

Beam-Related Backgrounds and Machine Parameters

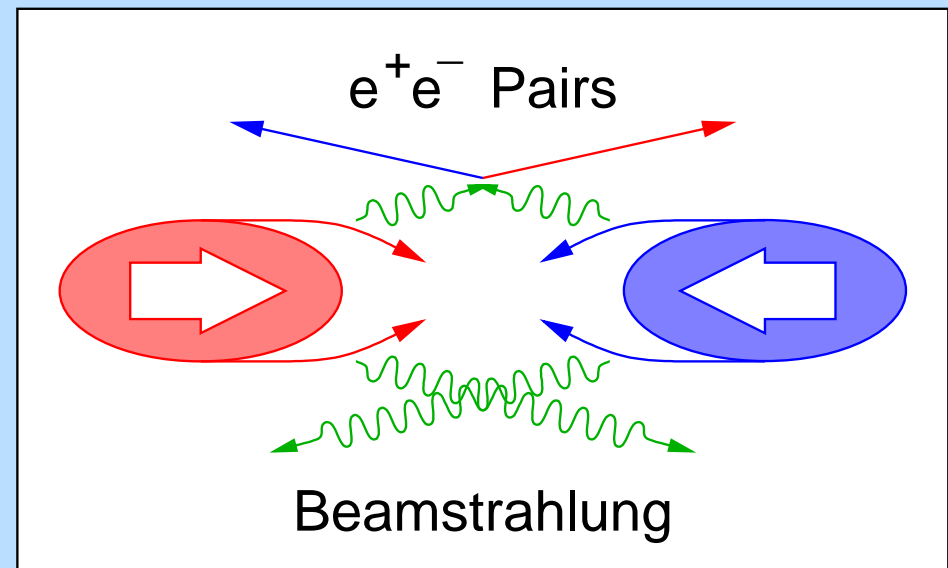
How MDI Issues May Affect Your Measurements

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Beam-Beam Interaction

The ILC has the novel problem of beamstrahlung

- high luminosity is essential for measurements
- tiny bunch size is required ($\sigma_x \approx 500$ nm, $\sigma_y \approx 5$ nm)
- bunches have a very high electric space charge
- particles are deflected and can emit photons (“beamstrahlung”)
- 10^8 TeV / BX are lost



Electron-Positron Pairs

Beamstrahlung photons can scatter to e^+e^- pairs

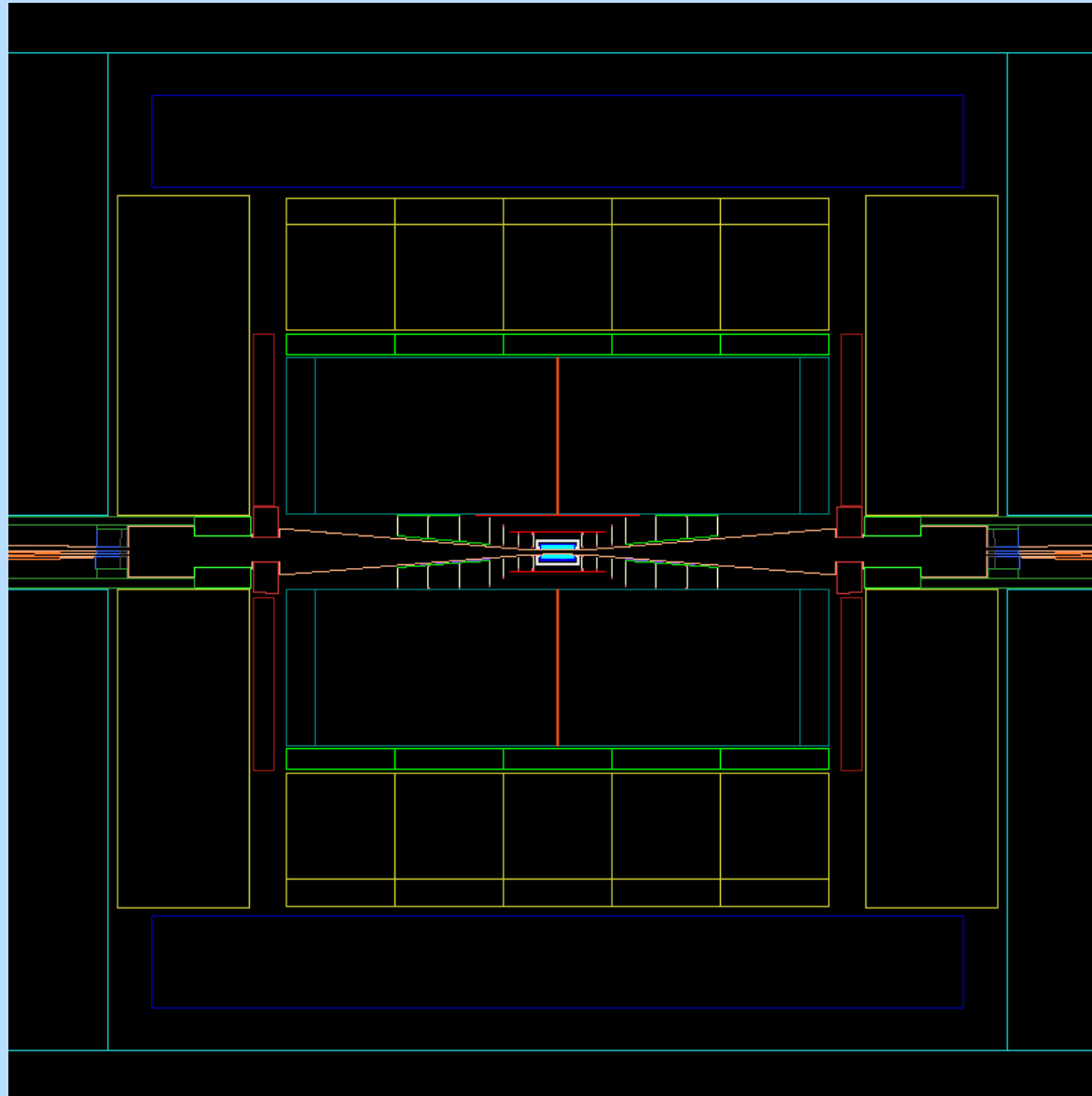
- 10^5 particles per BX for ILC beam parameters
- energies in the GeV range (100 TeV / BX in total)
- strongly focused in the forward direction (small θ)
- but sometimes also large polar angles (large θ)

Several processes can contribute

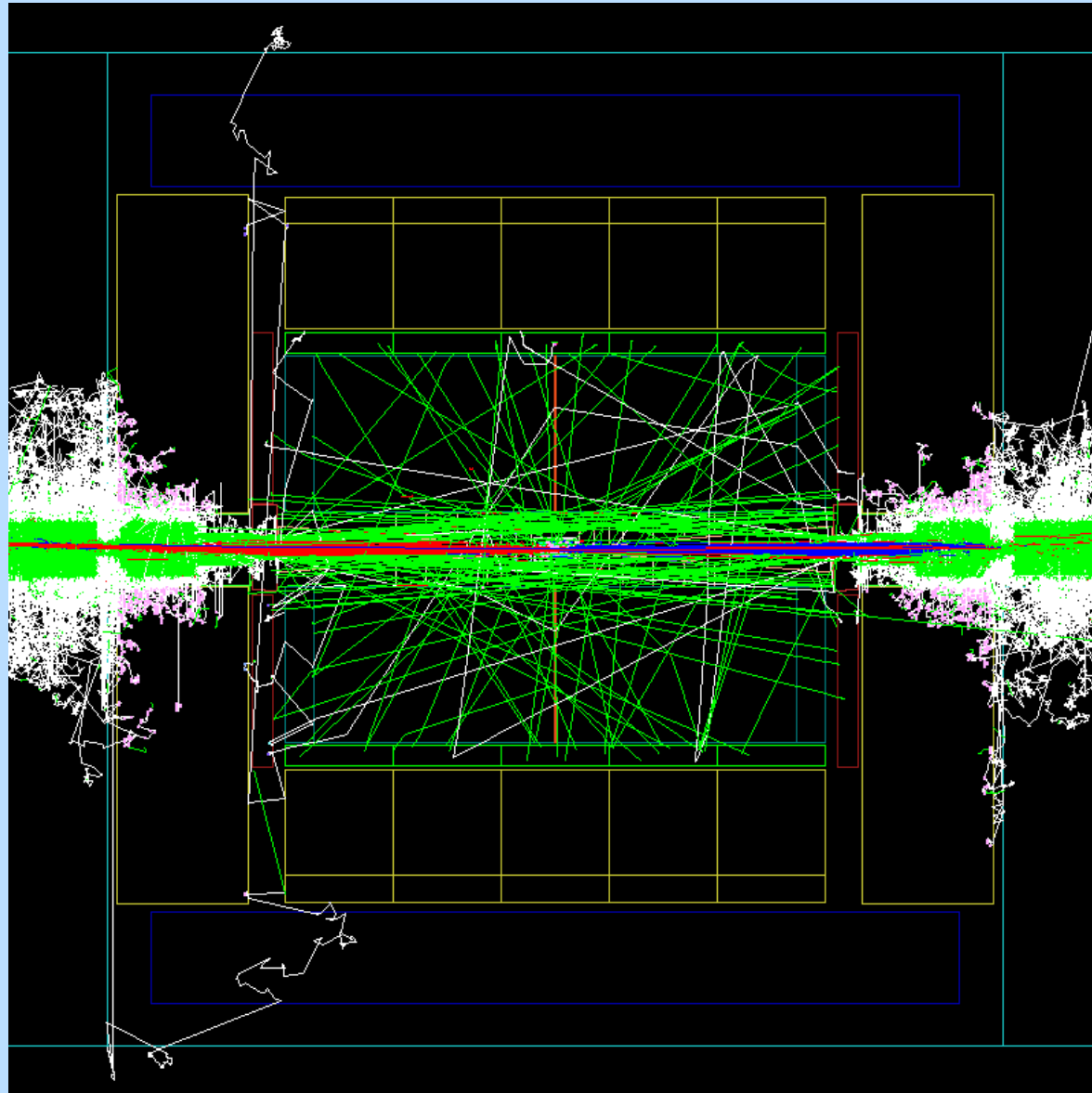
- incoherent and coherent pair creation
- real-real, real-virtual, virtual-virtual scattering

Pairs are a major source of detector backgrounds!

The Whole Detector – Before ...



The Whole Detector – After 1/10 BX



Pairs in the Detector

Vertex detector

- direct hits from the IP (suppressed by the field)
- backscattering particles from the forward region

Main gaseous tracker

- conversion of backscattering photons
- tracks from the IP (rare, but mostly curlers)
- recoil tracks from neutron-proton collisions (CH_4)

Calorimeters

- randomly distributed low-energy hits
- possible neutron radiation damage of SiPMs

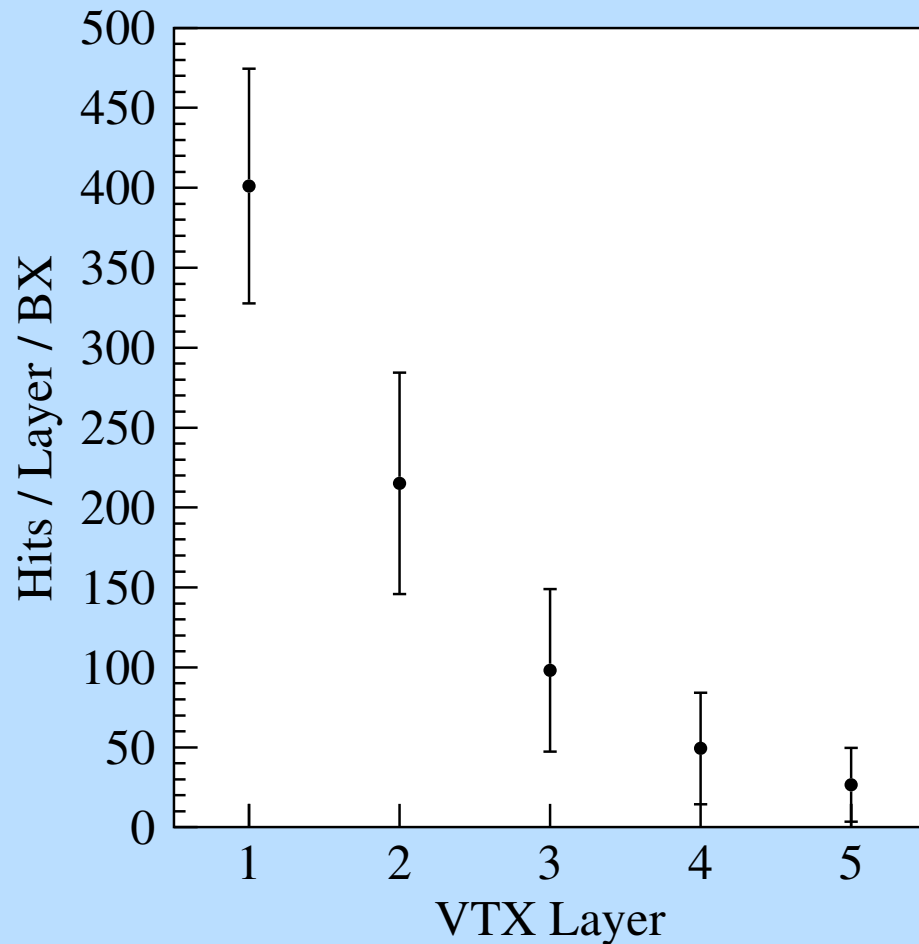
Other Kinds of Backgrounds

Other sources of backgrounds

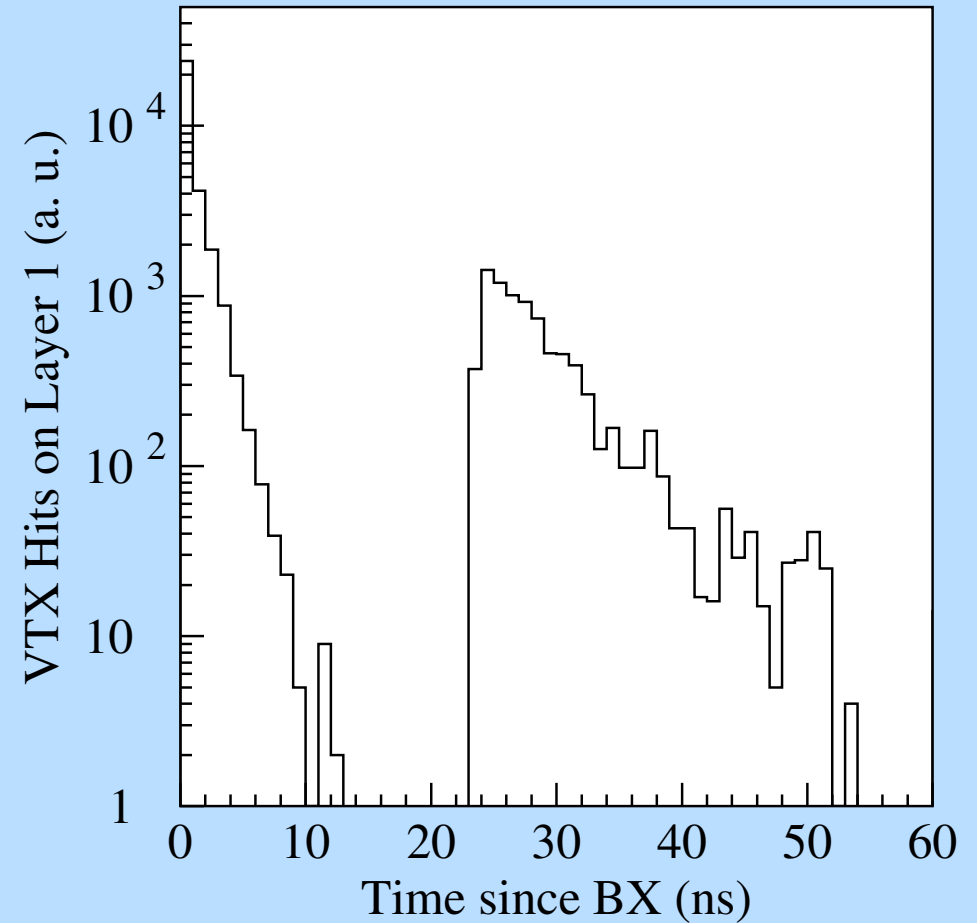
- beam halo muons → magnetised spoilers
- beam-gas interaction → vacuum requirements
- synchrotron radiation from beam delivery → exit
- particle losses in the extraction line → careful!
- beam dumps → avoid direct line of sight

Those can be controlled by proper design,
but pairs are unavoidable: dominant source!

Vertex Detector – Hits



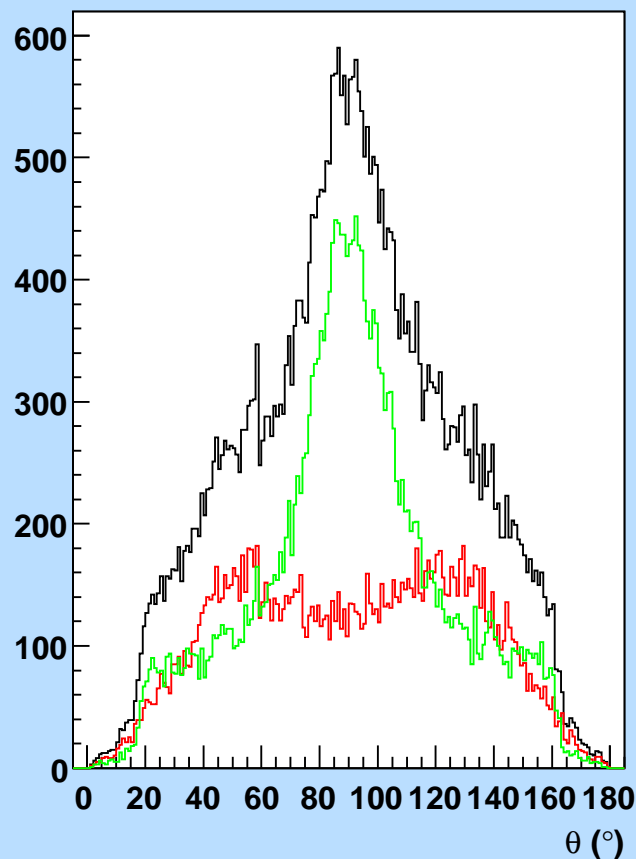
Innermost layer gets the most hits ($0.04 / \text{mm}^2 / \text{BX}$)



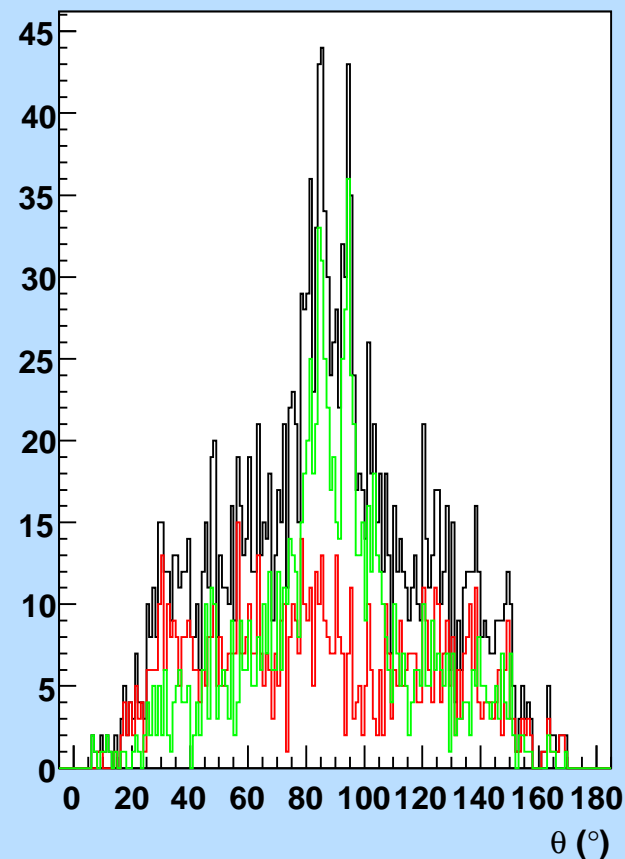
Clear separation of direct hits and backscatterers

Vertex Detector – Angle of Incidence

1



5



Take angle of incidence into account to calculate a realistic pixel occupancy (Rita De Masi, IReS)

Vertex Detector – Occupancy (R. De Masi)

Characteristics for vertex detector options

- pixel size: $25 \mu\text{m}$ (std.), $20\text{--}33 \mu\text{m}$ (CMOS)
- integration time: $50\text{--}200 \mu\text{s}$ (std.), $25\text{--}100 \mu\text{s}$ (CMOS)
- number of hit pixels: 3 (std.), 5 (CMOS), θ -dependent

Resulting occupancies in the vertex layers

- innermost (15 mm): 0.11 (std.), 0.02 (CMOS)
- outermost (60 mm): 0.002 (std.), 0.0008 (CMOS)

Those are only average numbers

- local occupancy can be much higher
- values can be reduced by an anti-DID field

Vertex Detector – Results

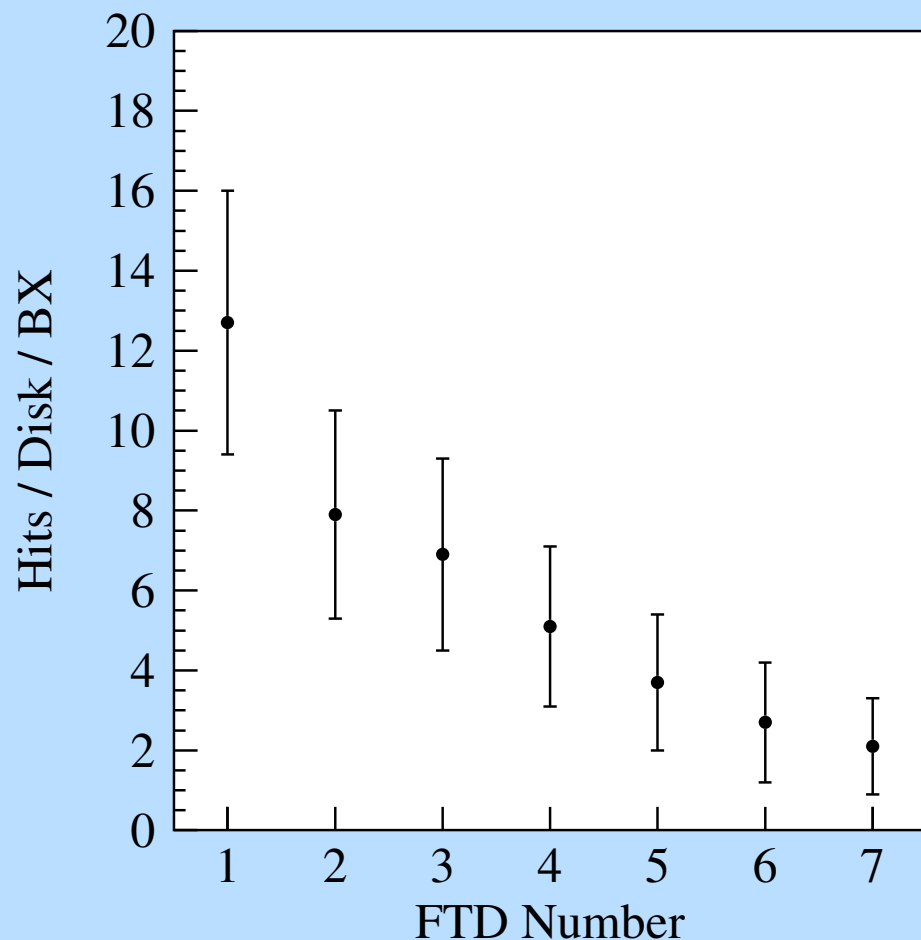
Hits on the vertex detector

- innermost layer has 400–800 hits / BX
- most hits direct, but also from backscatterers
- background levels drive the VTX design
- resulting backgrounds are still manageable

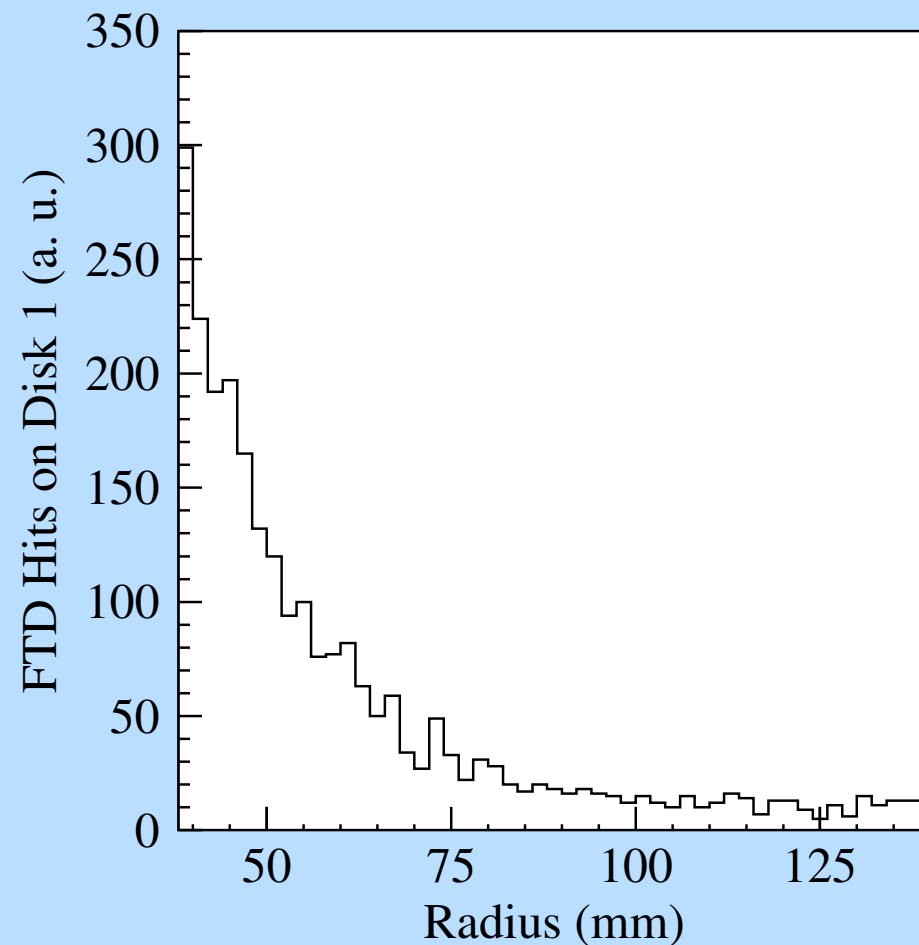
Neutron fluence in the vertex detector

- extrapolation from 100 BX to 500 fb⁻¹ total run time
- energy-dependent weighting of neutrons (NIEL model)
- fluence (10^8 n / cm²) is uncritical for all layers

Forward Tracking Discs – Hits

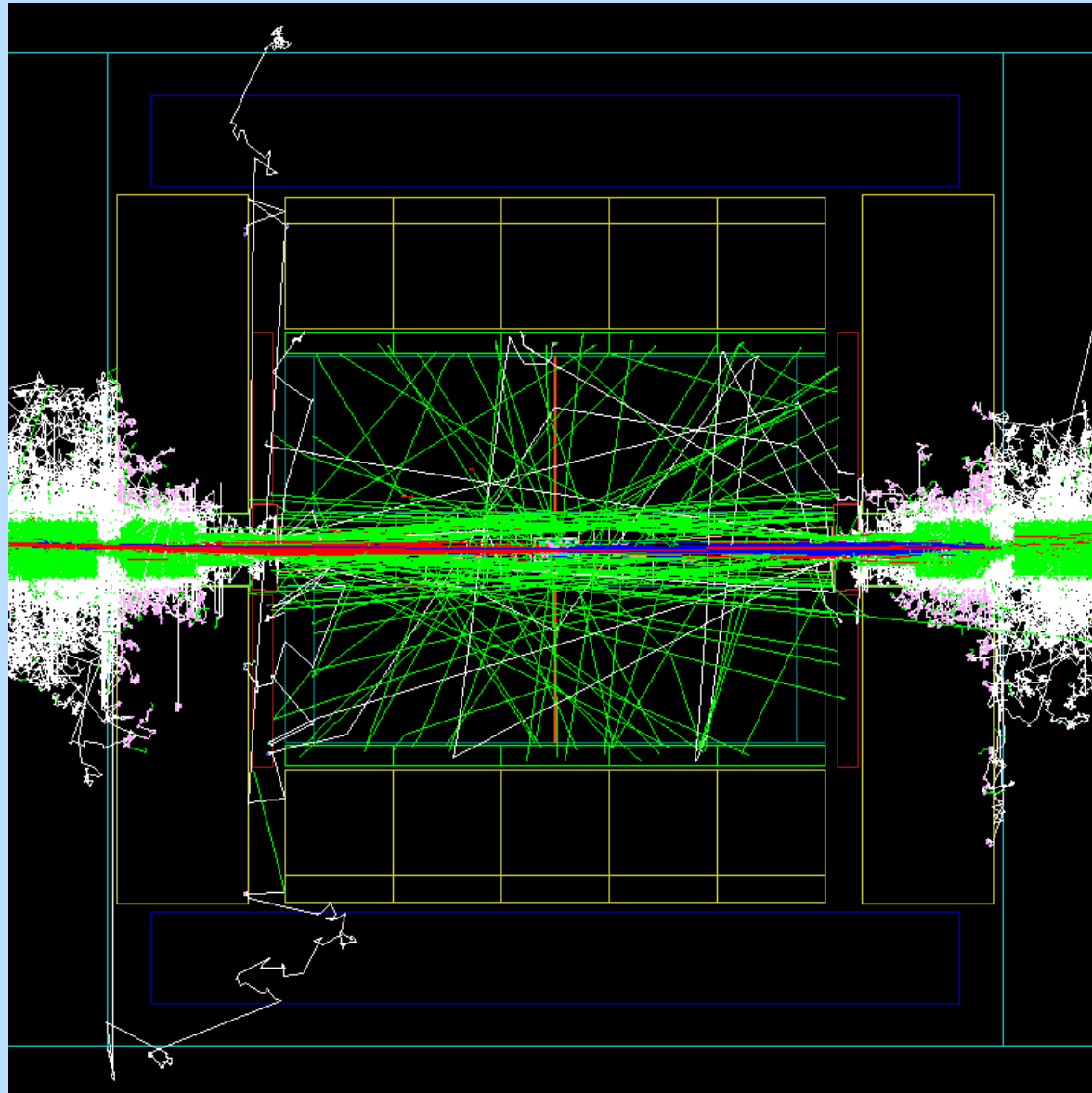


Outer discs have larger
inner (and outer) radii



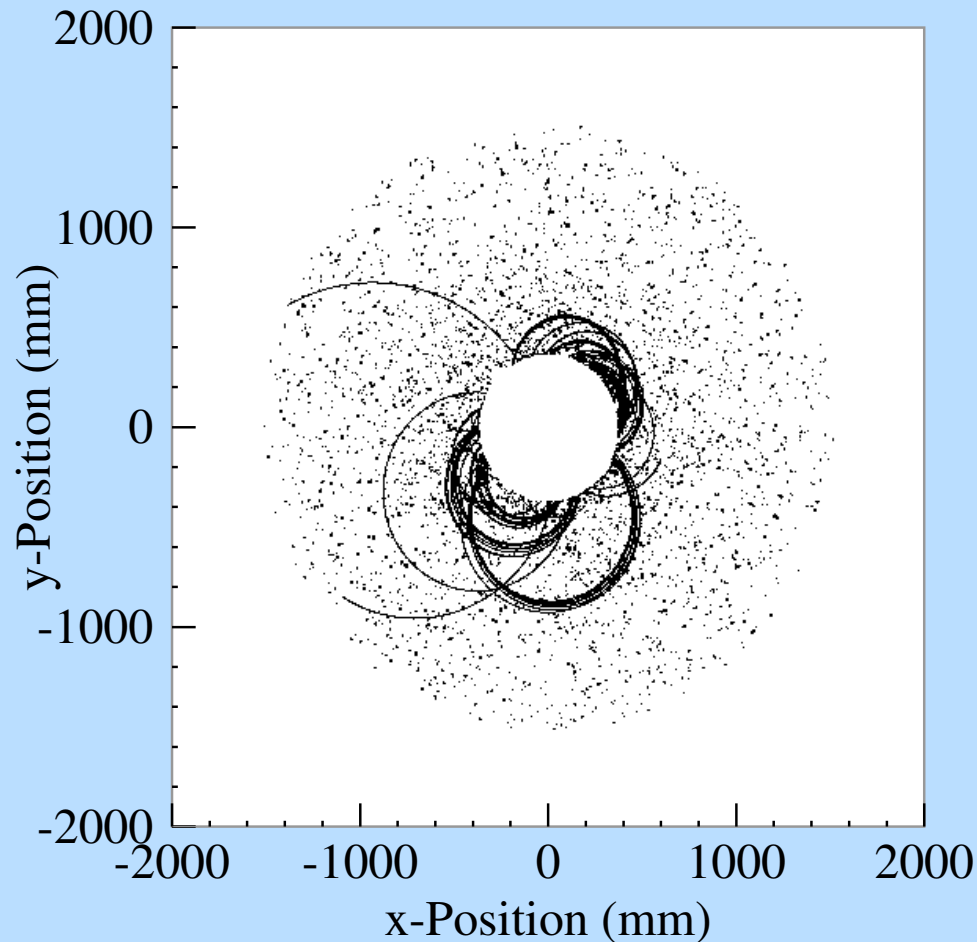
Tracking for small θ
will be difficult!

TPC – Backgrounds

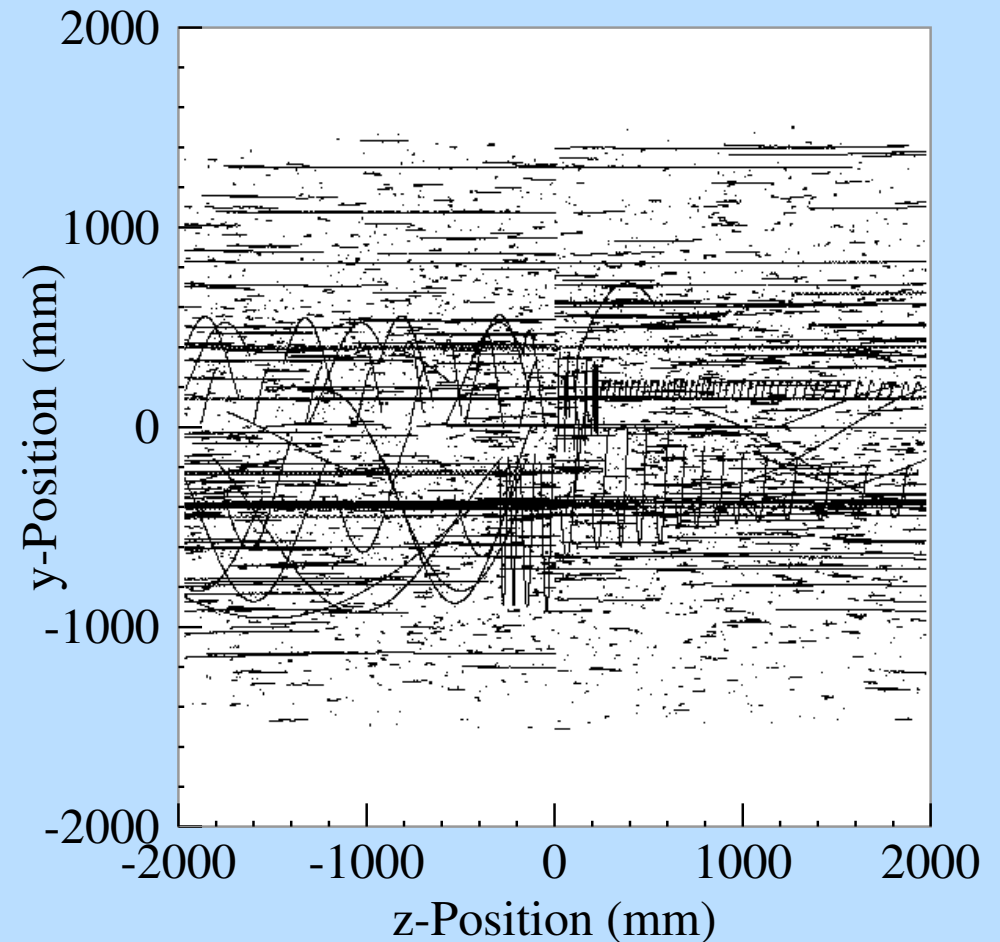


TPC – Spatial Distribution of Hits

Mokka hits in the TPC (overlay of 100 BX)



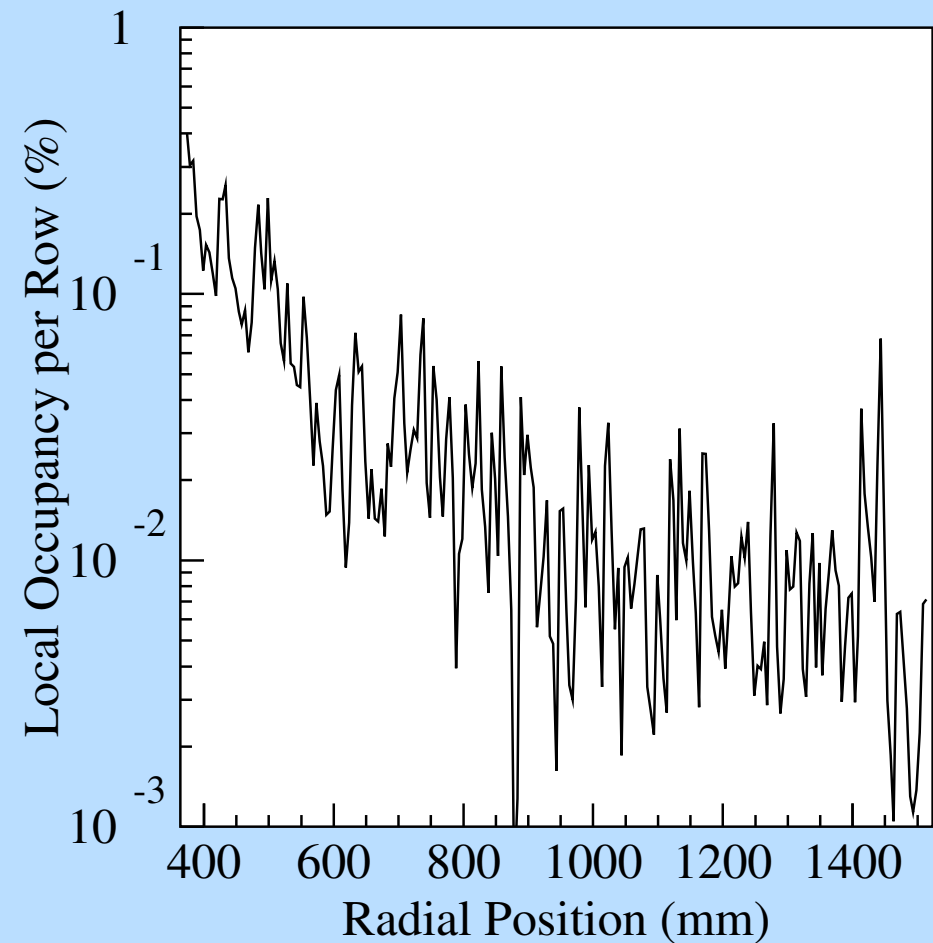
Front view



Side view

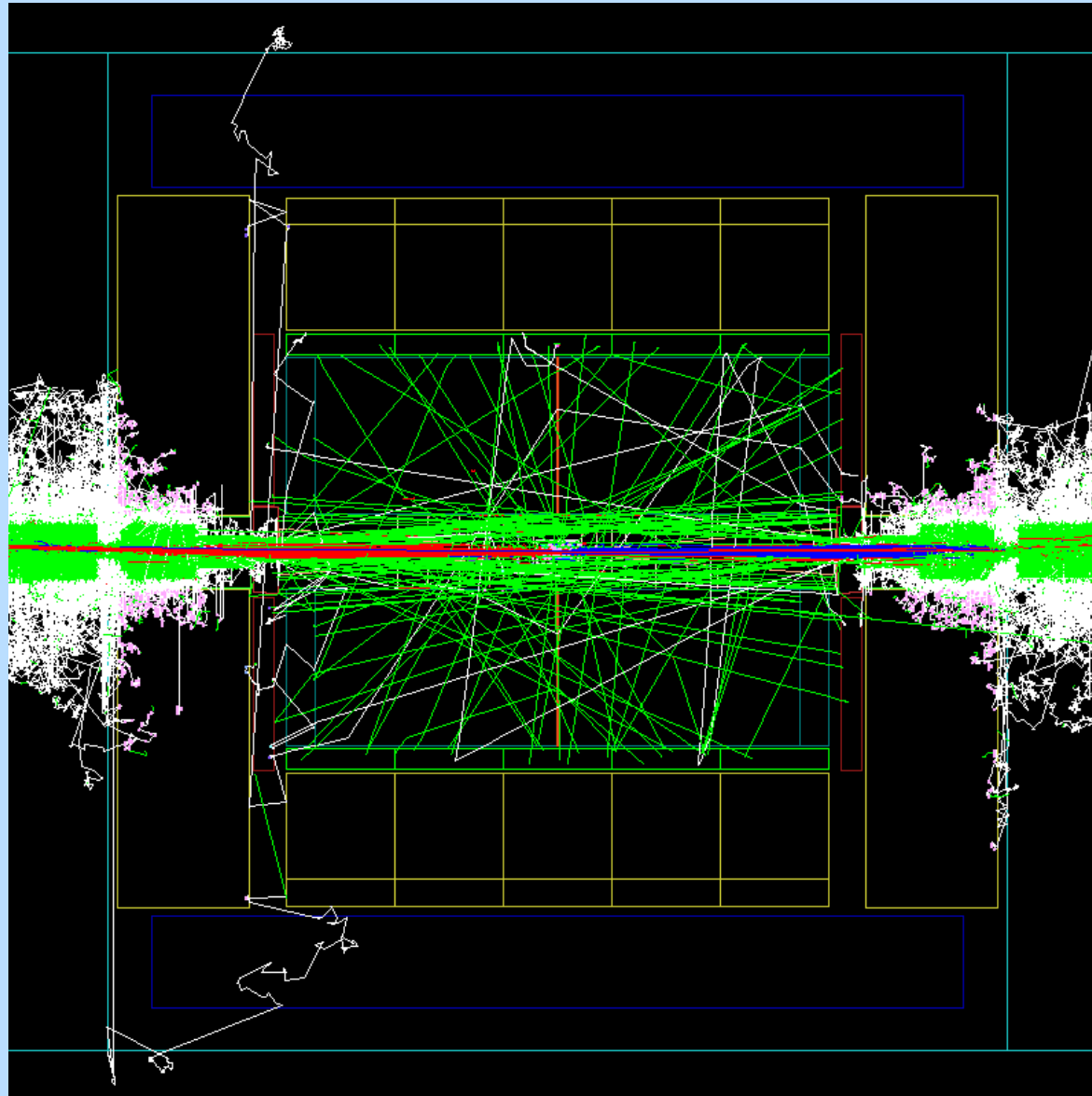
TPC – Occupancy

- highest occupancies at small radii
- overall value stays very well below 1 %
- outside-in tracking always possible
- n-p scattering gives negligible contribution
- backgrounds will be no problem for the TPC



Overlay of 100 BX

HCAL Endcap – Backgrounds



HCAL Endcap – Radiation Damage

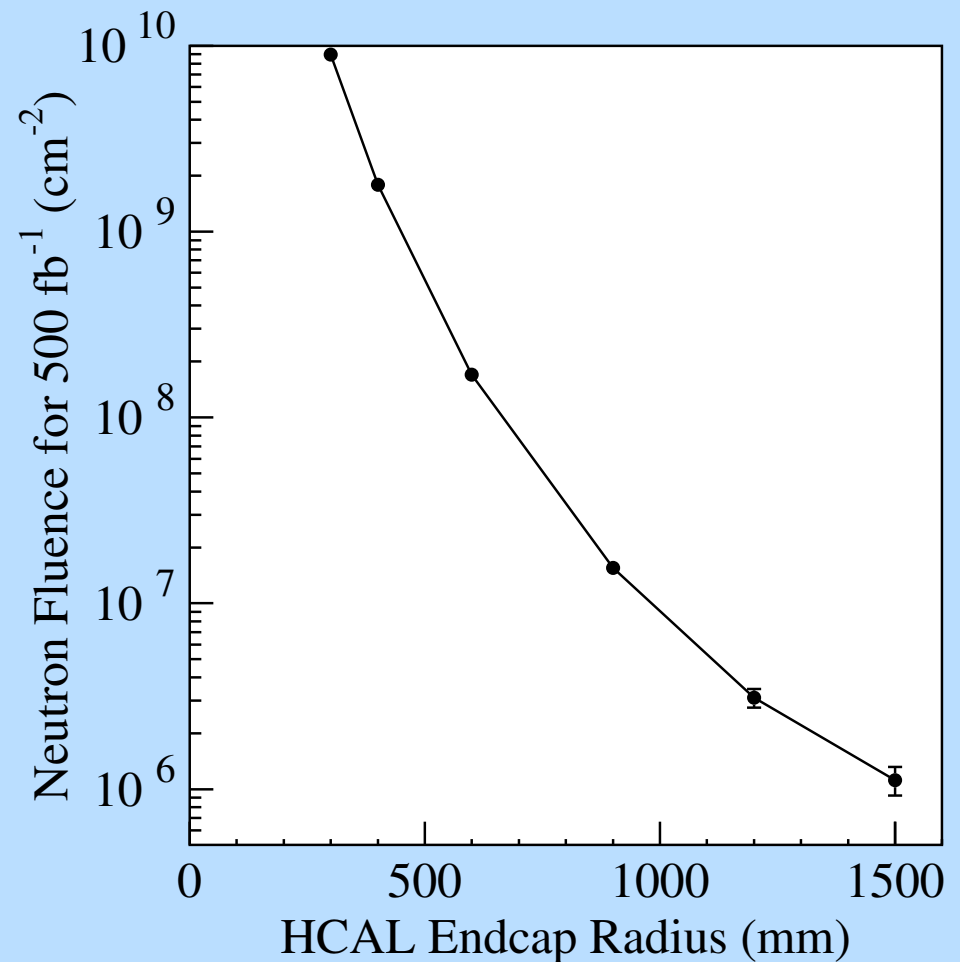
Simulation results (500 fb^{-1})

- neutrons are critical only at small radii
- photons are harmless

Possible solutions

- include neutron absorber
- replace innermost SiPMs after some years
- accept increased noise

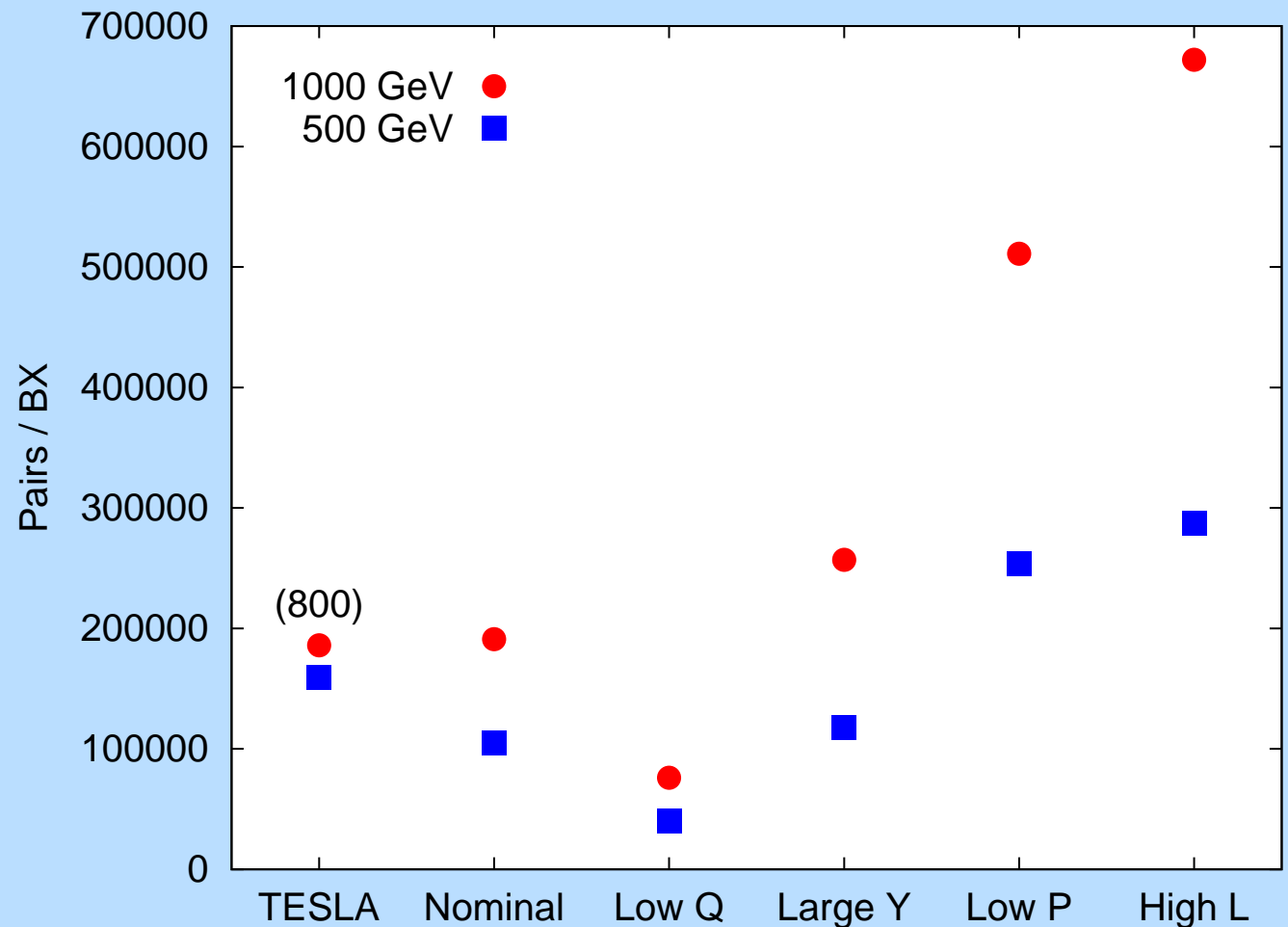
Tungsten tube is important!



ILC Beam Parameters – Numbers

$$\mathcal{L} = \frac{n_b N^2 f_{\text{rep}}}{4\pi\sigma_x\sigma_y} H_D$$

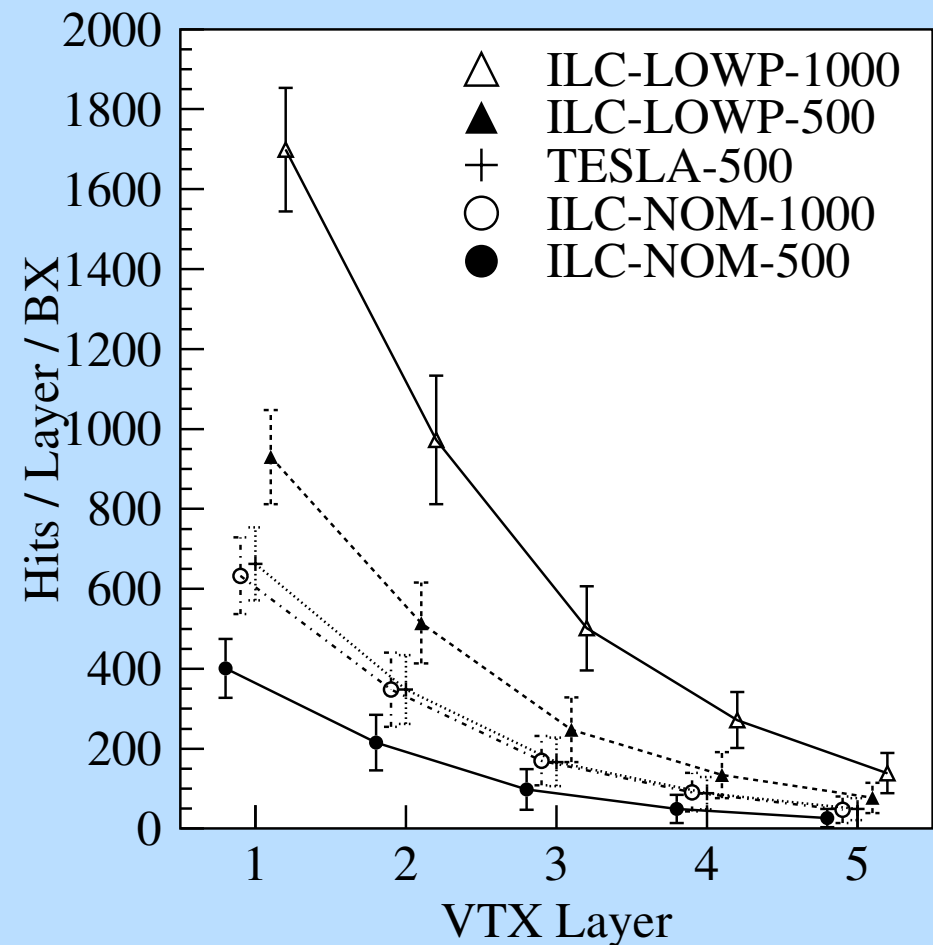
$$\delta \propto \left(\frac{N}{\sigma_x + \sigma_y} \right)^2$$



S. Gronenborn (EUROTeV-Memo-2005-003-1)

ILC Beam Parameters – Backgrounds

- “Low Power” option:
2.5 times more hits
- But: half the number
of bunches per train
- Integrated backgrounds
(over a fixed time)
do not change much
- Upgrade to 1000 GeV:
2 times more hits



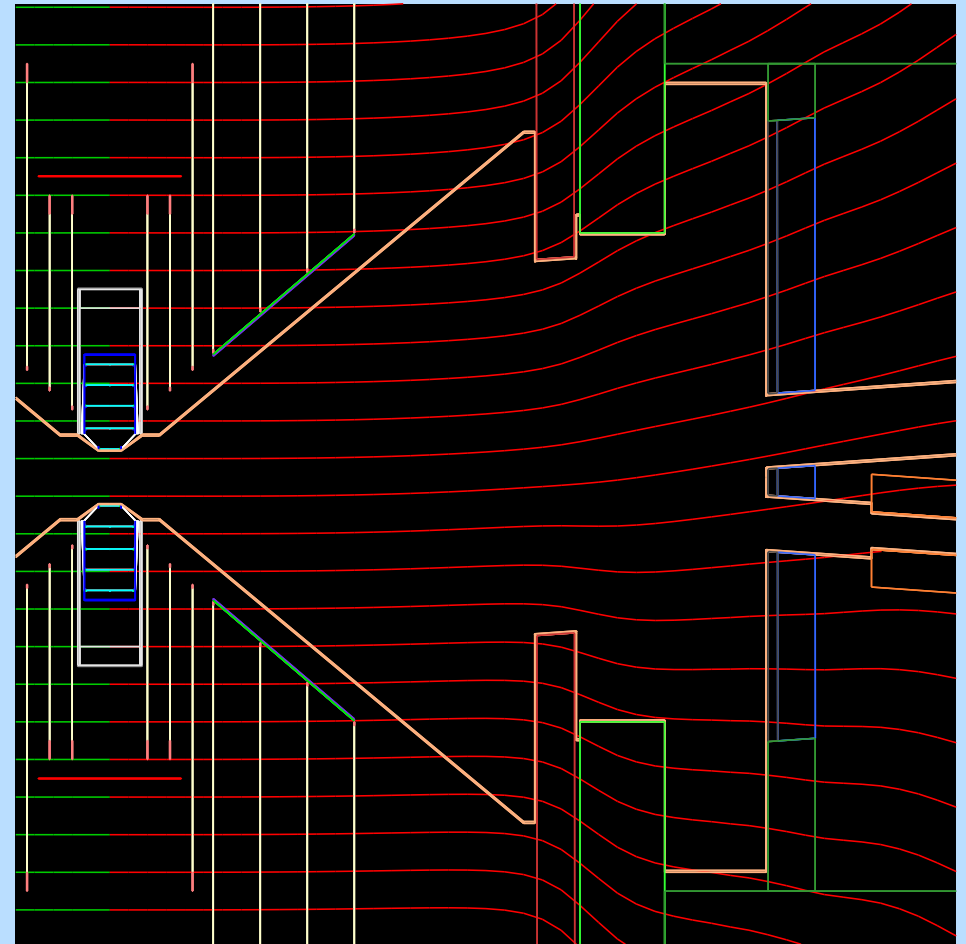
Magnetic Field Configuration

Solenoid field (4 Tesla)

- bends high- E tracks
- confines low- E tracks to innermost regions

Anti-DID field (14 mrad)

- bends main field towards hole for outgoing beam
- origins: polarimetry
- reduction of backgrounds
- impact on tracking?



Compressed view 1 : 10

Anti-DID vs. no DID

Vertex detector

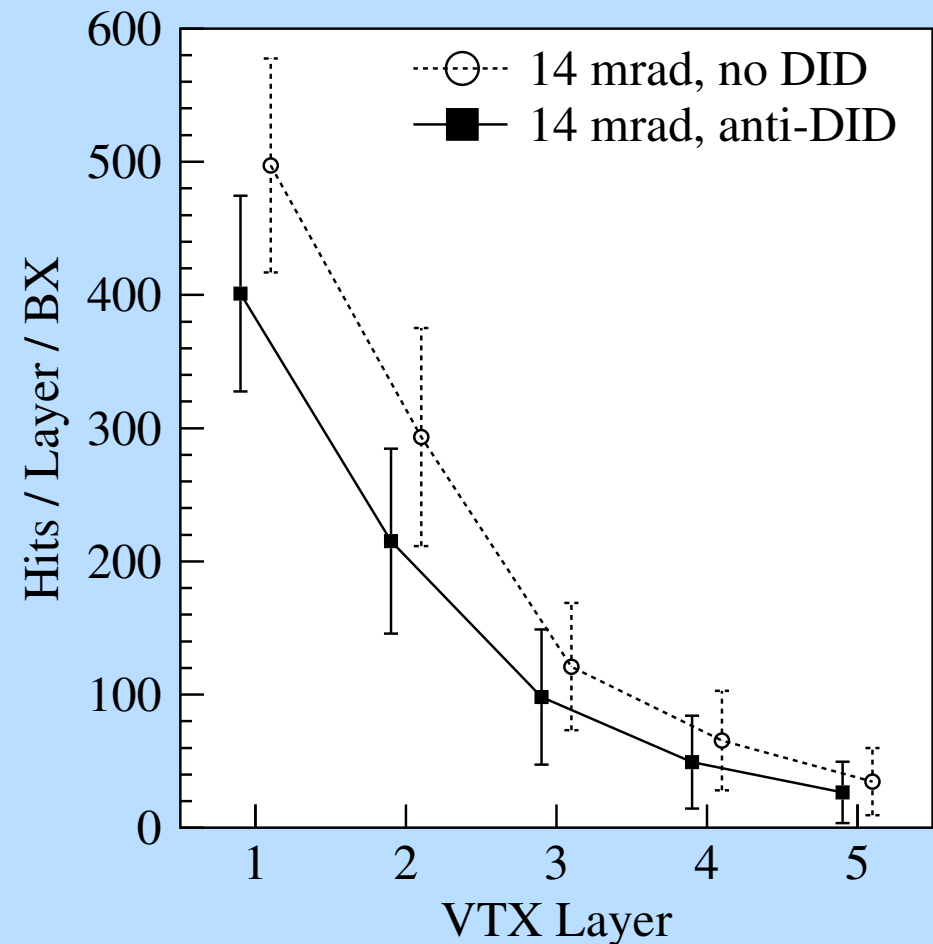
- more backscattering
- asymmetric hits in φ

Forward Tracking Discs and LumiCal

- asymmetric hits in φ

TPC

- more backscattering
- twice more hits



BeamCal Absorber

Graphite absorber (low Z)
in front of the BeamCal

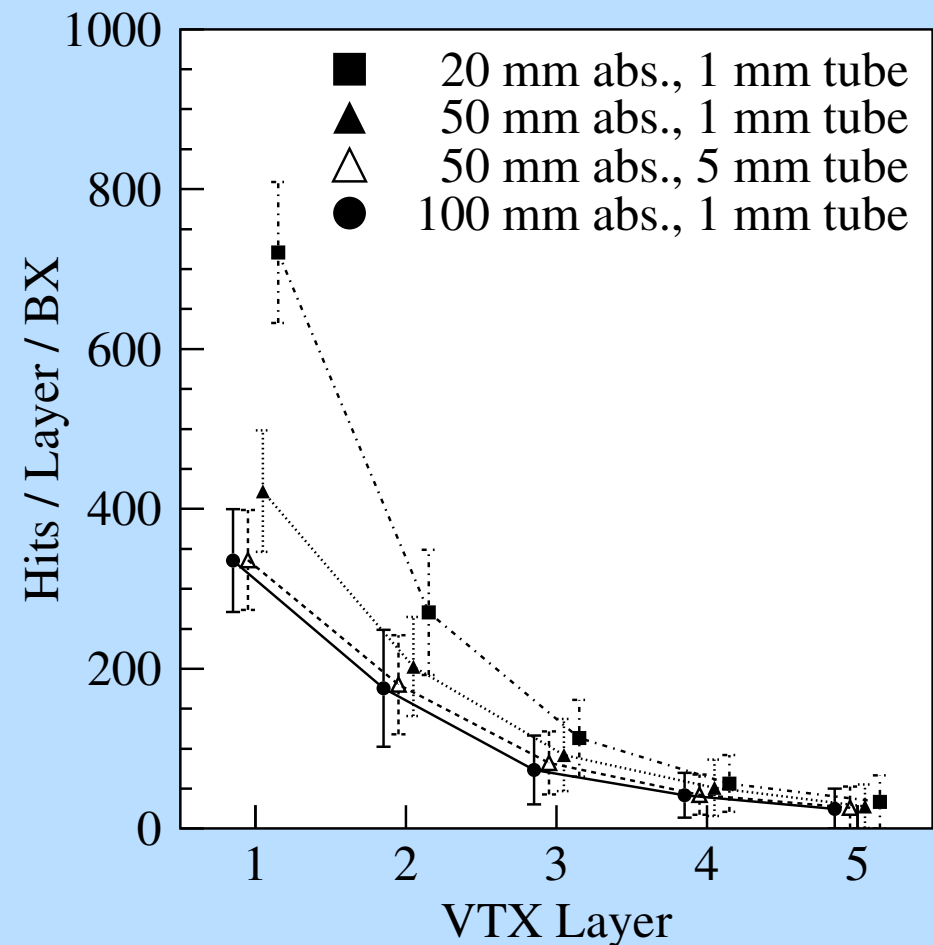
- reduces backscattering
- decreases performance

Variation of thickness

- 5 cm seems reasonable

Additional absorber inside

- will not hurt the BeamCal
- better suppression of detector backgrounds



Uncertainties

- Statistics from 100 BX generally sufficient
- Guinea-Pig is reliable on the level of 10–20 %
- Modelling of neutrons is always difficult
→ assume uncertainty factor of two
- Small geometry changes can have large effects
→ easily 2–3 times more backgrounds

- Always aim for a safety factor of five, at least!
- Don't forget other possible background sources

Summary

- e^+e^- pairs are a major source of backgrounds
- But: other possible sources must not be forgotten
- Current levels seem uncritical for all subdetectors
- Further studies are ongoing (see also Marc's talk)
- Backgrounds scale roughly with the luminosity
- Anti-DID is favourable for background suppression and luminosity determination (see Iftach at Sendai) but what about the TPC? (see Ron's talk later)
- Final impact on reconstruction and analysis?
- More MDI: discussion at 14:00 h, Uwe's talk at 17:30 h