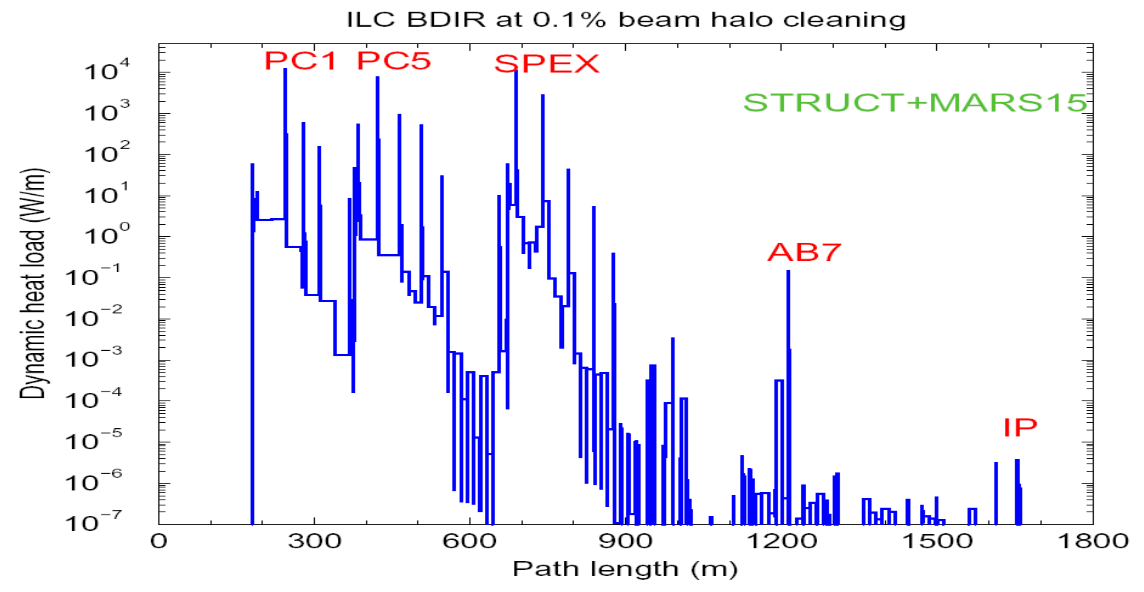


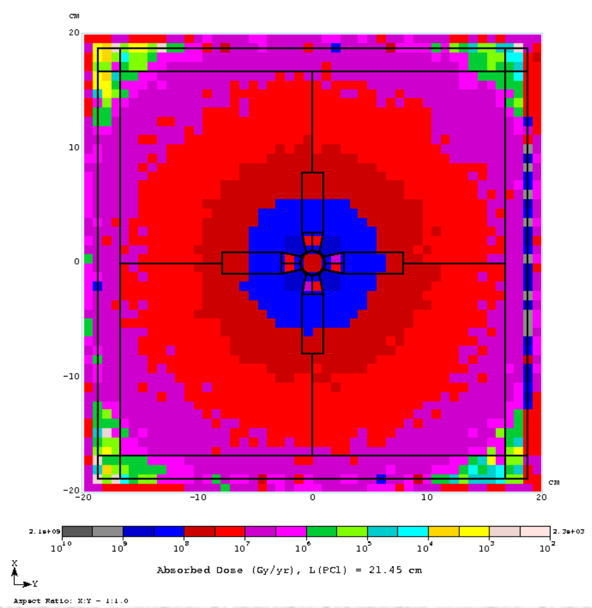


Red: machine background (no spoilers)
Green: machine background (with 9&18-m walls)
Blue: e+e- events
t=0 is bunch crossing

BDS background
from e^+ tunnel only

DYNAMIC HEAT AND RADIATION LOADS IN BDS





50 W/m on spoilers, 5-7 kW/m on protection collimators, up to 80 W/m on quads (*well above the limit of 1 W/m → local shielding*).

First quad downstream of 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). 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.

Temperature rise and stress are not 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.

Energy Deposition and Radioactivation in BDS

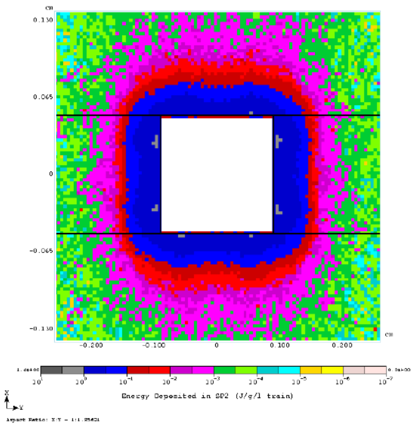


Figure 7: Energy deposited in the spoiler SP2.

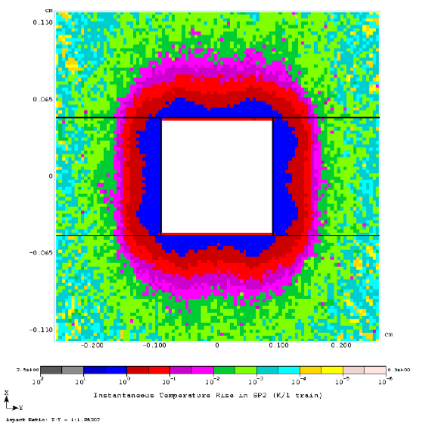


Figure 8: Instantaneous temperature rise in the spoiler SP2.

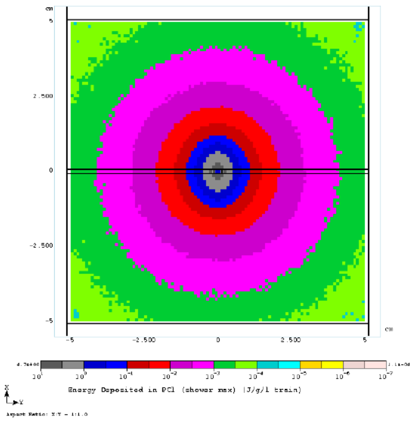


Figure 9: Energy deposited in the collimator PC1 at a collimator depth where the energy deposition is maximal.

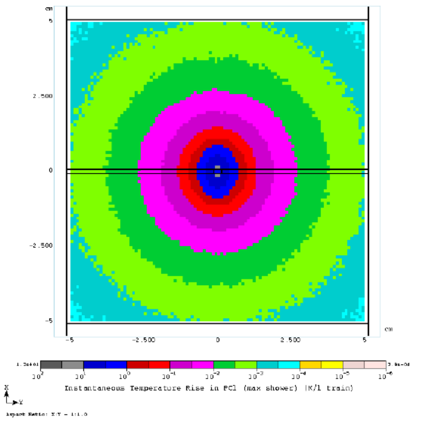
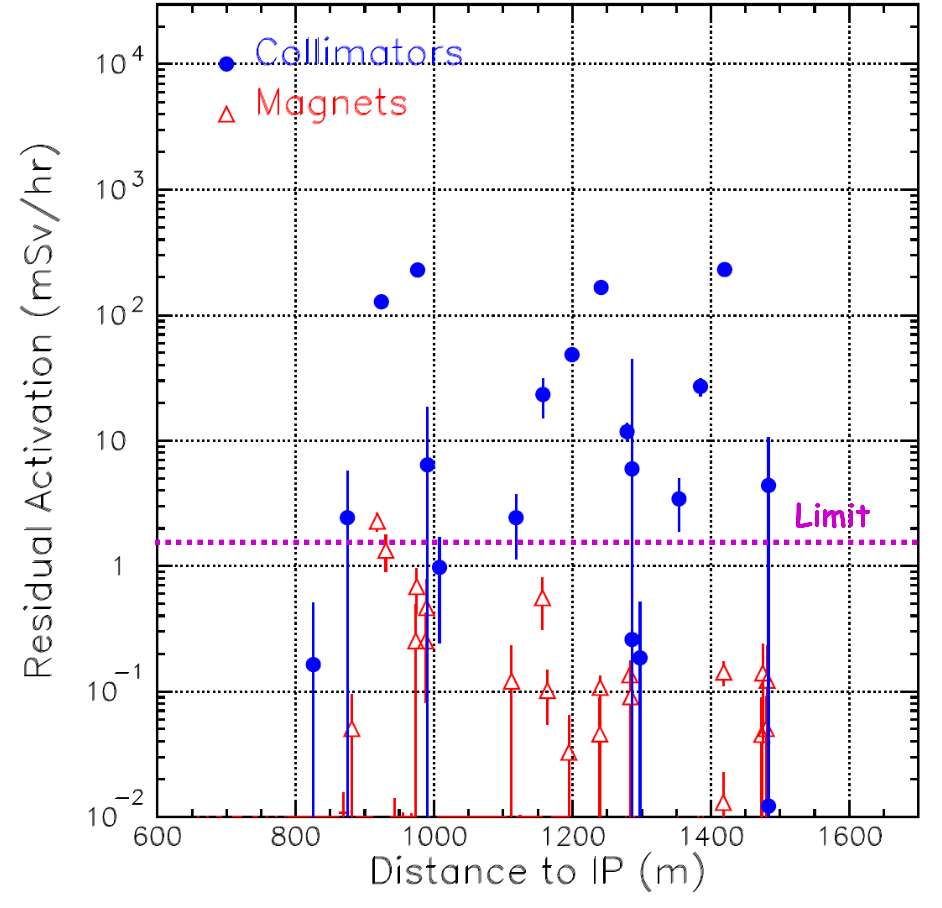


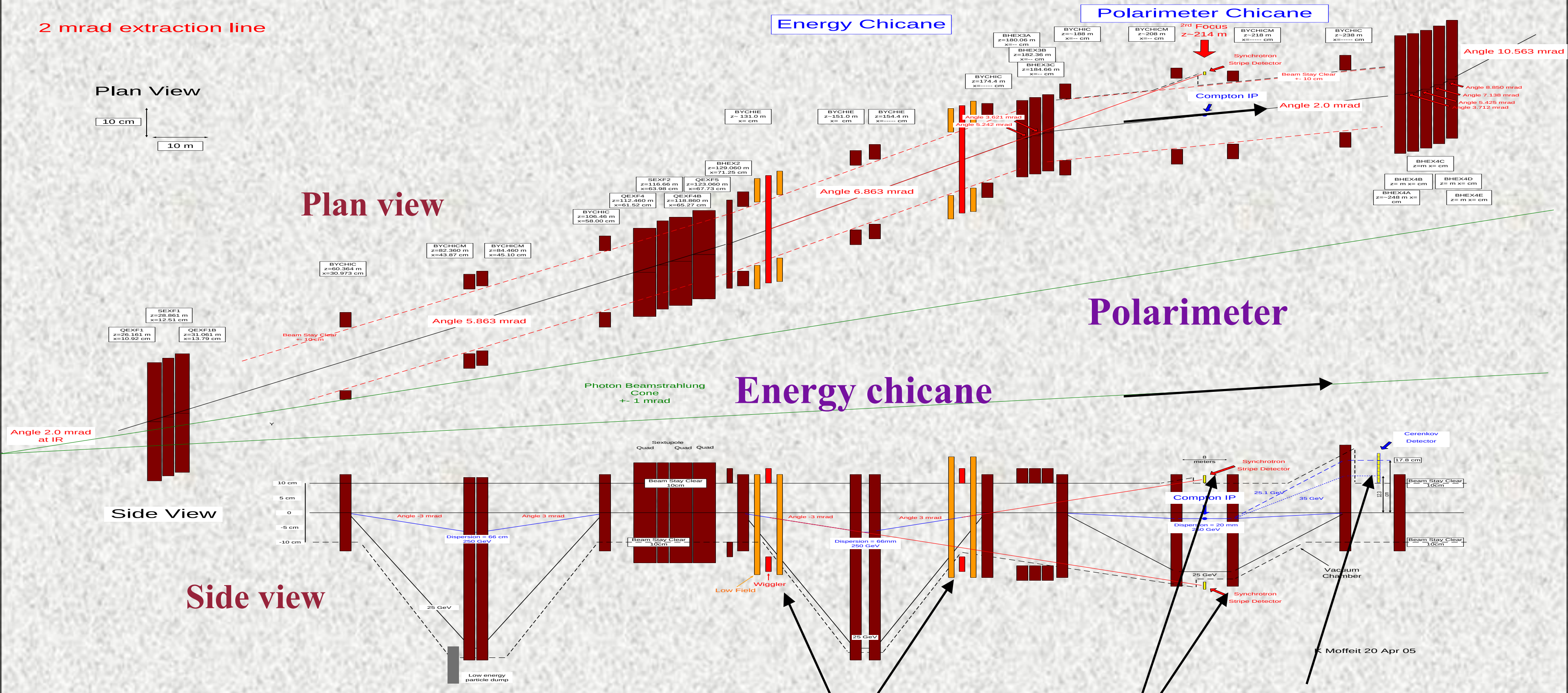
Figure 10: Instantaneous temperature rise in the collimator PC1 at a collimator depth where the energy deposition is maximal.

Local shielding is needed to meet hands-on maintenance and ground-water activation limits

Residual dose on contact (30day/1day)



MDI: 2-mrad Extraction



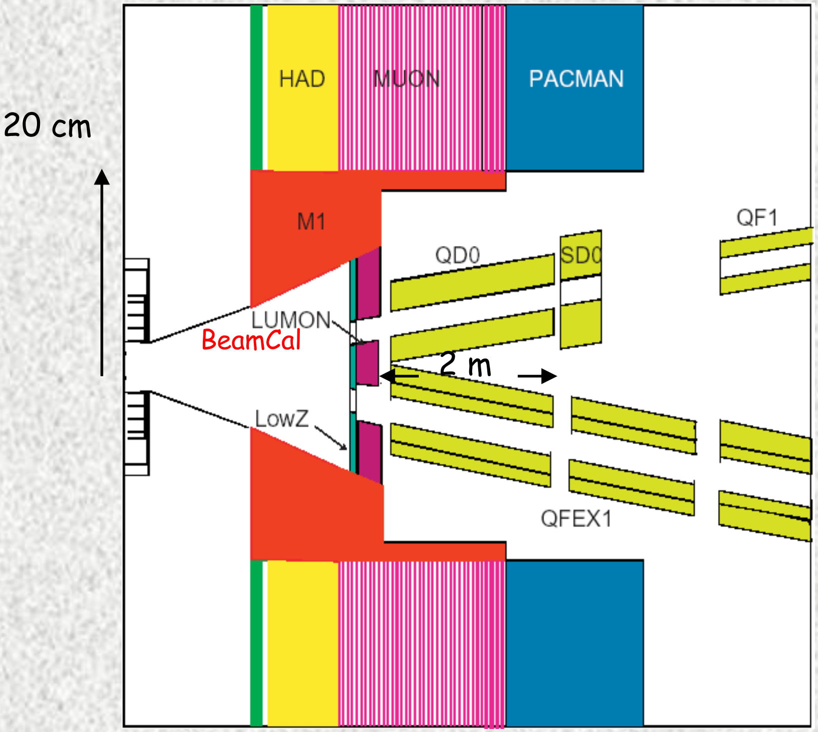
wigglers

SR detectors

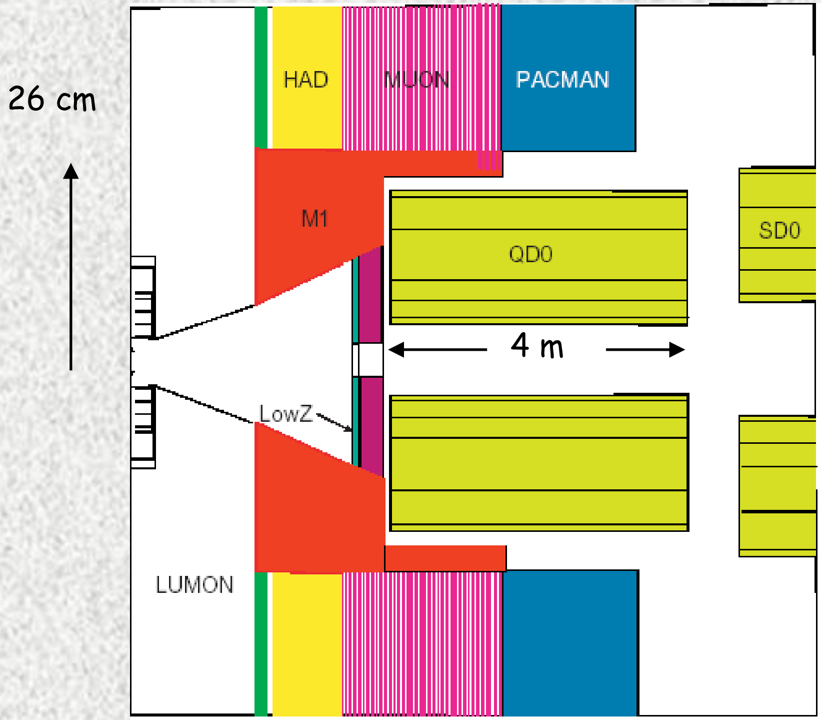
Compton detector

MDI: SiD Configuration

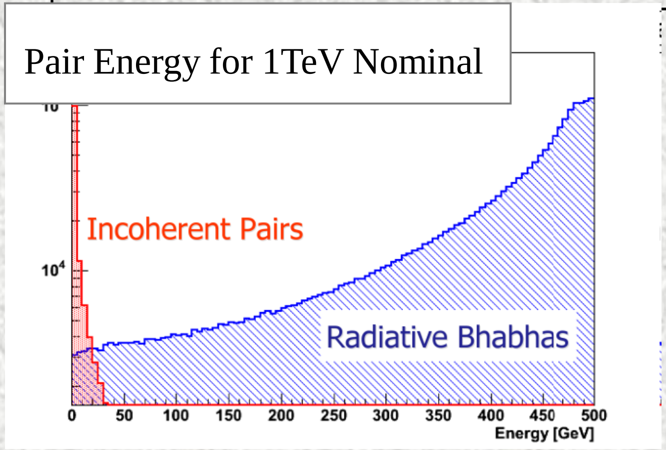
20 mrad

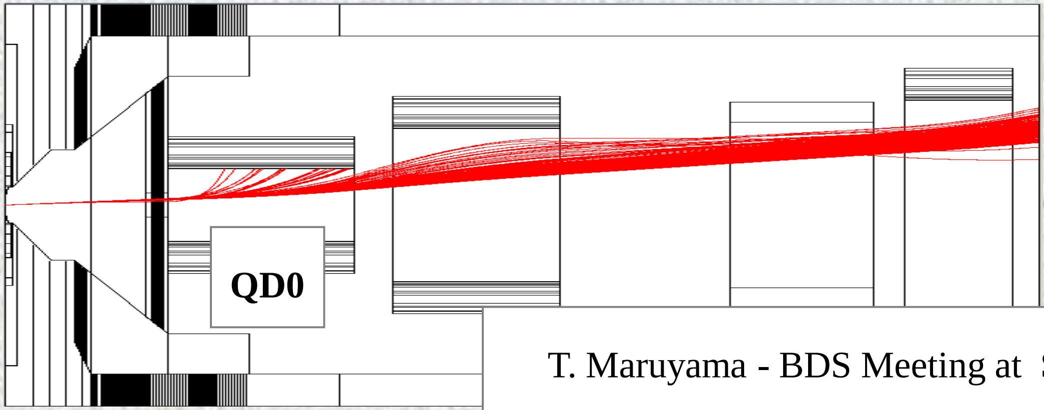


2 mrad



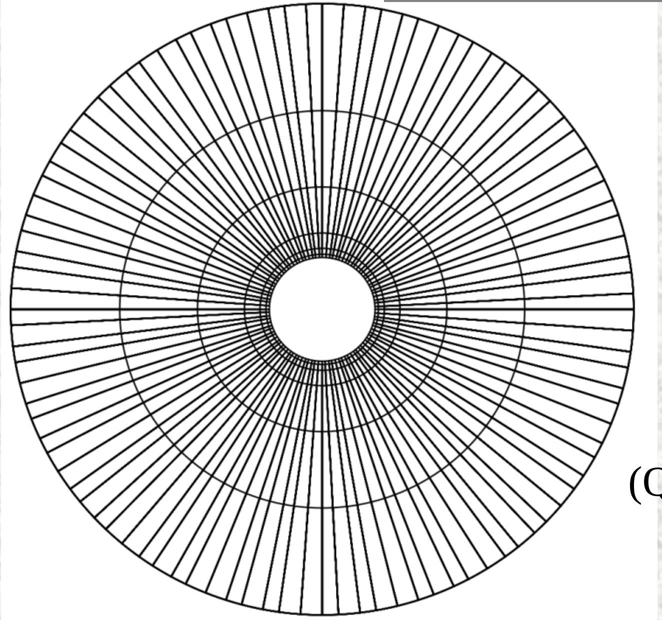
2mrad Extraction Line: Losses in SC QD0 from Radiative Bhabhas


Pair Energy for 1TeV Nominal



T. Maruyama - BDS Meeting at SLAC

27/7/5



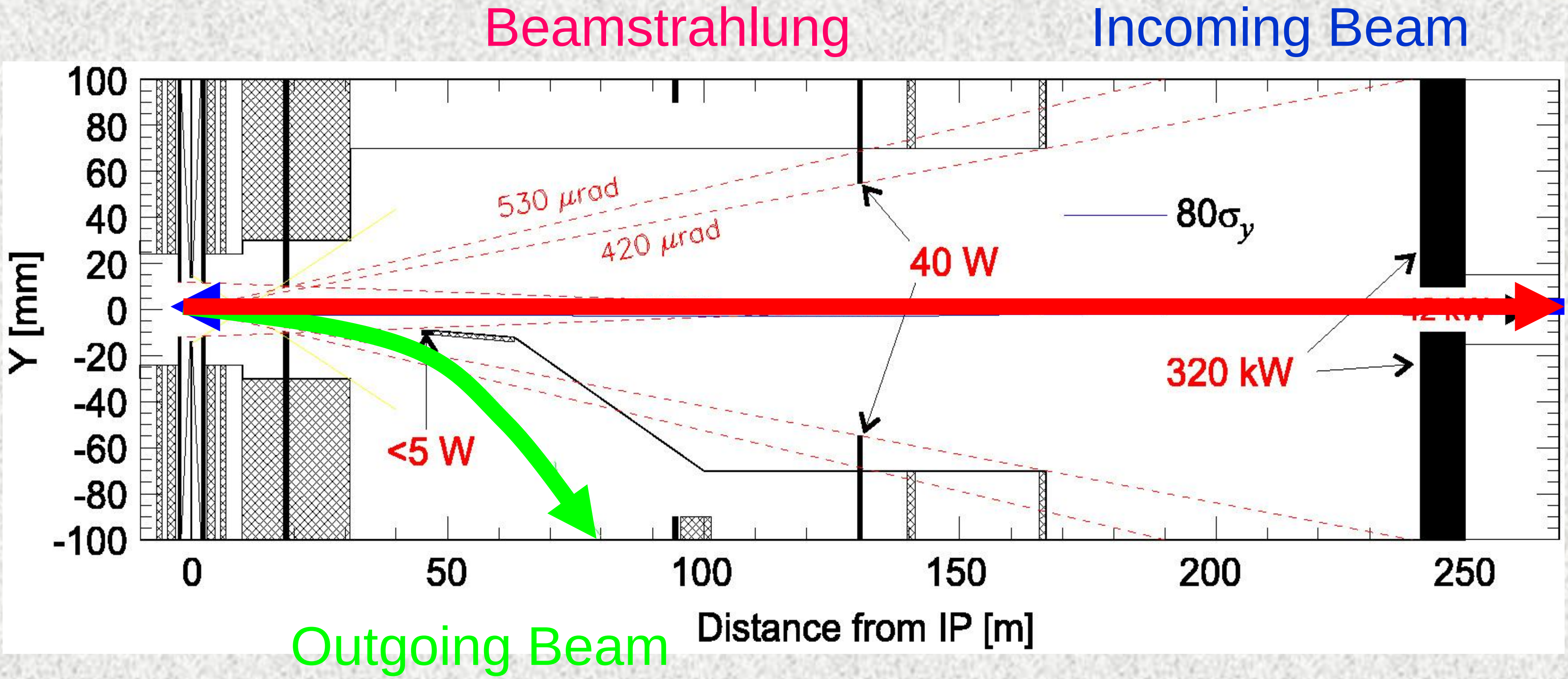
dz = 1cm

⊗

(QD0 Scored into 300000 volumes)

- Radiative Bhabhas created as a result of bremsstrahlung
- Can cause damaging heat loads in the Superconducting QD0
- Magnet designers have stipulated that this quad can only take 0.5mW/g before quenching

Integrated Extraction Line Design



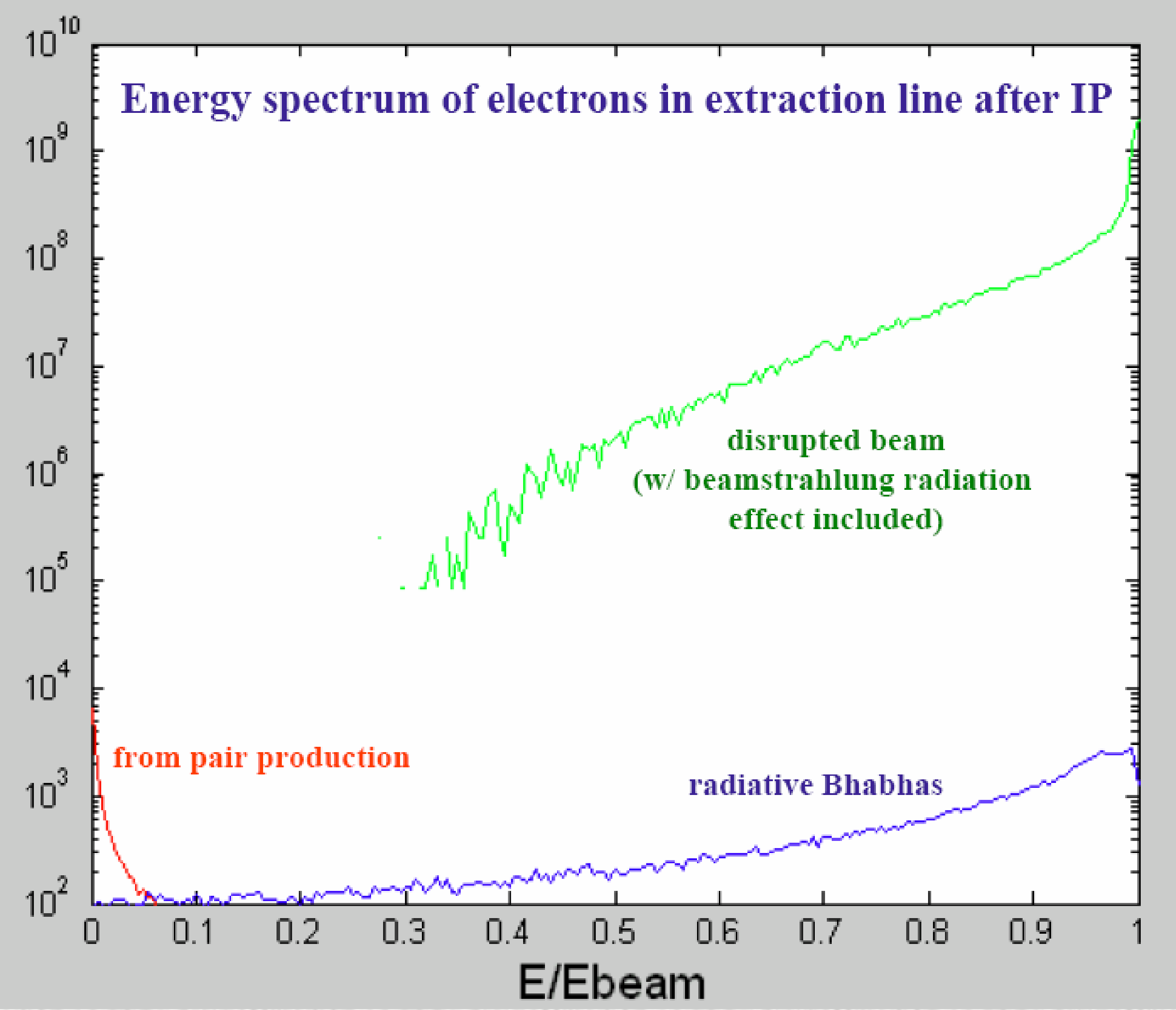
Beamstrahlung

Incoming Beam

Outgoing Beam

BEAMSSTRAHLUNG TO EXTRACTION LINE

4% of the beam energy gets radiated into photons due to beamsstrahlung



MDI: Instrumentation for Luminosity, Luminosity Spectra and Luminosity Tuning

Luminosity

Bhabha LumiCAL detector from 40-120 mrad

Luminosity Spectrum

Bhabha acolinearity measurements using forward tracking and calorimetry from 120-400 mrad

\+ additional input from beam energy, energy spread and energy spectrum measurements

Luminosity Tuning

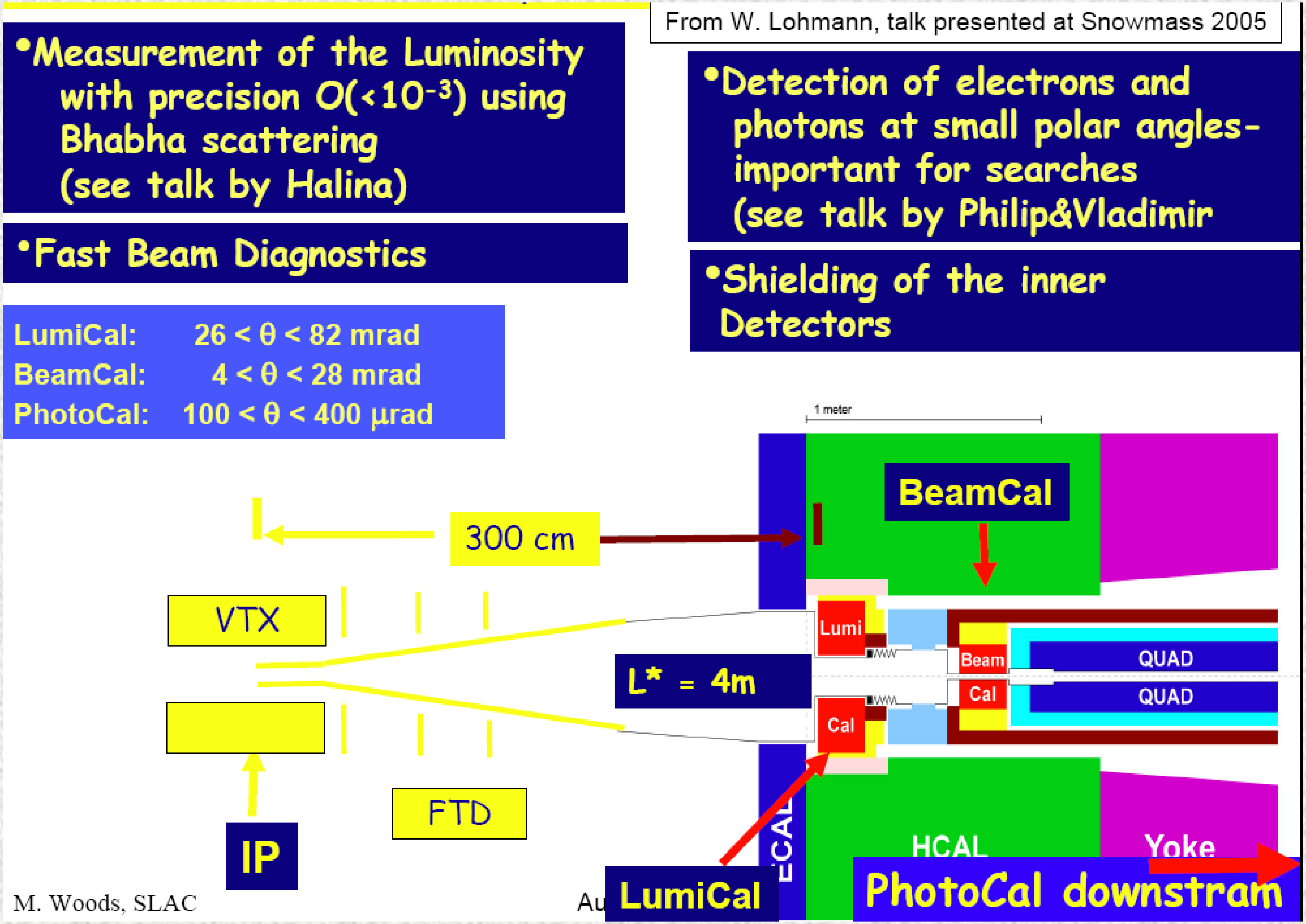
IP BPMs

Pair BeamCAL detector from 5-40 mrad

Beamsstrahlung detector?

Radiative Bhabhas?

MDI: Functions of the Very Forward Detectors

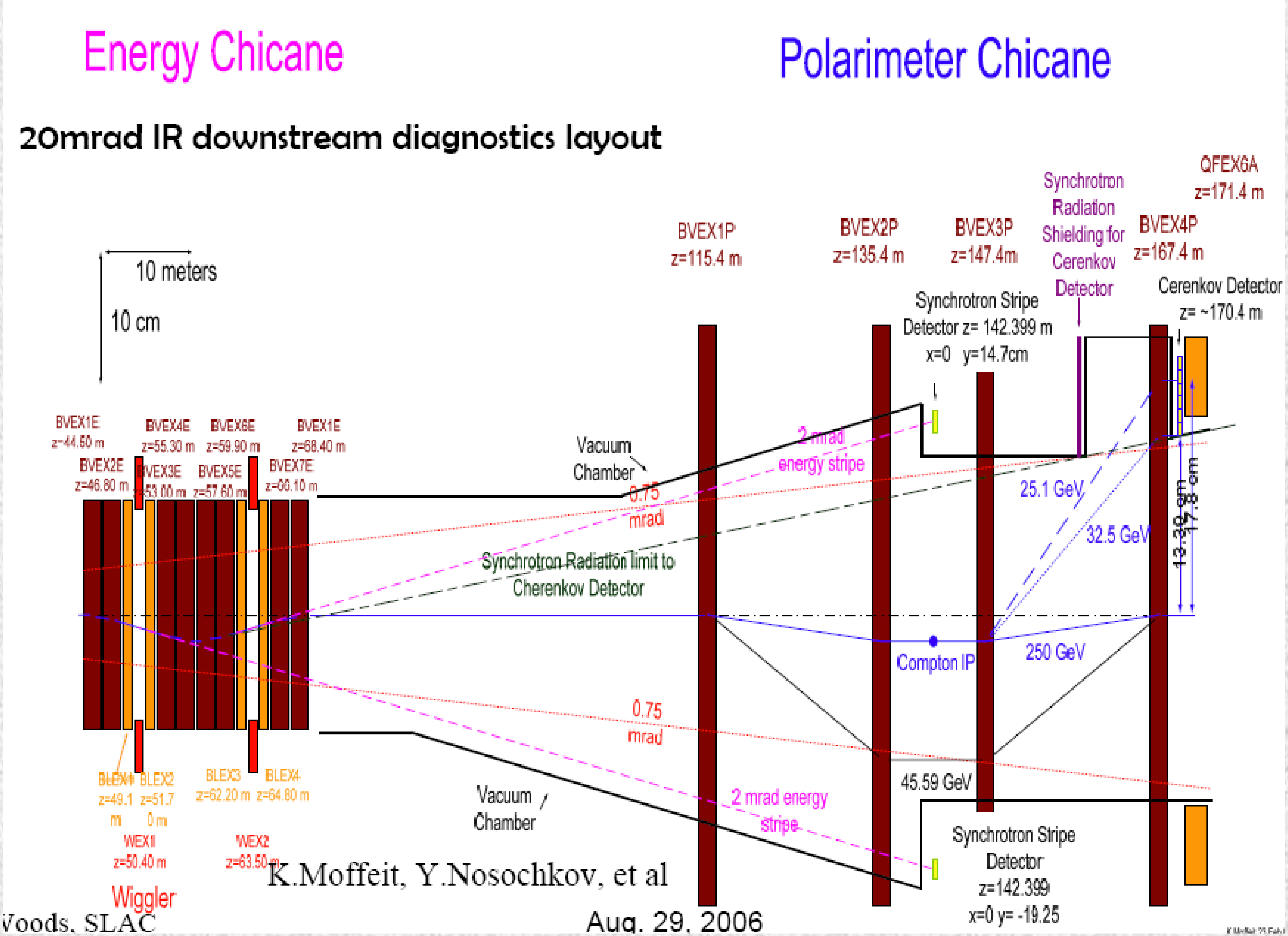


From W. Lohmann, talk presented at Snowmass 2005

- Measurement of the Luminosity with precision $O(<10^{-3})$ using Bhabha scattering (see talk by Halina)
- Fast Beam Diagnostics
- Detection of electrons and photons at small polar angles- important for searches (see talk by Philip&Vladimir
- Shielding of the inner Detectors

LumiCal:	$26 < \theta < 82$ mrad
BeamCal:	$4 < \theta < 28$ mrad
PhotoCal:	$100 < \theta < 400$ µrad

MDI: Extraction Line Diagnostics at 20 mrad



Energy Chicane

Polarimeter Chicane

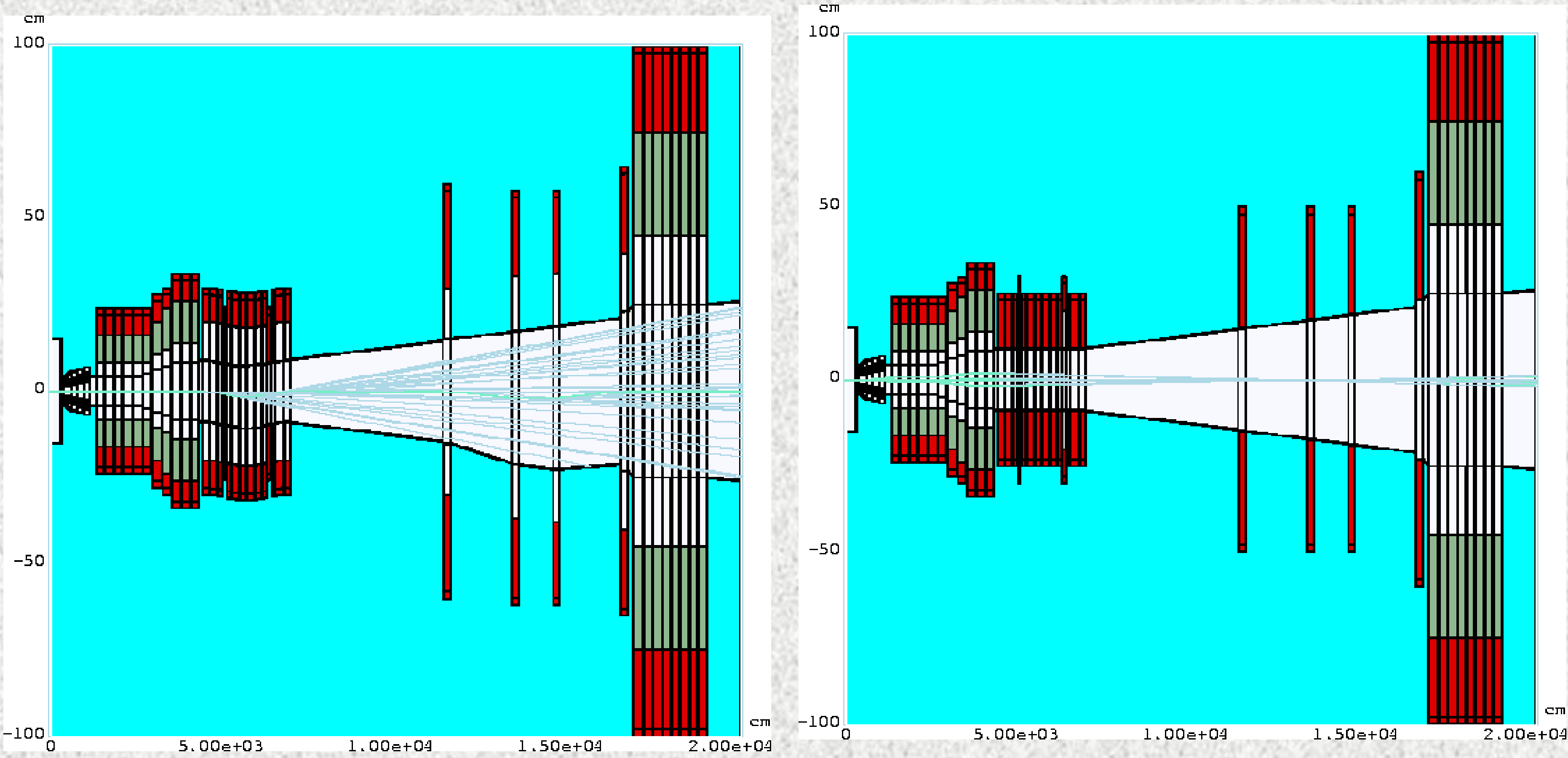
20mrad IR downstream diagnostics layout

K.Moffeit, Y.Nosochkov, et al

Voods, SLAC

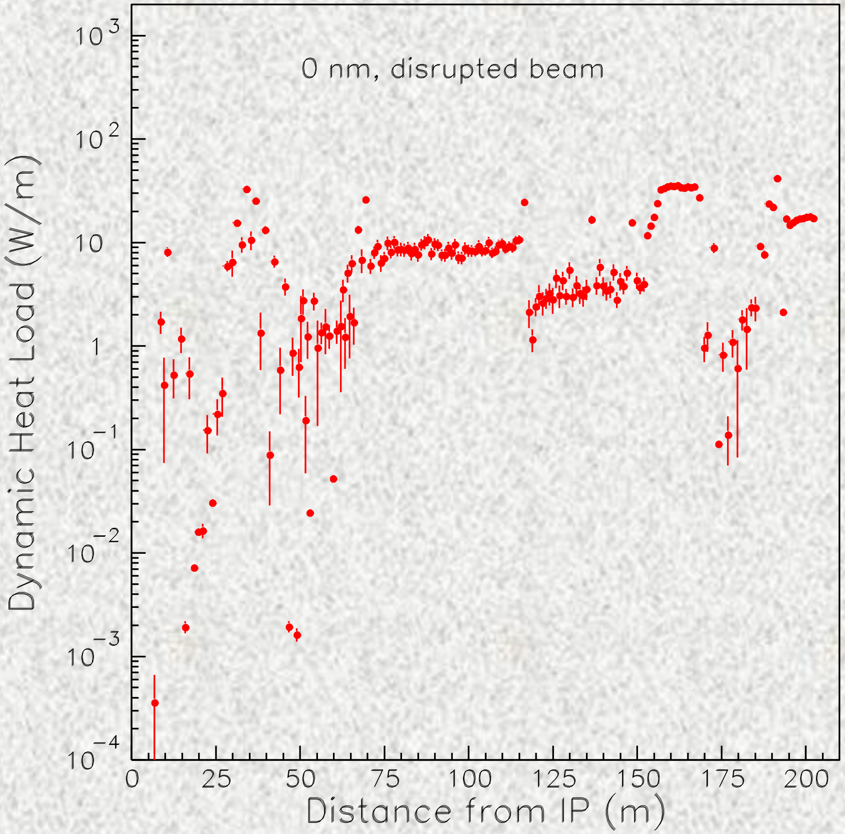
Aug. 29, 2006

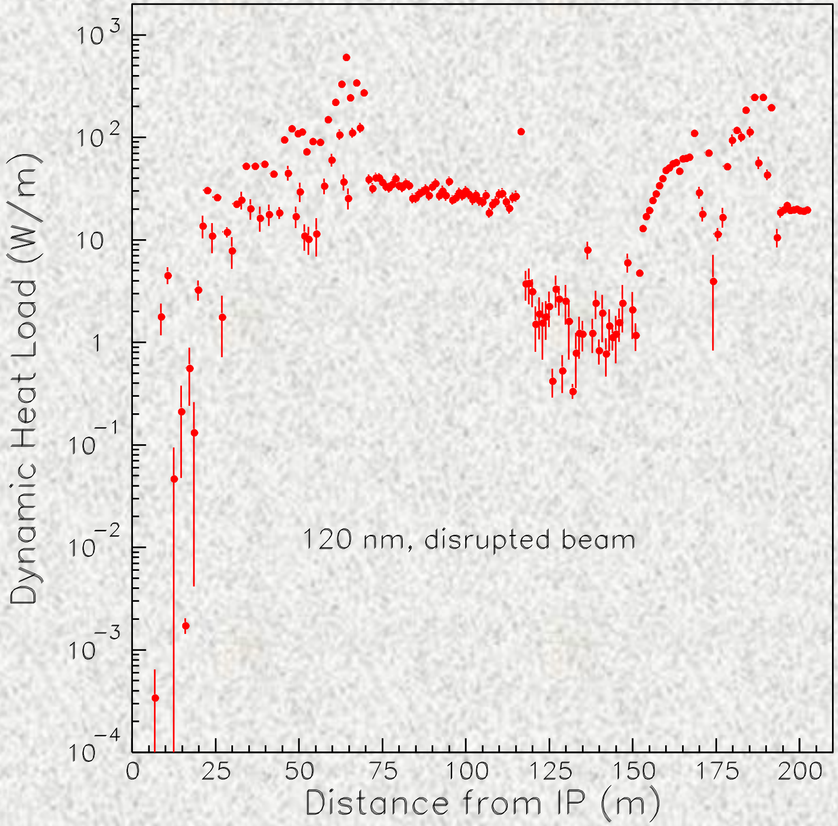
20-MRAD EXTRACTION LINE IN MARS15



Synchrotron photons generated by disrupted beams: elevation view (left) and plan view (right)

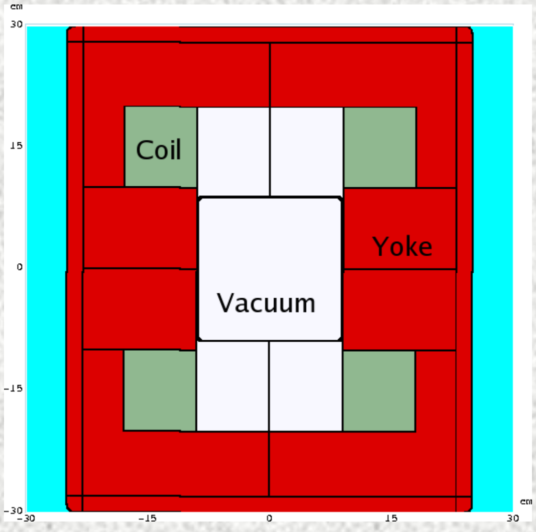
DYNAMIC HEAT LOADS IN EXTRACTION LINE



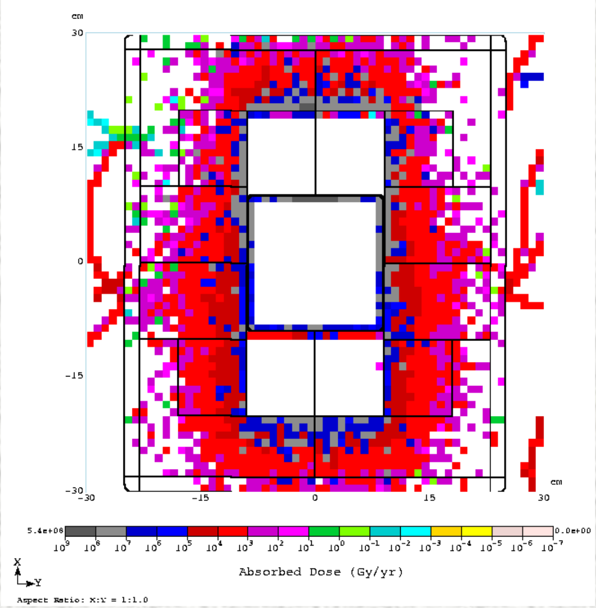


Up to 50 W/m without vertical displacement (left) and
up to 500 W/m with 120-nm vertical displacement (right)

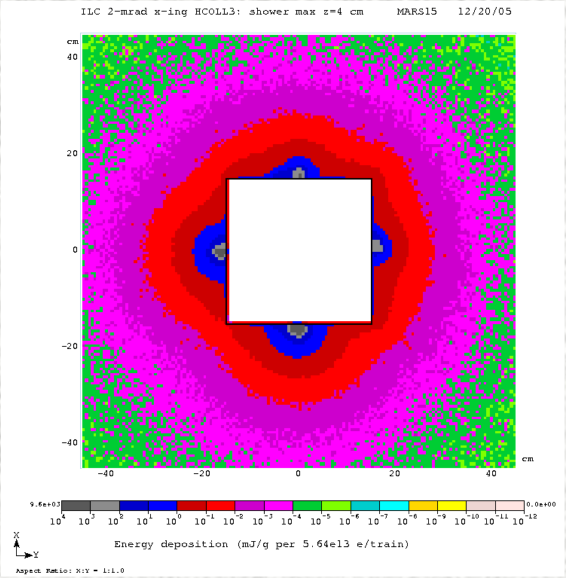
RADIATION DOSES IN EXTRACTION LINES



Magnet at 60 m



20-mrad: dose at 60 m



2-mrad: dose in mask at 153 m

20-mrad x-ing:

Up to 40 MGy/yr with 120-nm vertical displacement: 1-month lifetime

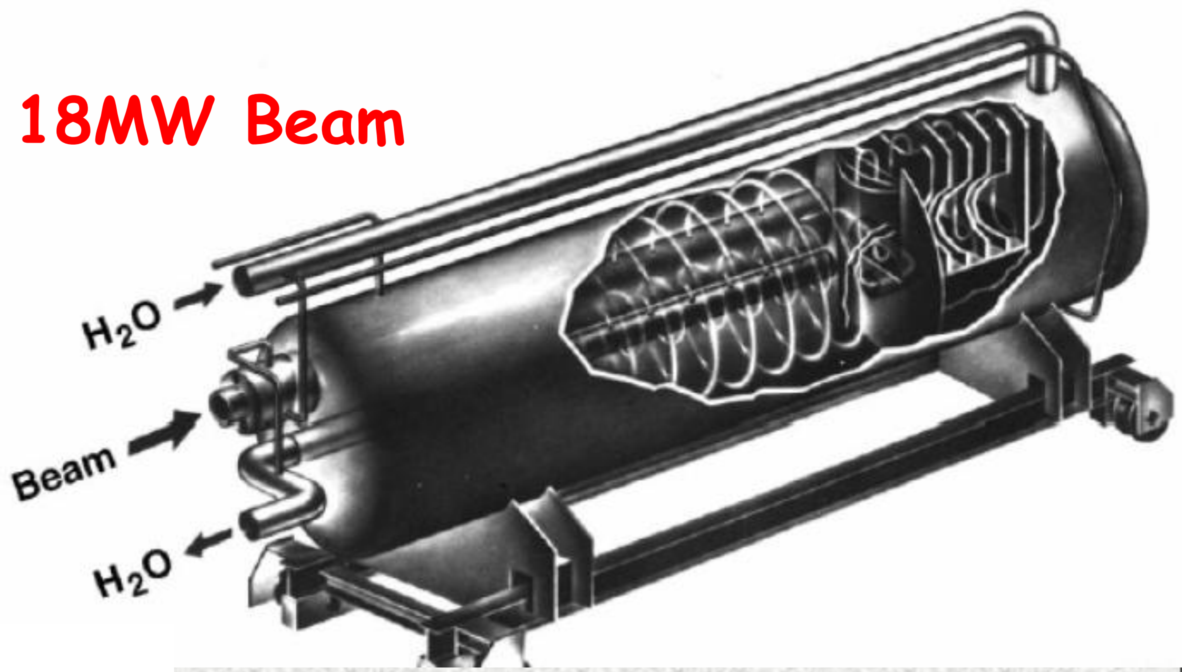
Up to 4 MGy/yr without VD (normal operation):
1-year lifetime → protection collimators (masks).

2-mrad x-ing:

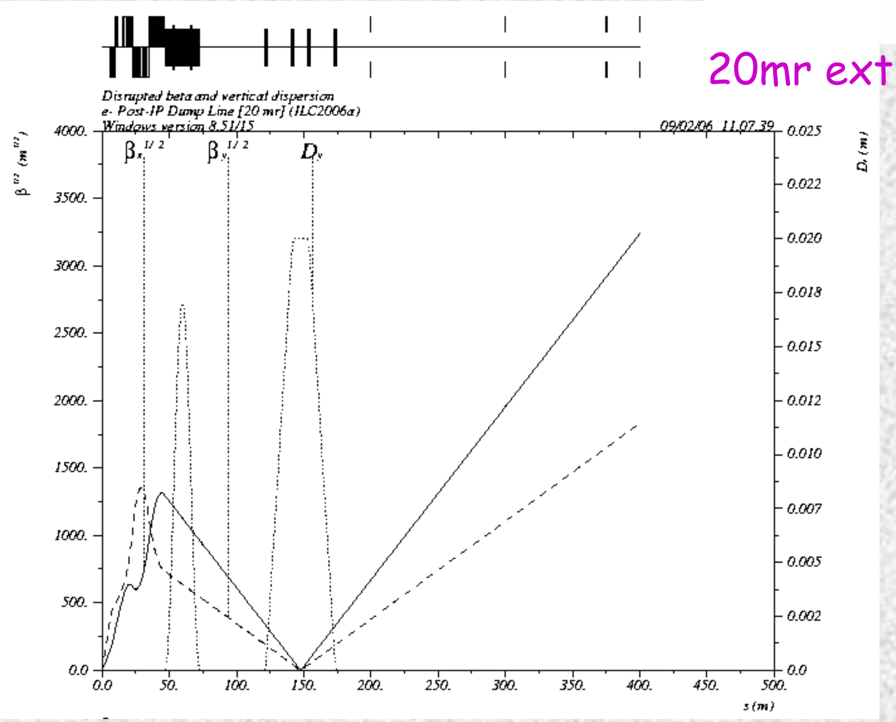
0.76 MW synch radiation loss → protection collimators with tens of kW on them and up to 1 TGy/yr peak dose

Residual dose on the magnets is about 10 times above the limits in the 25 to 70-m region from IP (for 120nm)

Beam Dump for 18MW Beam



- Water vortex
- Window, 1mm thin, ~30cm diameter hemisphere
- Raster beam with dipole coils to avoid water boiling
- Deal with H, O, catalytic recombination etc.



20mr extraction optics

Undisrupted or disrupted beam size does not destroy beam dump window without rastering. Rastering to avoid boiling of water

Collider Hall Shielding

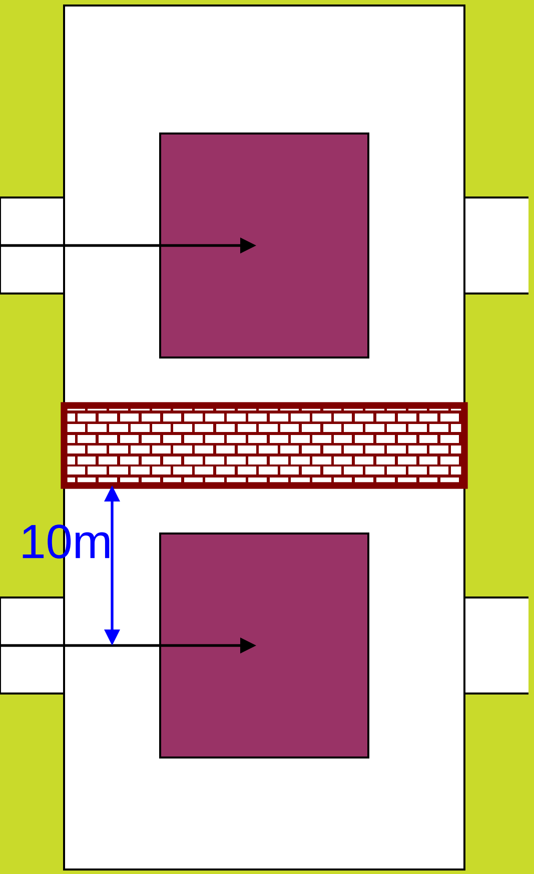
Shielding is designed to give adequate protection both in normal operation, when beam losses are low, and for "maximum credible beam accident" when full beam is lost in undesired location (but switched off quickly, so only one or several trains can be lost).

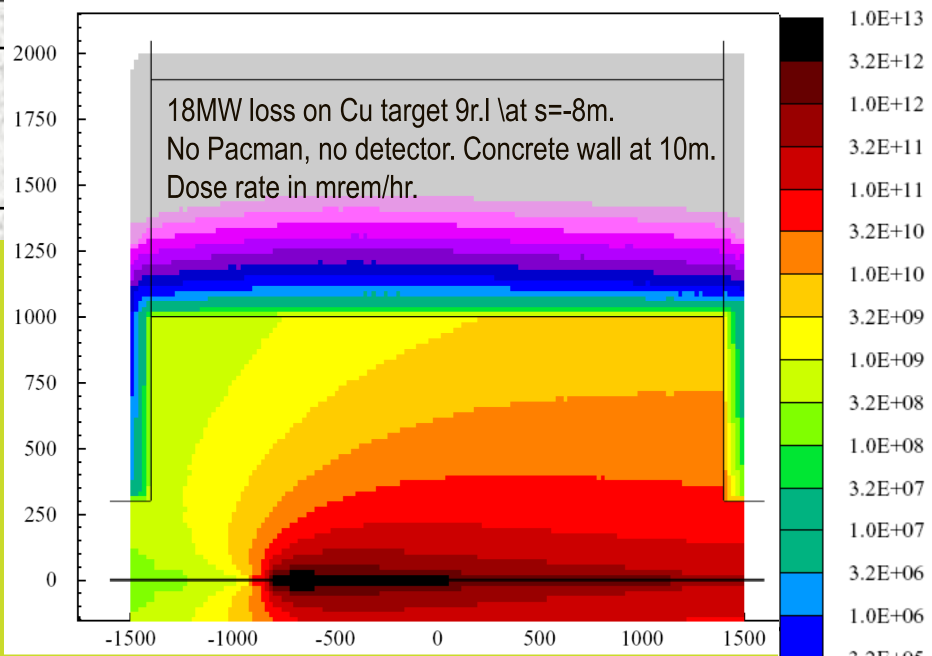
Limits are different for normal and accident cases, e.g. what is discussed as guidance for IR shielding design:

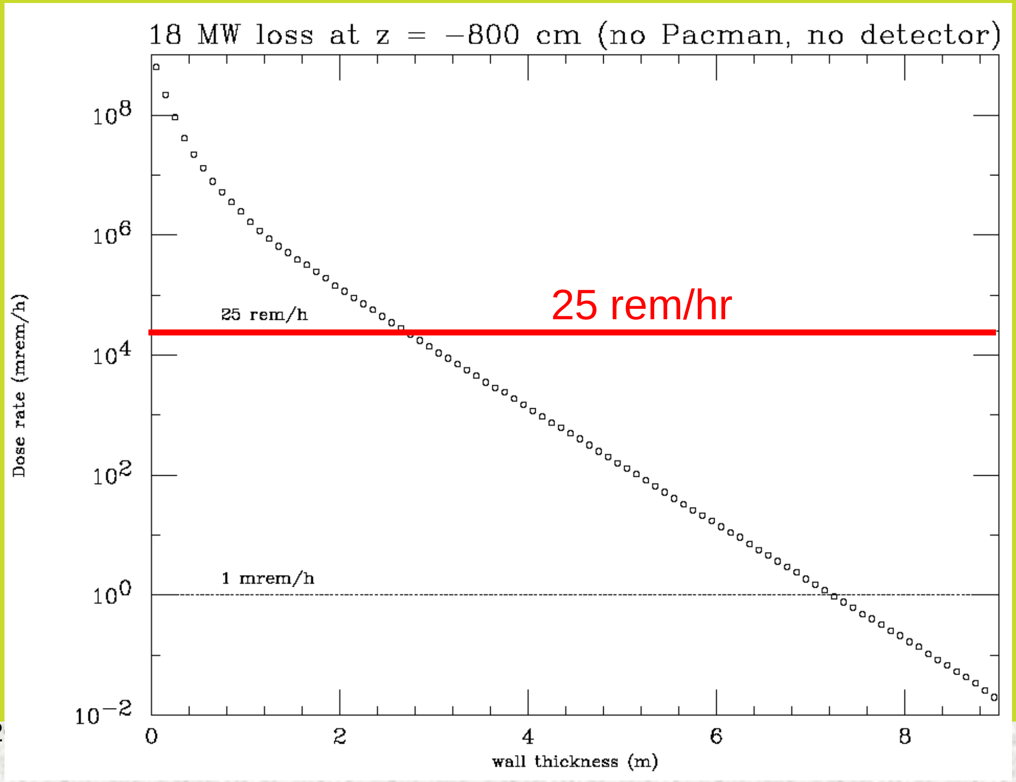
- Normal operation: dose less than 0.05 mrem/hr (integrated less than 0.1 rem in a year with 2000 hr/year)
  - For radiation workers, typically ten times more is allowed
- Accidents: dose less than 25 Rem/hr (SLAC number here) and integrated less than 0.1 Rem for 36MW of maximum credible incident (MCI).

Radiation at IR Beam Accident

For 36MW MCI, the concrete wall at 10m from beamline should be ~3.1m



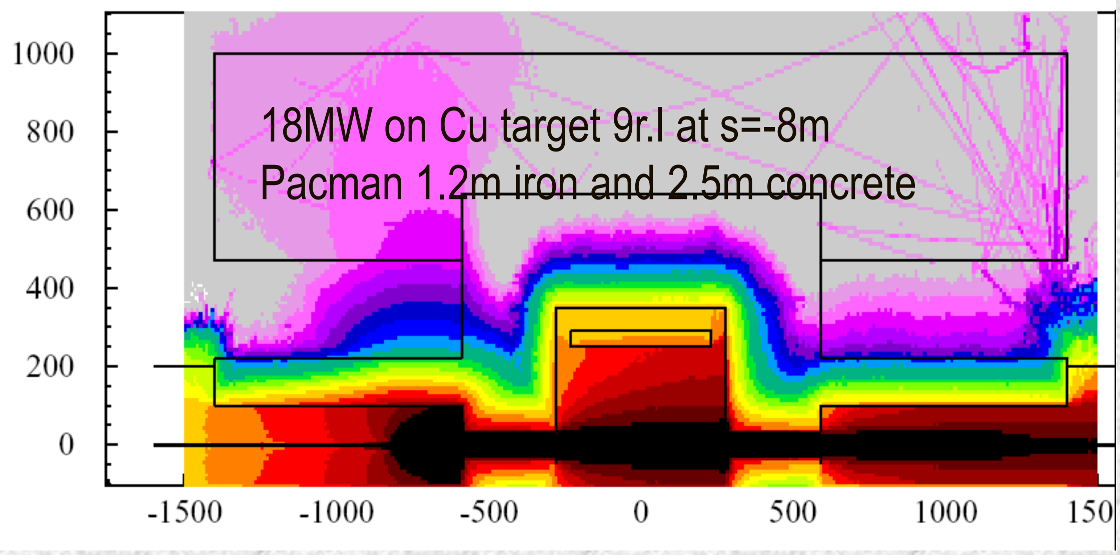

18MW loss on Cu target 9r.l \at s=-8m.
No Pacman, no detector. Concrete wall at 10m.
Dose rate in mrem/hr.

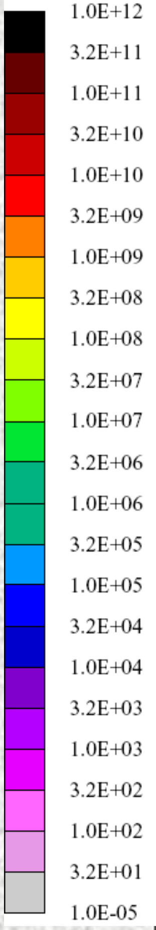

18 MW loss at z = −800 cm (no Pacman, no detector)

Self-Shielding Detector

Detector itself is well shielded except for incoming beamlines.

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

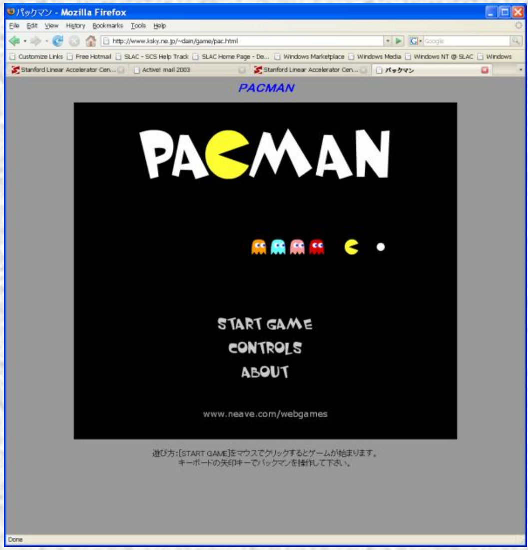




18MW lost at s=-8m.
Pacman has Fe: 1.2m, Concrete: 2.5m

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

dose at r=7m
0.23rem/hr



遊び方:[START GAME]をマウスでクリックするとゲームが始まります。
キーボードの矢印キーでパックマンを操作して下さい。