Pair Backgrounds at the ILC Vertex Detector

Full Detector Simulations with Mokka

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DESY FLC

Background at the ILC

e^+e^- pairs are a main source of background

- created through beam-beam interaction
- crash into forward calorimeters (BeamCal) and magnets of the beam delivery / extraction line
- create neutrons, photons, and charged particles

Different kinds of impact on the detector

- direct hits from primary e^+e^-
- indirect hits from backscattered secondaries
- radiation damage from particle fluence (esp. neutrons)

Simulation Tools

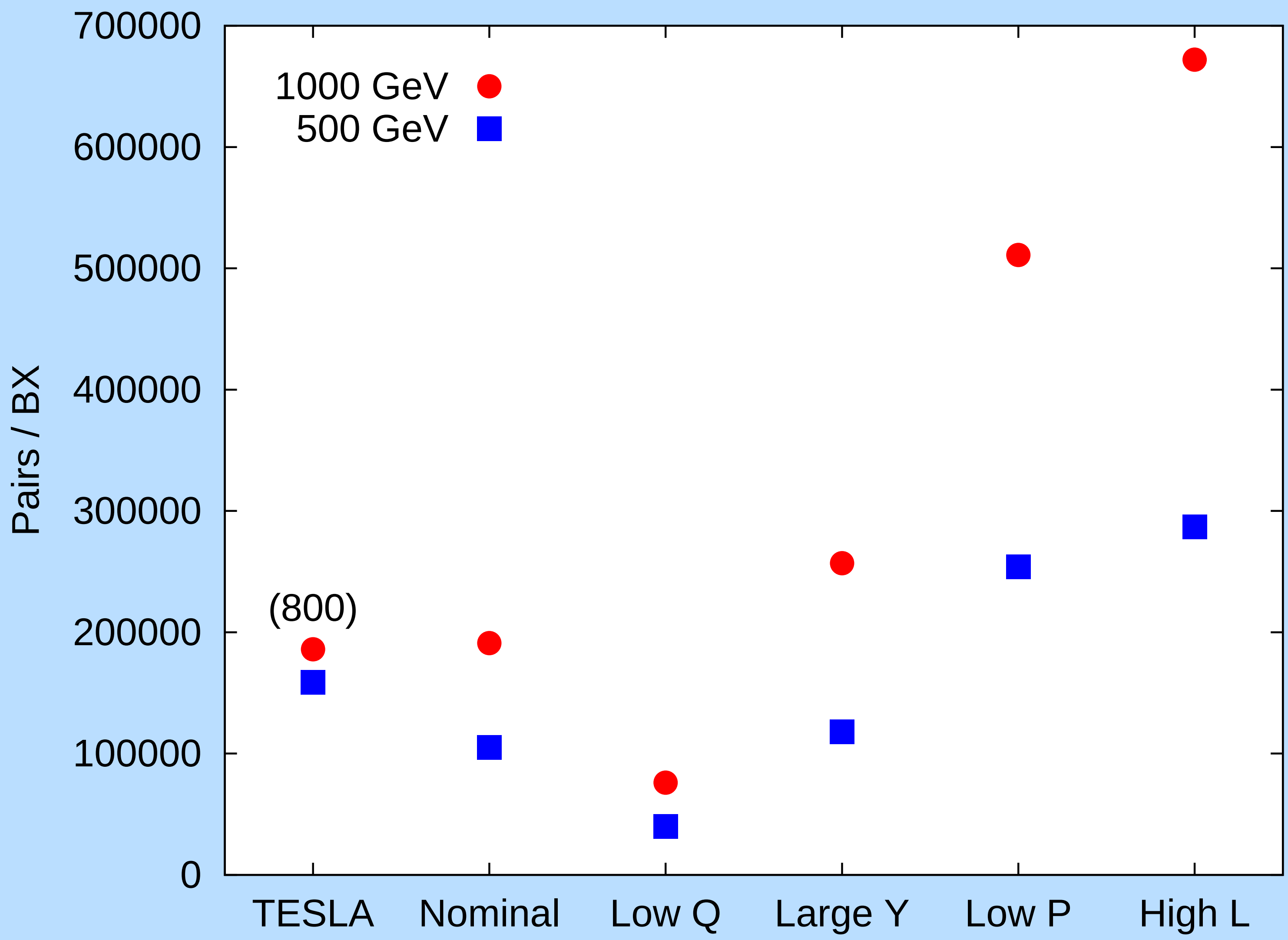
Guinea Pig (e^+e^- pairs generator)

- used with TESLA beam parameters
- gives $\approx 130\,000$ particles per BX

Mokka (full detector simulation)

- version: 06-00 with Geant 4.8.0.p01
- physics list: `QGSP_BERT_HP` (Geant 4 built-in) with high-precision neutron models
- geometry: “small” LDC design with new forward region (crossing angles: 2 mrad and 20 mrad with DID)
- simulated 100 BX for both geometries

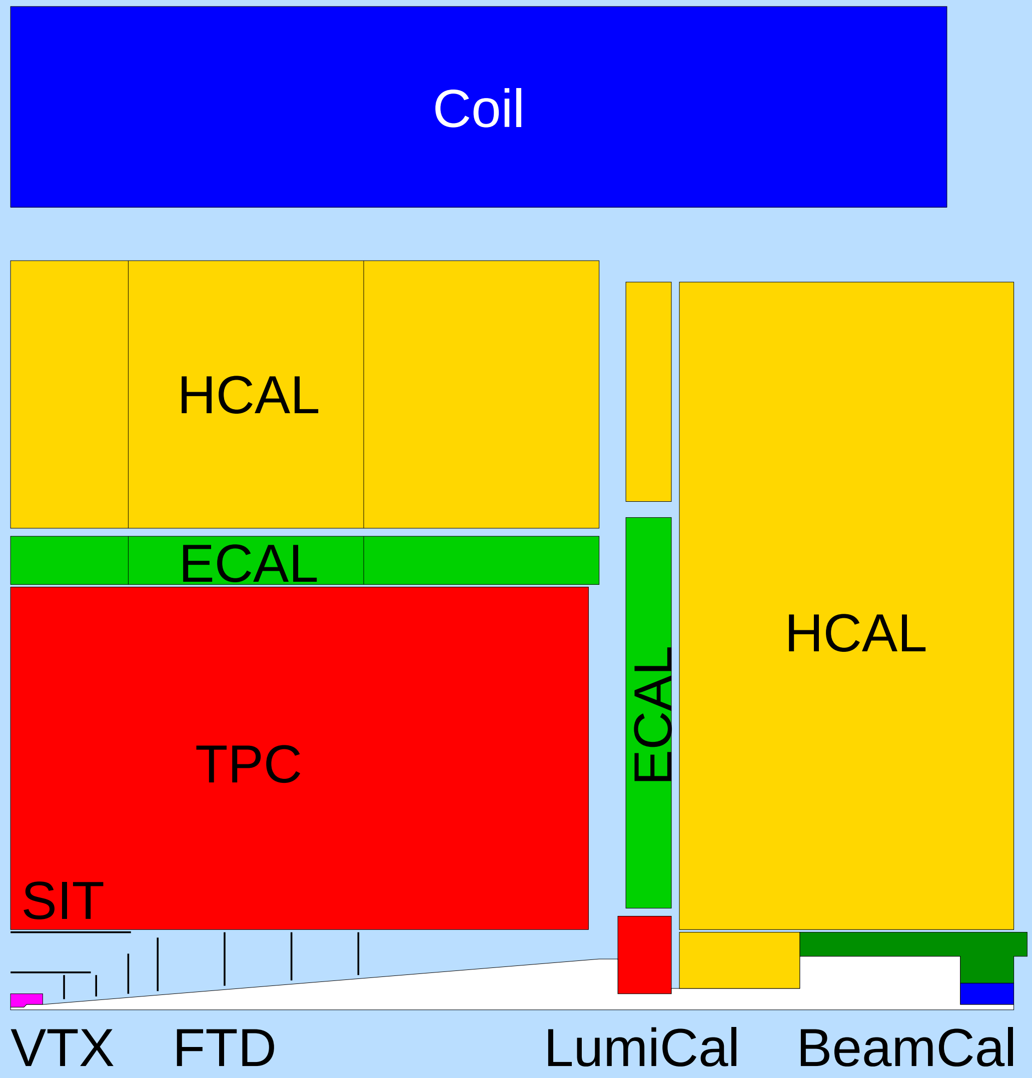
ILC Beam Parameters



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

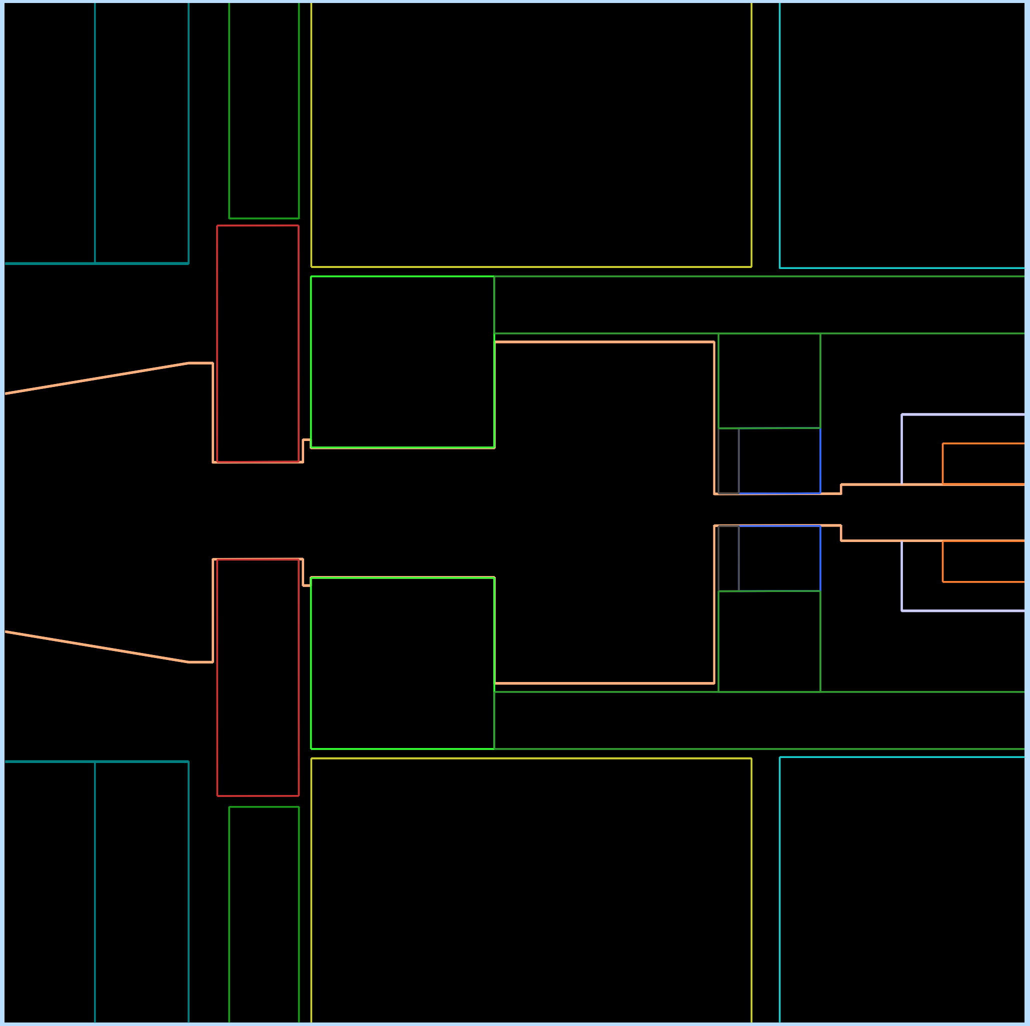
“Small” LDC Detector Design

- Coil and TPC have been shortened
- ECAL and LumiCal have been pulled towards the IP
- FF at $L^* = 4.05\,\mathrm{m}$ remains unchanged
- BeamCal stays where it was
- New layout of the forward region



LDC Forward Region – 2 mrad

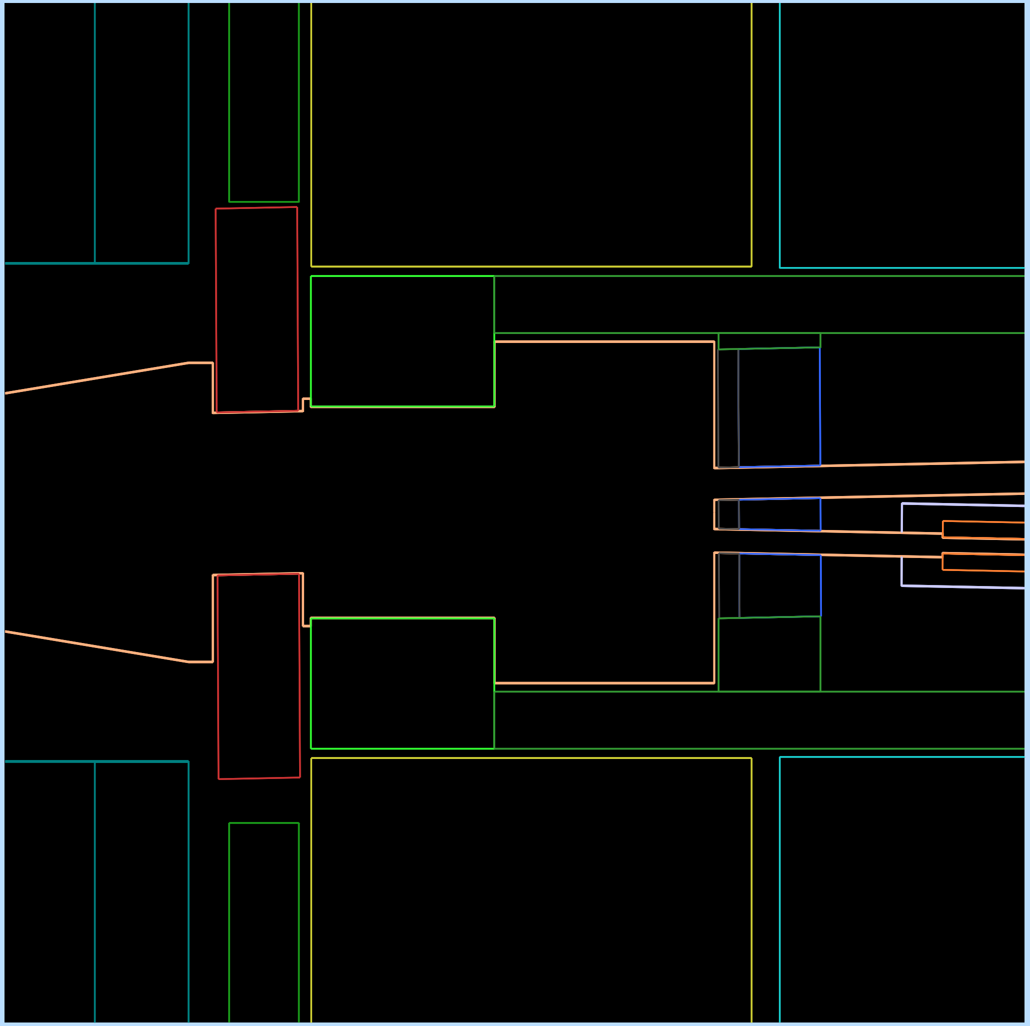
- LumiCal (red)
  $R_i = 80\,\text{mm}$
- Low-Z absorber
- BeamCal (blue)
  $R_i = 20\,\text{mm}$
- Centered on the downstream axis
- No DID field



Compressed view 1:2

LDC Forward Region – 20 mrad

- LumiCal (red)
  $R_\mathrm{i} = 120\,\mathrm{mm}$
- Low-Z absorber
- BeamCal (blue)
  $R_\mathrm{i\,1} = 15\,\mathrm{mm}$
  $R_\mathrm{i\,2} = 20\,\mathrm{mm}$
- Centered on the downstream axis
- 20 mrad DID field

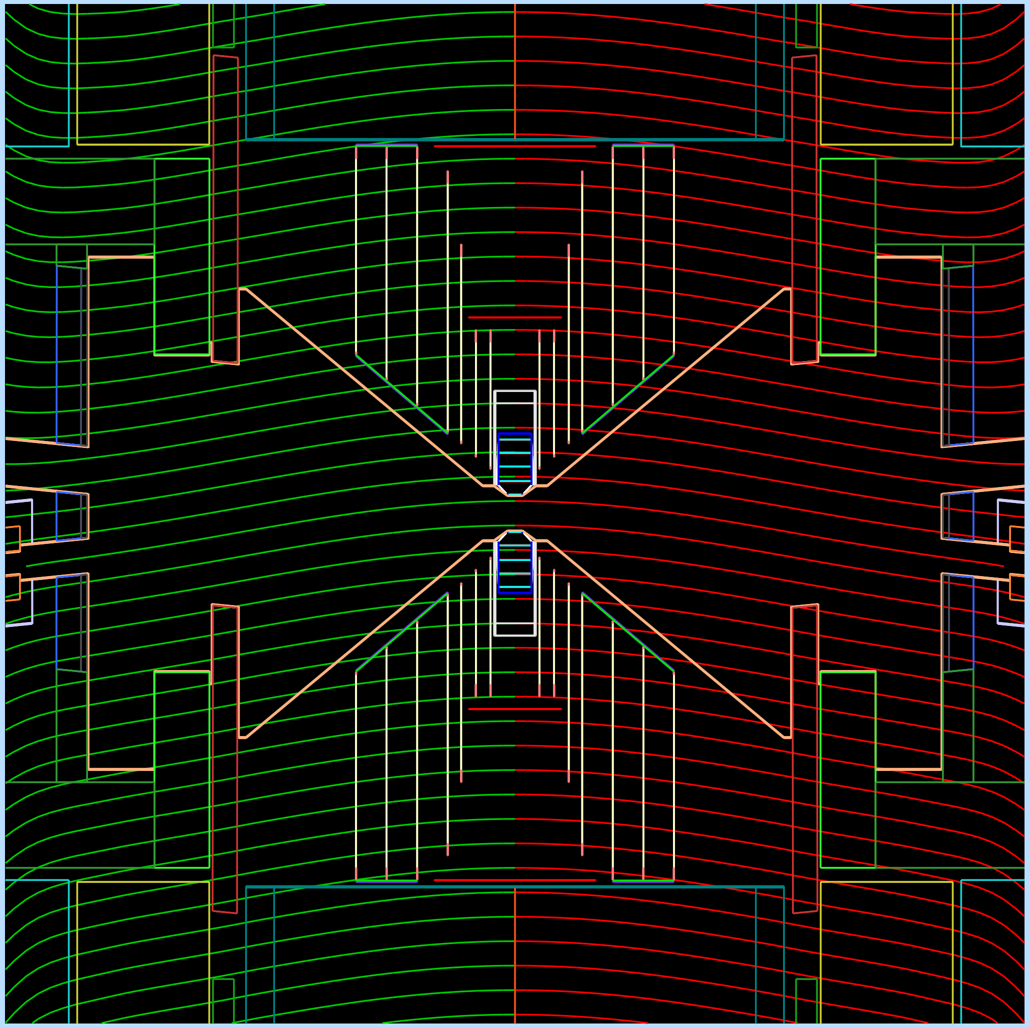


Compressed view 1:2

DID – Detector-Integrated Dipole

- Superimposed on the main solenoid field
- Introduced to prevent spin precession
- But has also a major impact on background

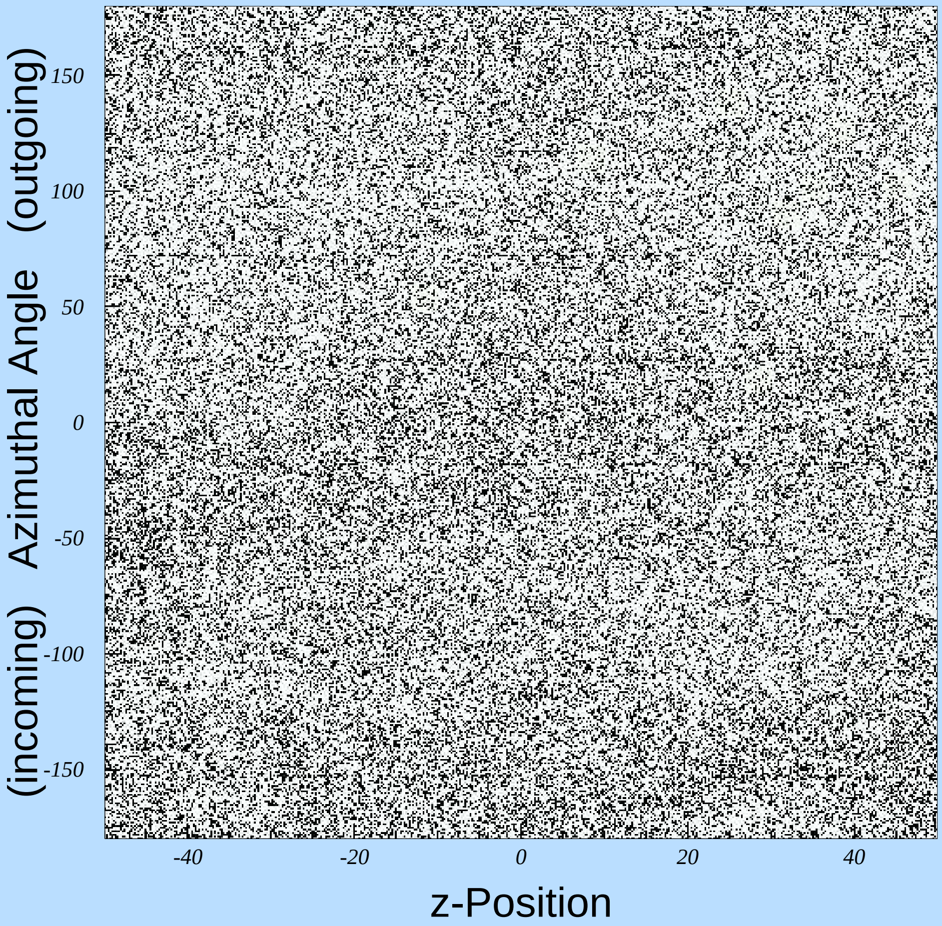
- Low-energy particles follow the field lines
- Tracks can be shifted in the *x*-direction



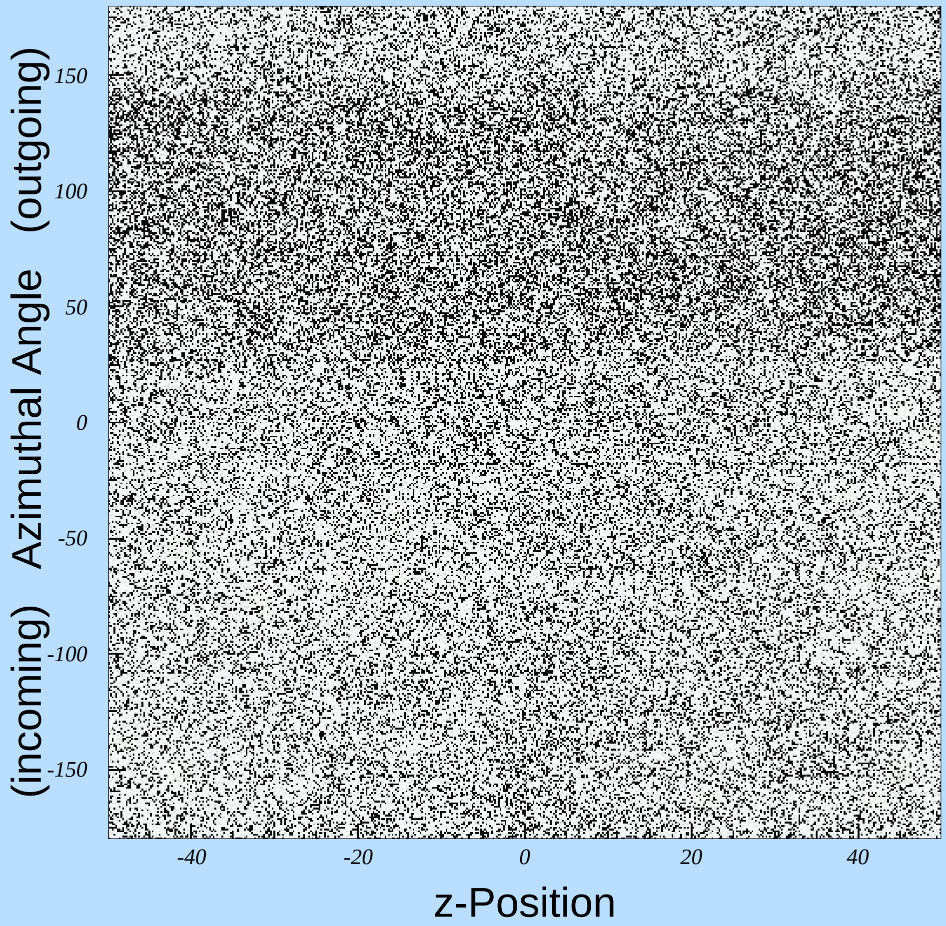
Compressed view 1:10

VTX Hits – z-phi-Plane

Mokka hits on VTX layer 1 (overlay of 100 BX)



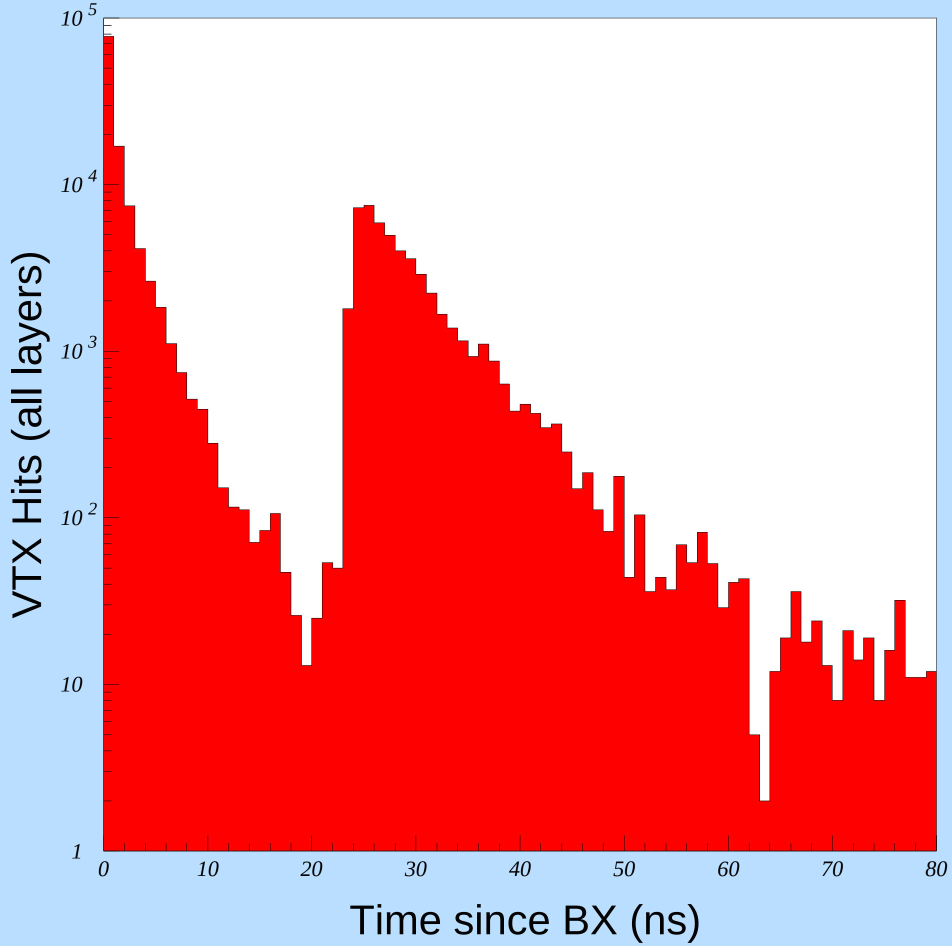
2 mrad



20 mrad, DID

VTX Hits – Time Structure

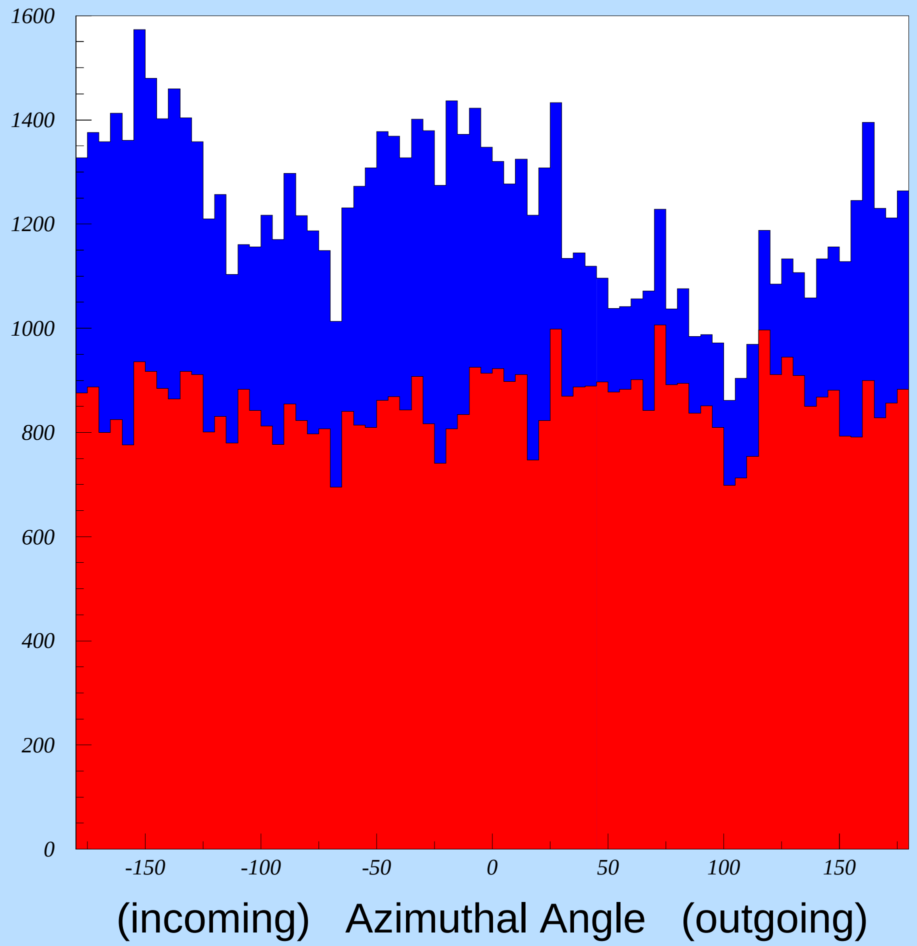
- Clear separation between direct hits and backscattered particles
- $t \approx 23\,\mathrm{ns}$ corresponds to a distance of 7.0 m (3.5 m in each direction)
- Most backscatterers come from the BeamCal



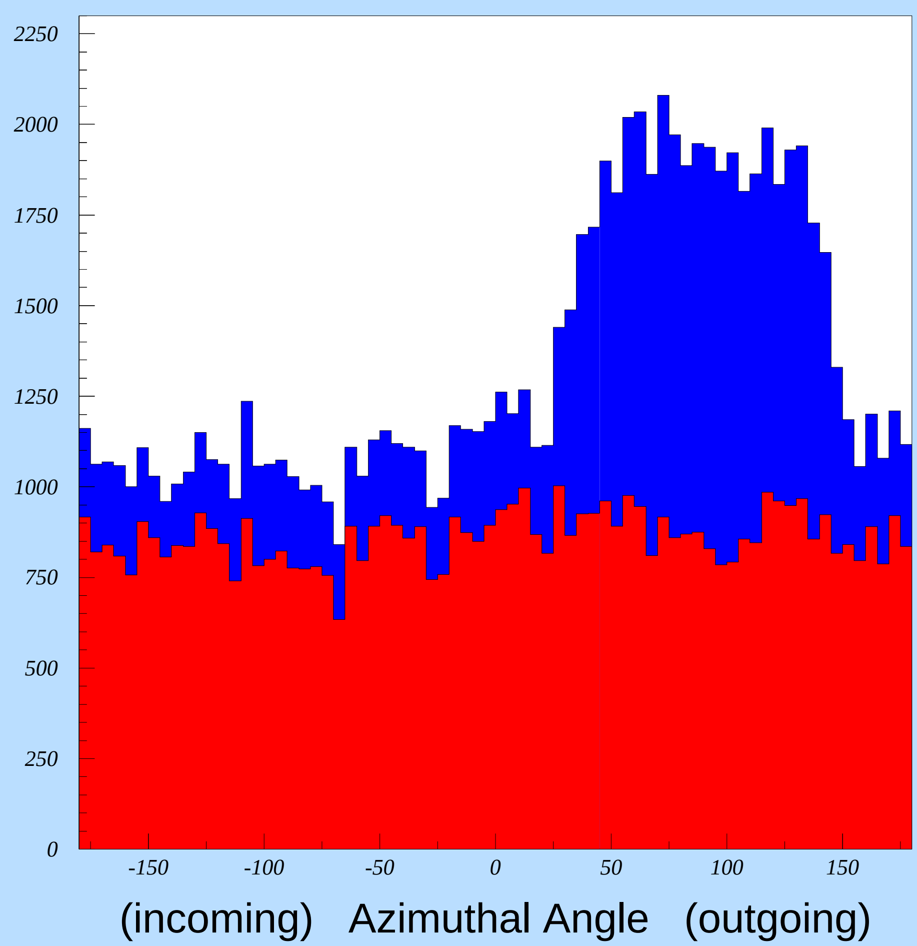
Structures for 2 mrad and 20 mrad look similar

VTX Hits – phi Distribution

Separation of immediate hits (red) and backscatterers (blue)



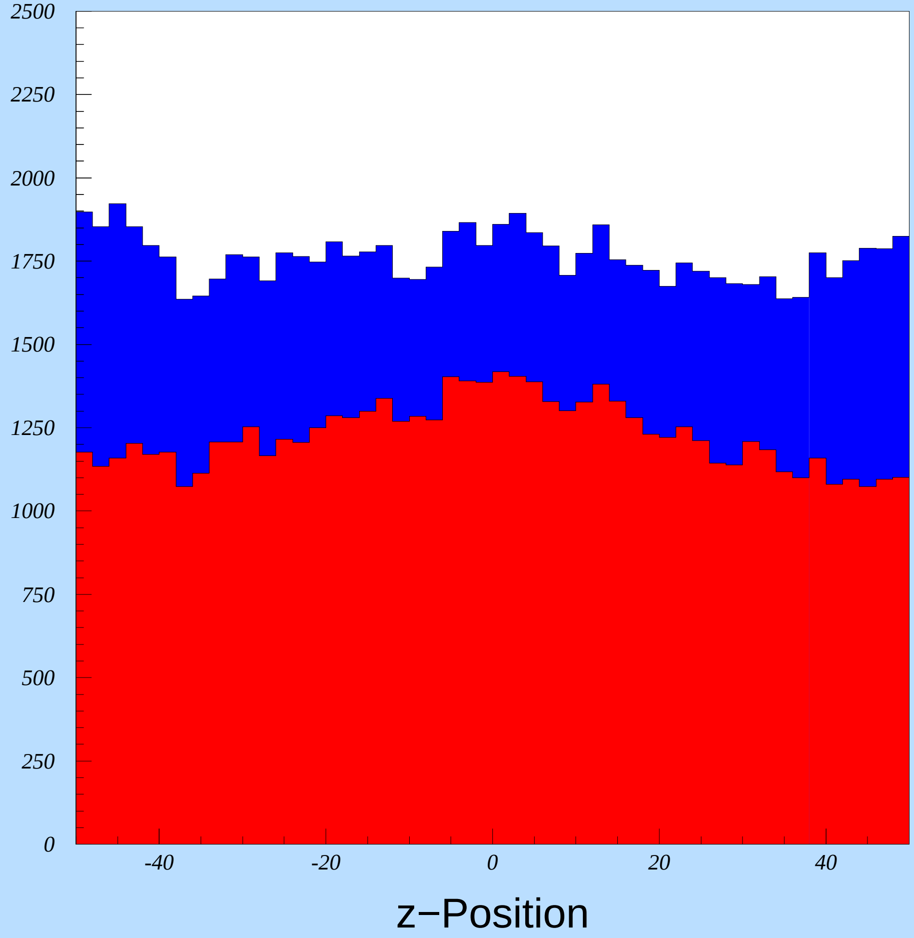
Layer 1, 2 mrad



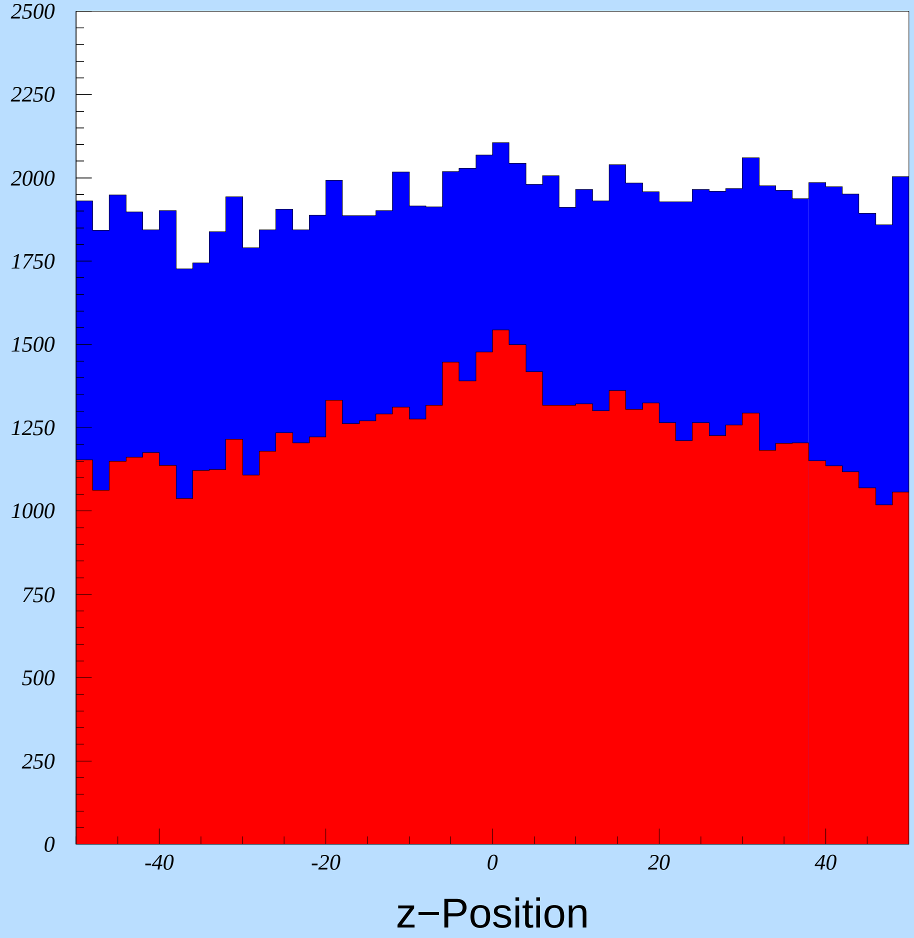
Layer 1, 20 mrad, DID

VTX Hits – z Distribution

Separation of immediate hits (red) and backscatterers (blue)

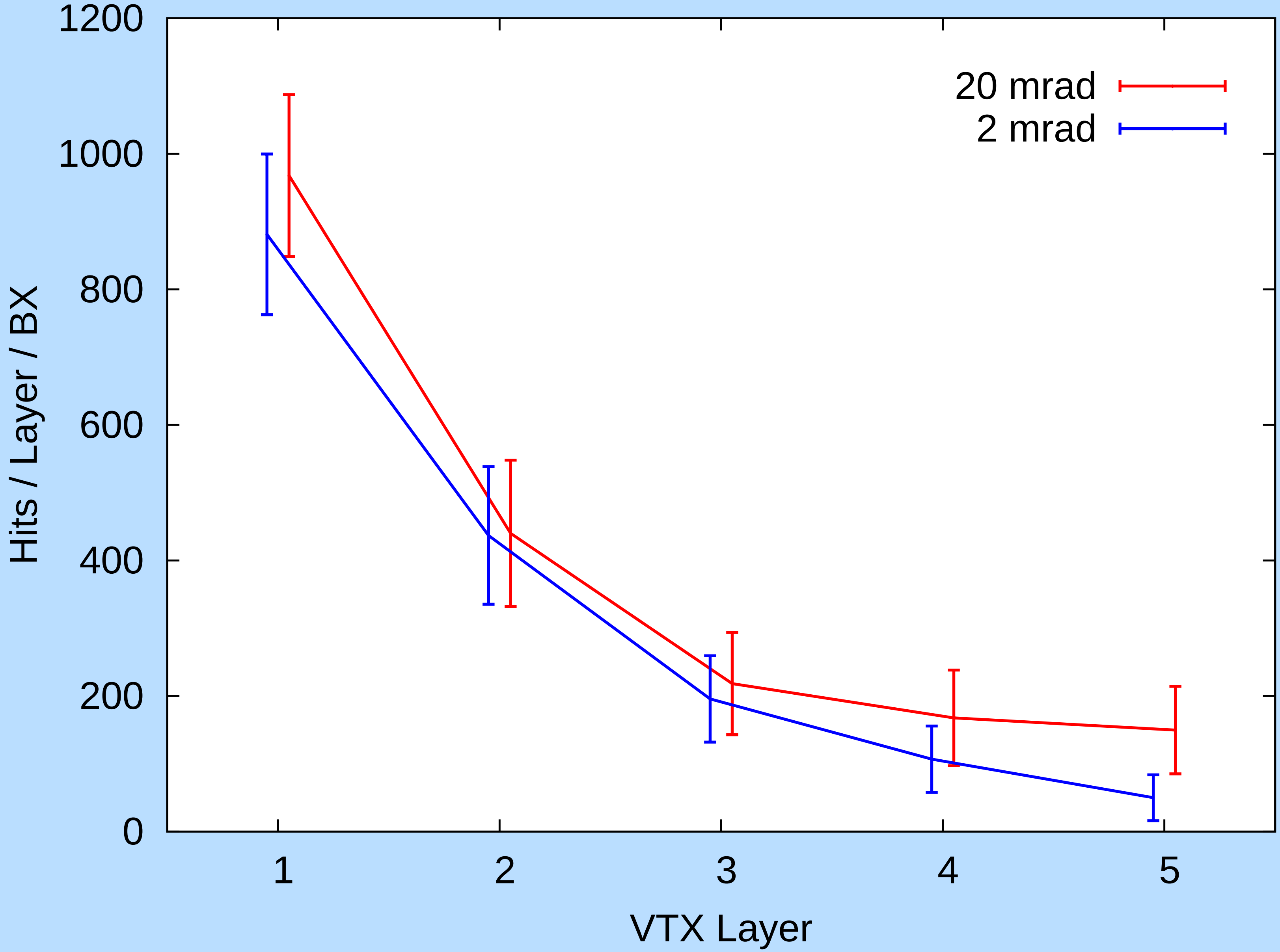


Layer 1, 2 mrad



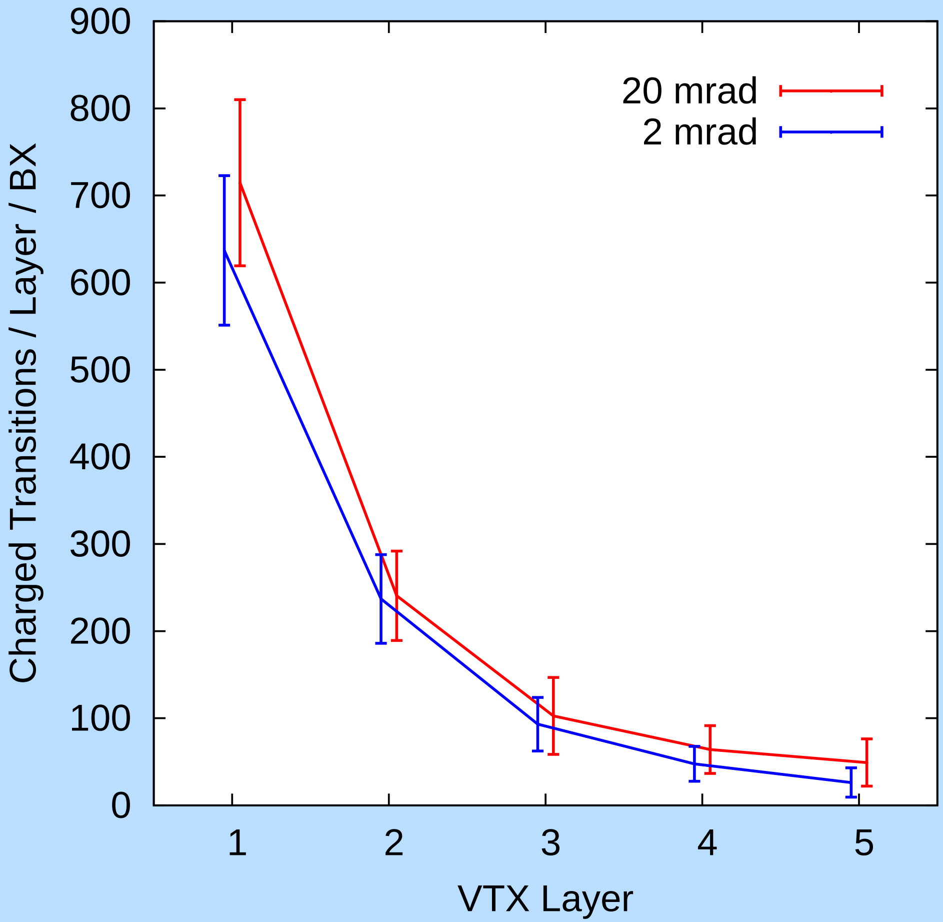
Layer 1, 20 mrad, DID

VTX Hits – All Layers

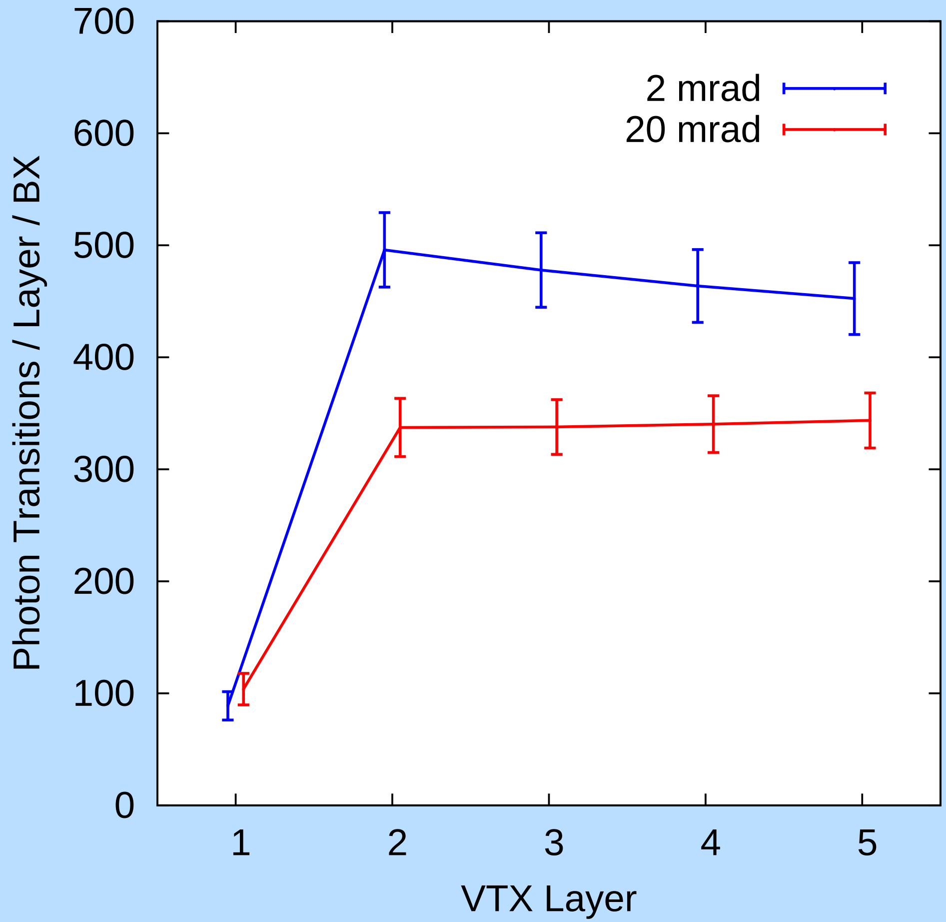


VTX Transitions – EM Particles

Particles passing through the VTX layers



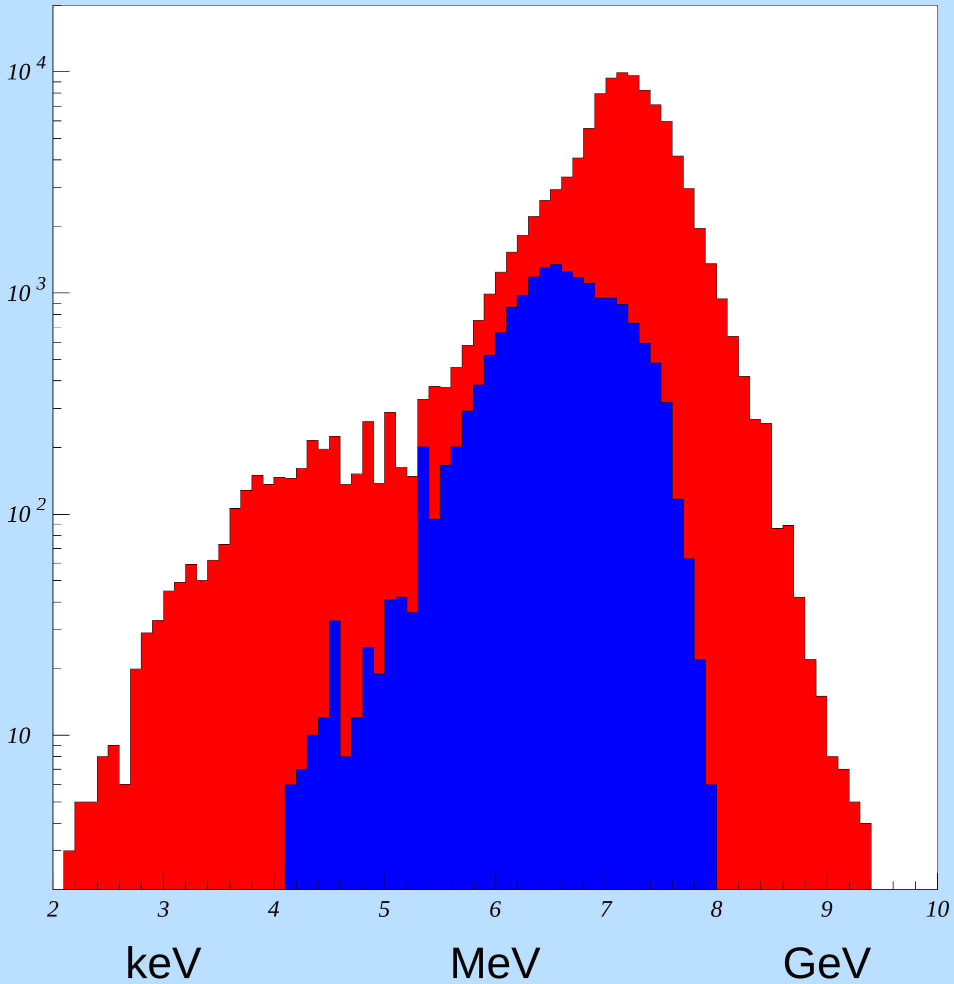
Charged (e^+e^-)



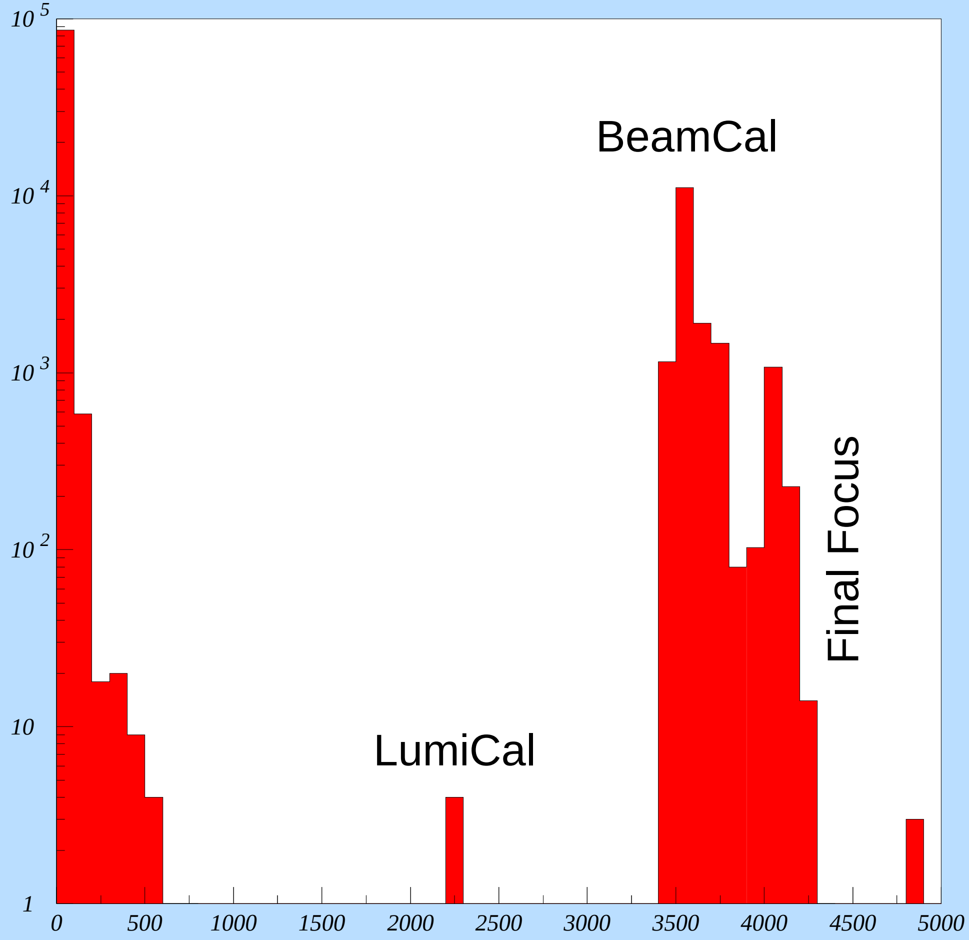
Photons

VTX Transitions – Charged Particles

Separation of near (red) and distant (blue) sources



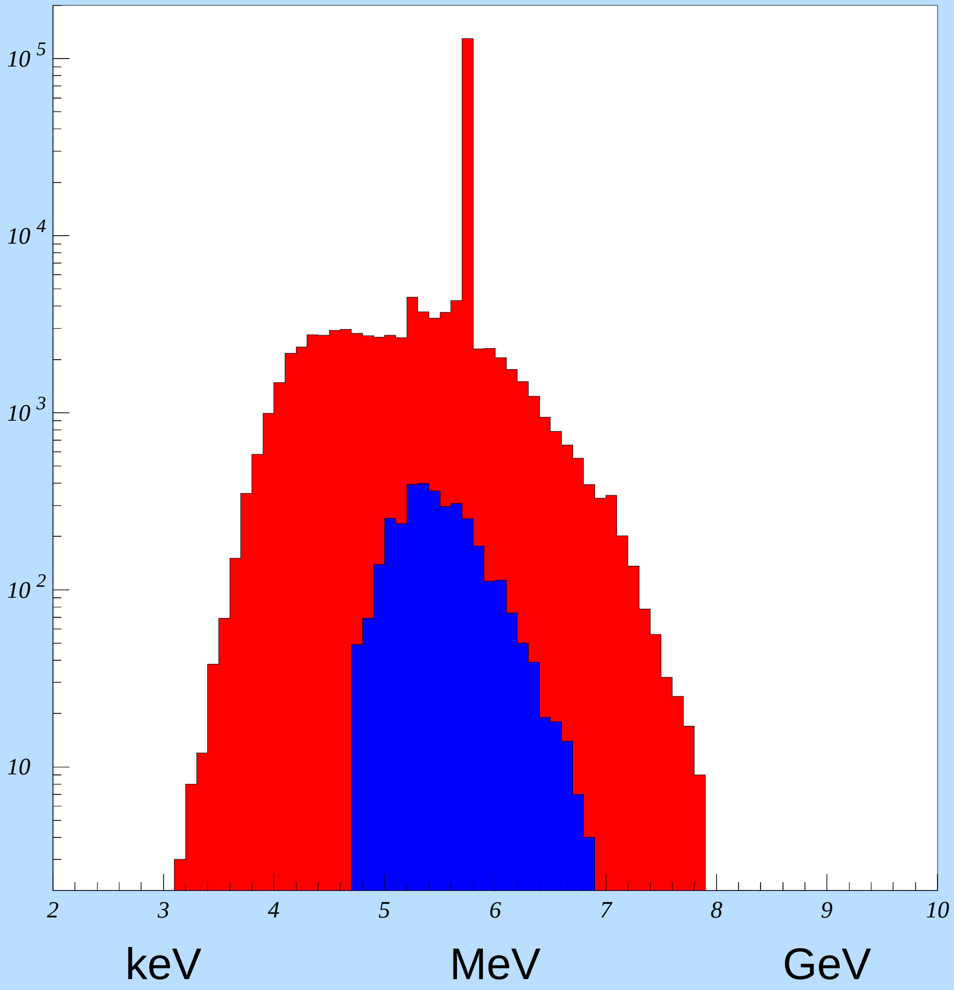
Energy spectrum



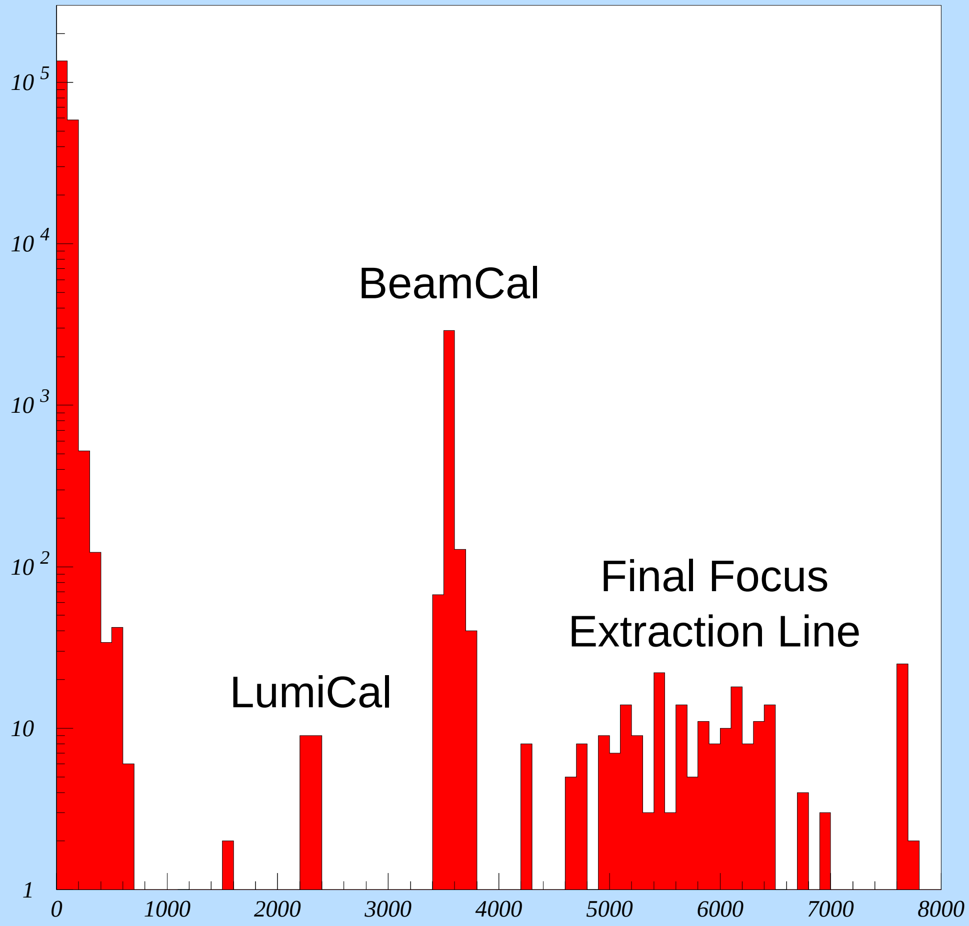
Origins, 2 mrad

VTX Transitions – Photons

Separation of near (red) and distant (blue) sources



Energy spectrum



Origins, 2 mrad

VTX Transitions – Neutron Fluence

Neutrons passing any VTX layer (with double counting)

- 1.7 ± 0.3 per BX for 2 mrad
- 9.2 ± 0.7 per BX for 20 mrad

Normalisation per unit area

- divide by total surface of $2.8 \cdot 10^3\,\mathrm{cm}^2$

Normalisation per nominal run time

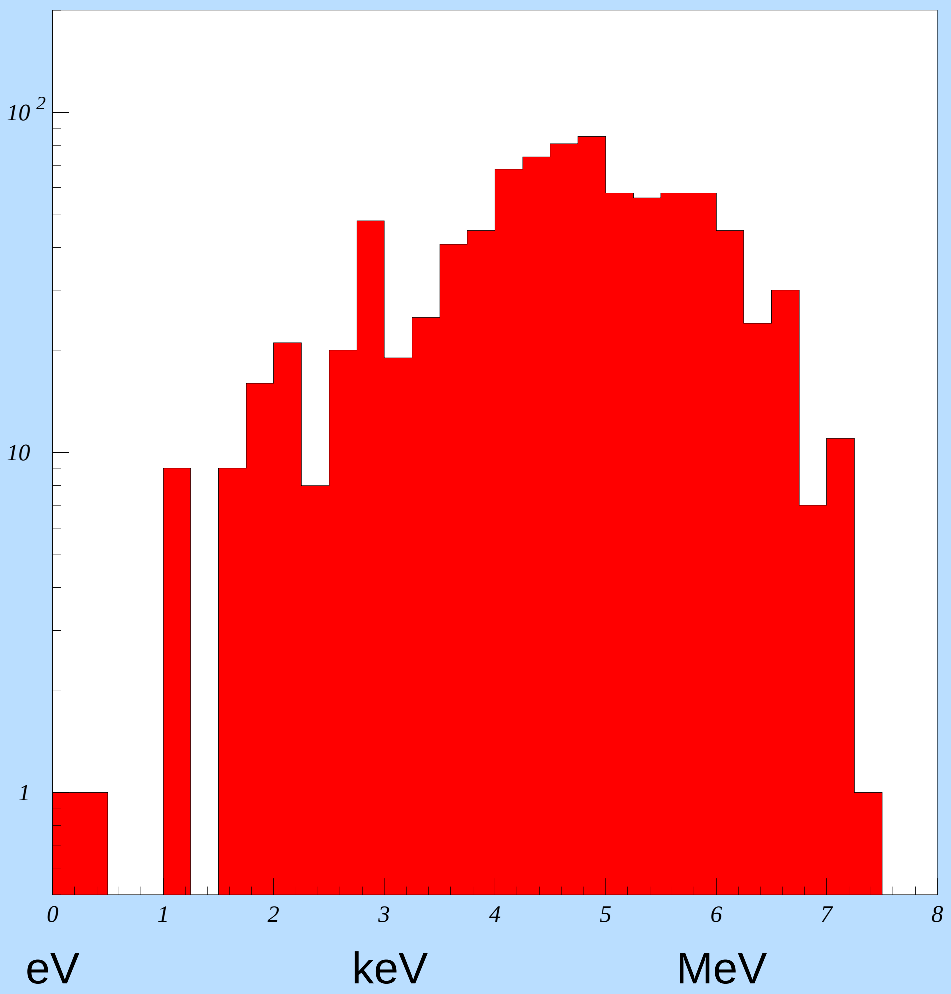
- $\int \mathcal{L}\,dt = 500\,\mathrm{fb}^{-1}$ corresponds to $2.3 \cdot 10^{11}$ BX

Neutron fluence (no energy scaling applied yet)

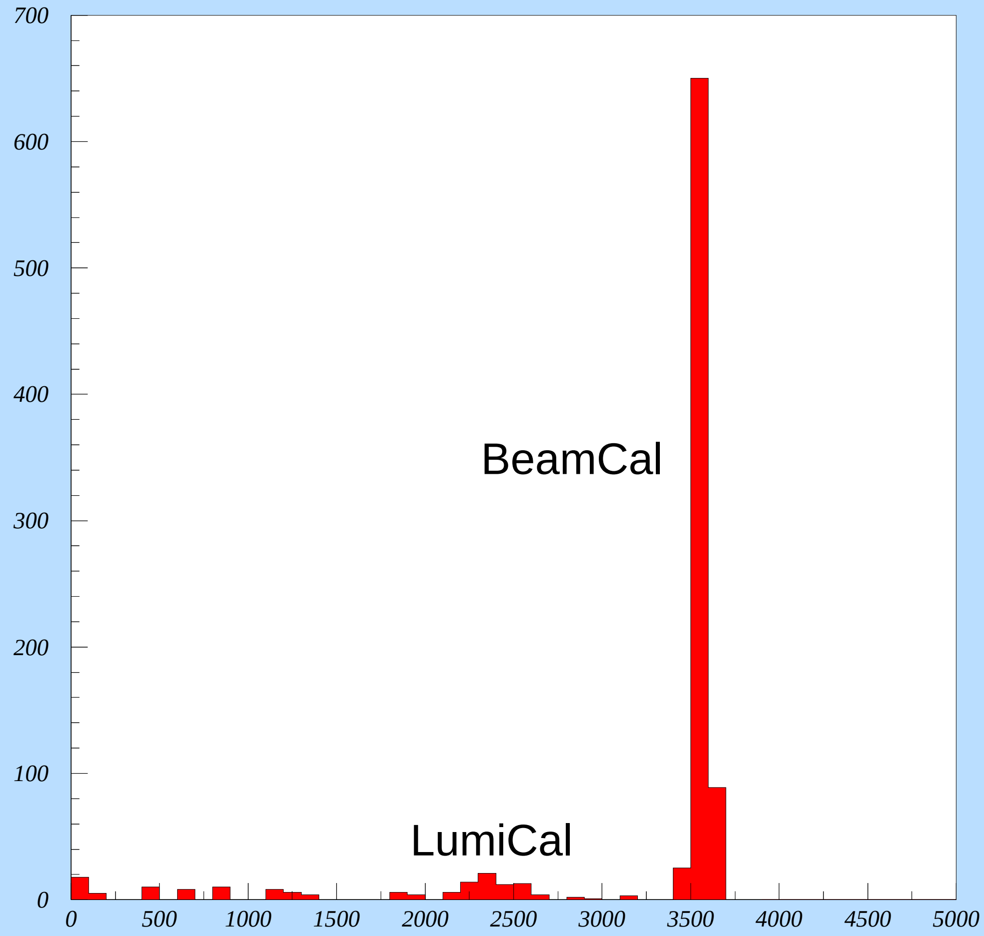
- $(1.4 \pm 0.2) \cdot 10^8$ neutrons / cm^2 for 2 mrad
- $(7.6 \pm 0.6) \cdot 10^8$ neutrons / cm^2 for 20 mrad

VTX Transitions – Neutrons

Statistics for neutrons are rather low . . .



Energy spectrum



Origins, 20 mrad

Comparison with Brahms (K. Büßer)

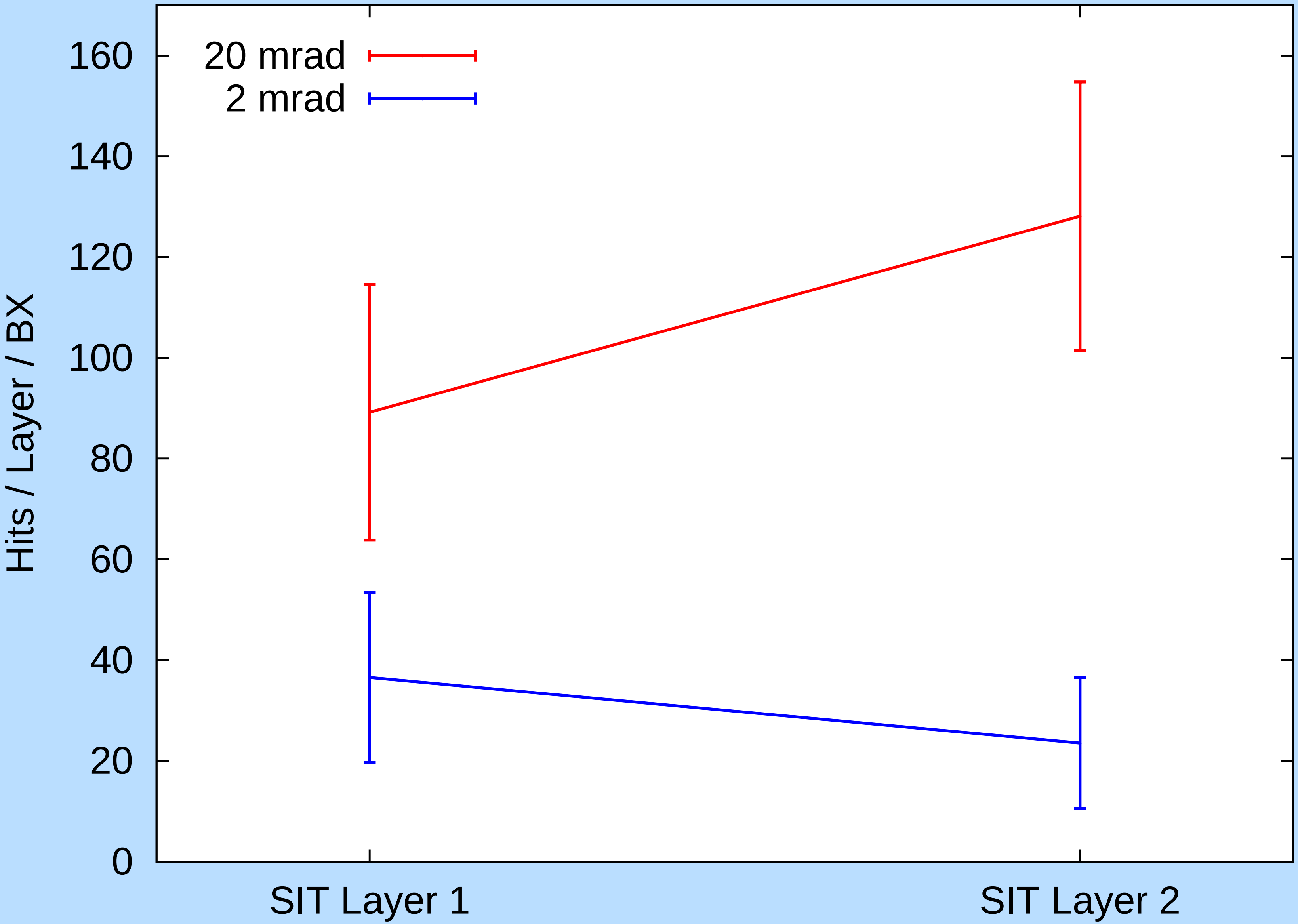
Qualitative agreement

- same generator input from Guinea Pig
- Brahms and Mokka have similar overall geometries
- backscattering is a geometrical effect

Quantitative differences

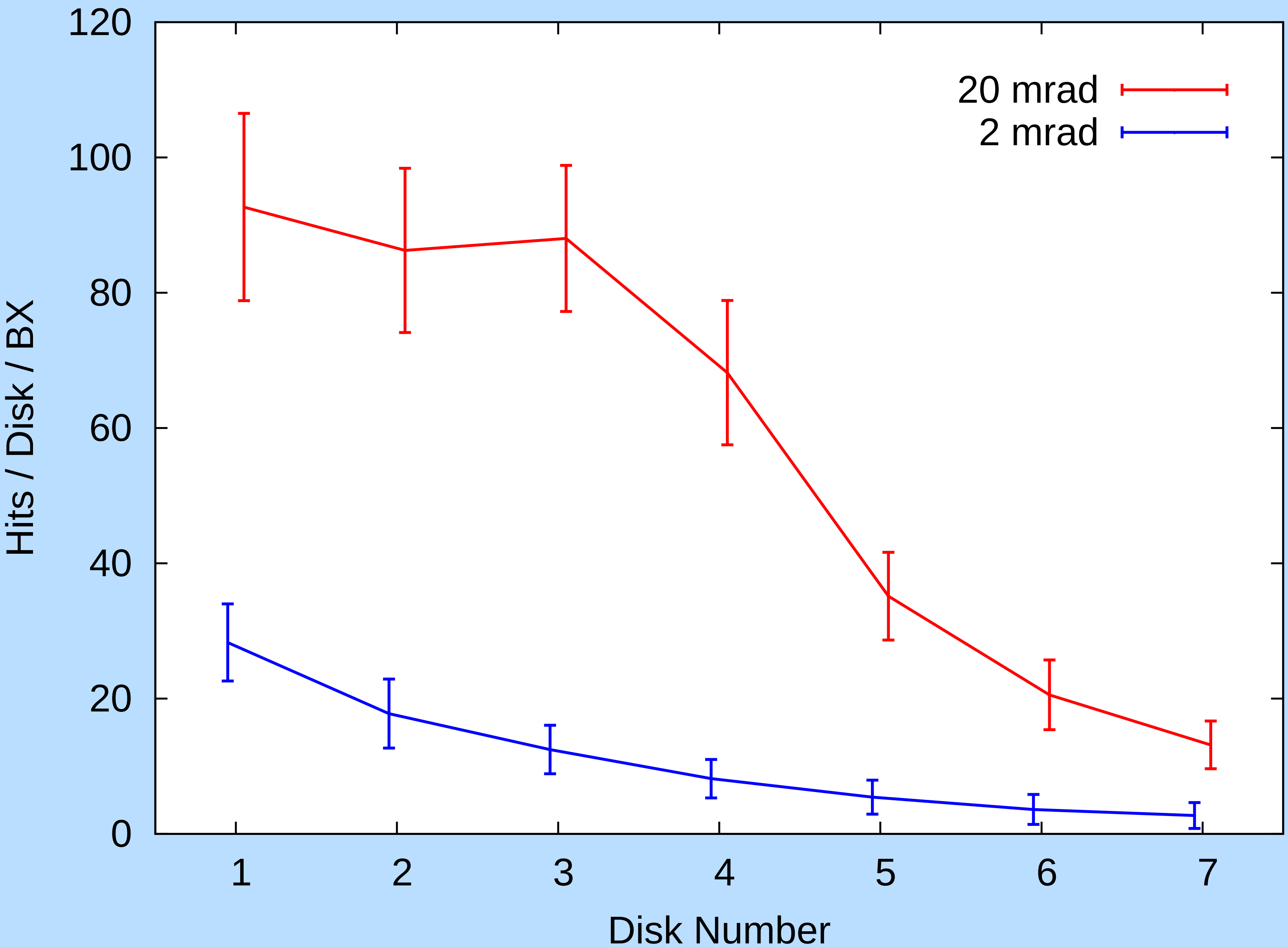
- Mokka has a new VTX model (larger sensitive area)
- Geant 4 physics lists include neutron contributions
- different cut mechanisms (energy cut vs. range cut)
- different effective cut values? (to be compared)
- different concepts of a “hit”? (to be looked into)

SIT Hits



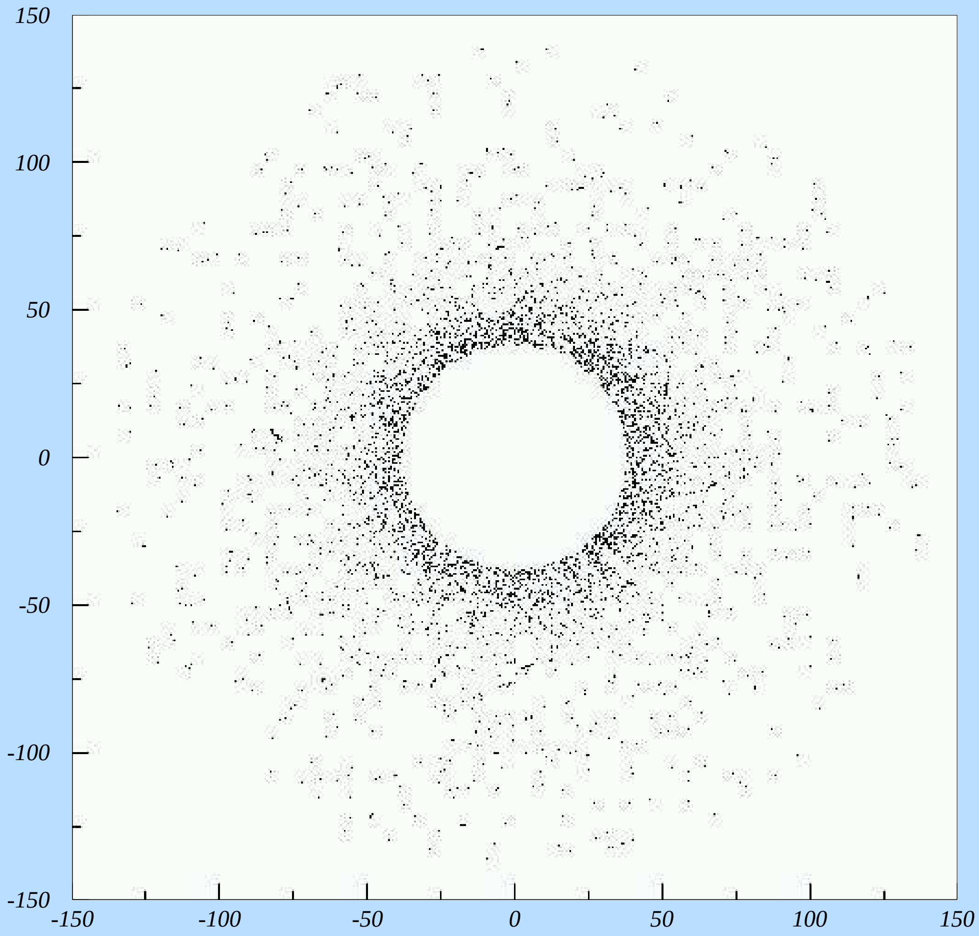
160
140
120
100
80
60
40
20
0
Hits / Layer / BX
20 mrad
2 mrad
SIT Layer 1
SIT Layer 2

FTD Hits – All Disks

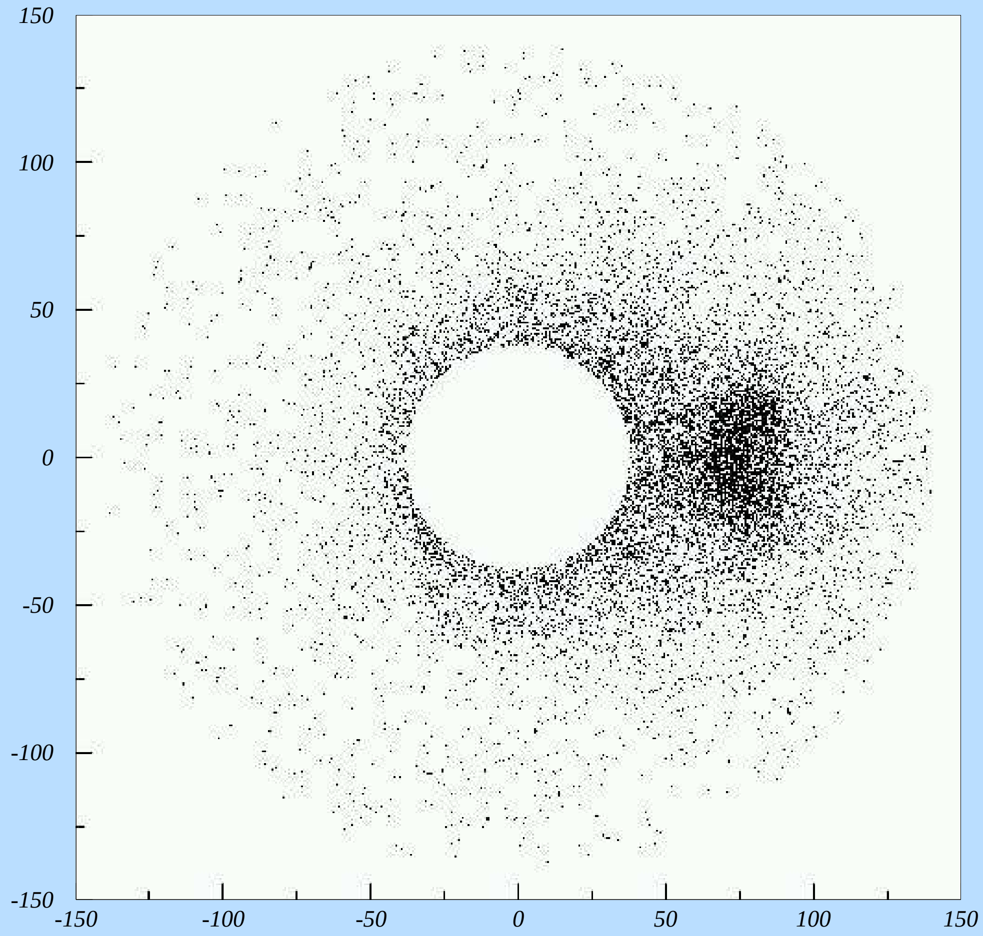


FTD Hits – xy-Plane

Mokka hits on the innermost FTD (overlay of 100 BX)



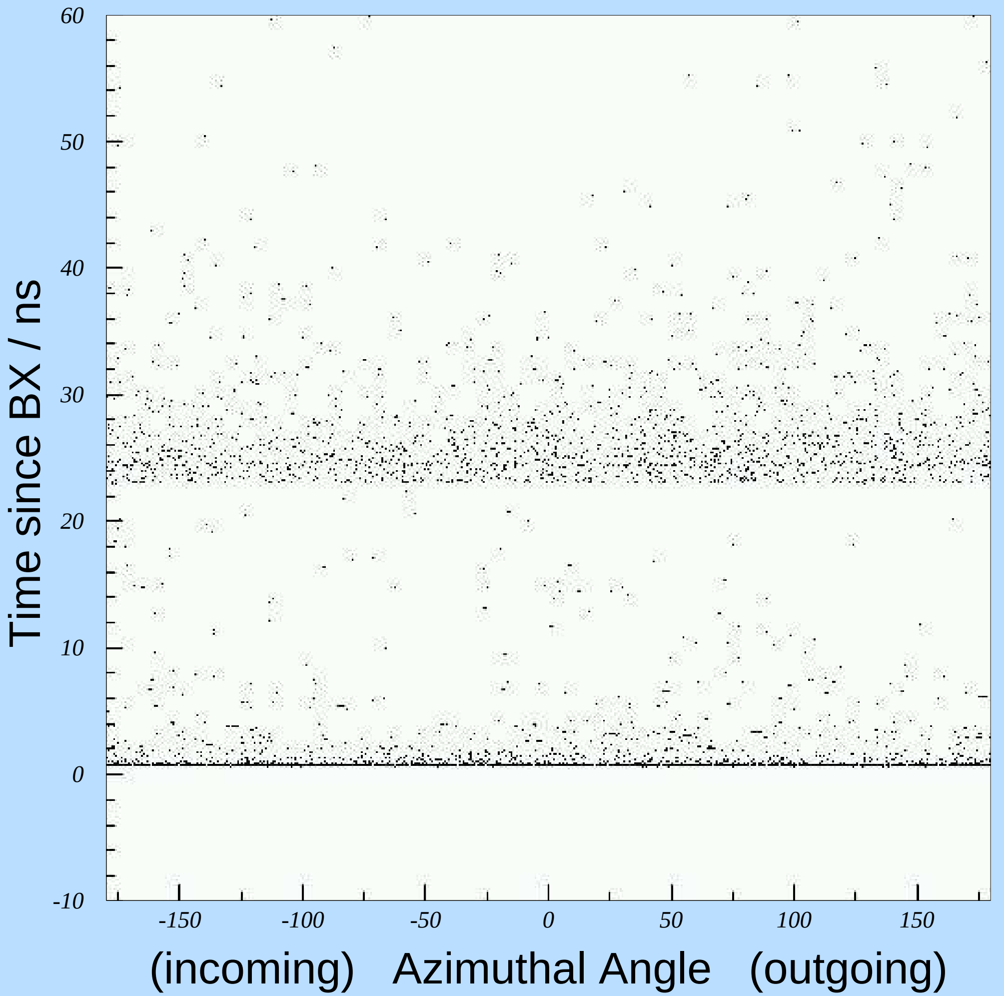
2 mrad



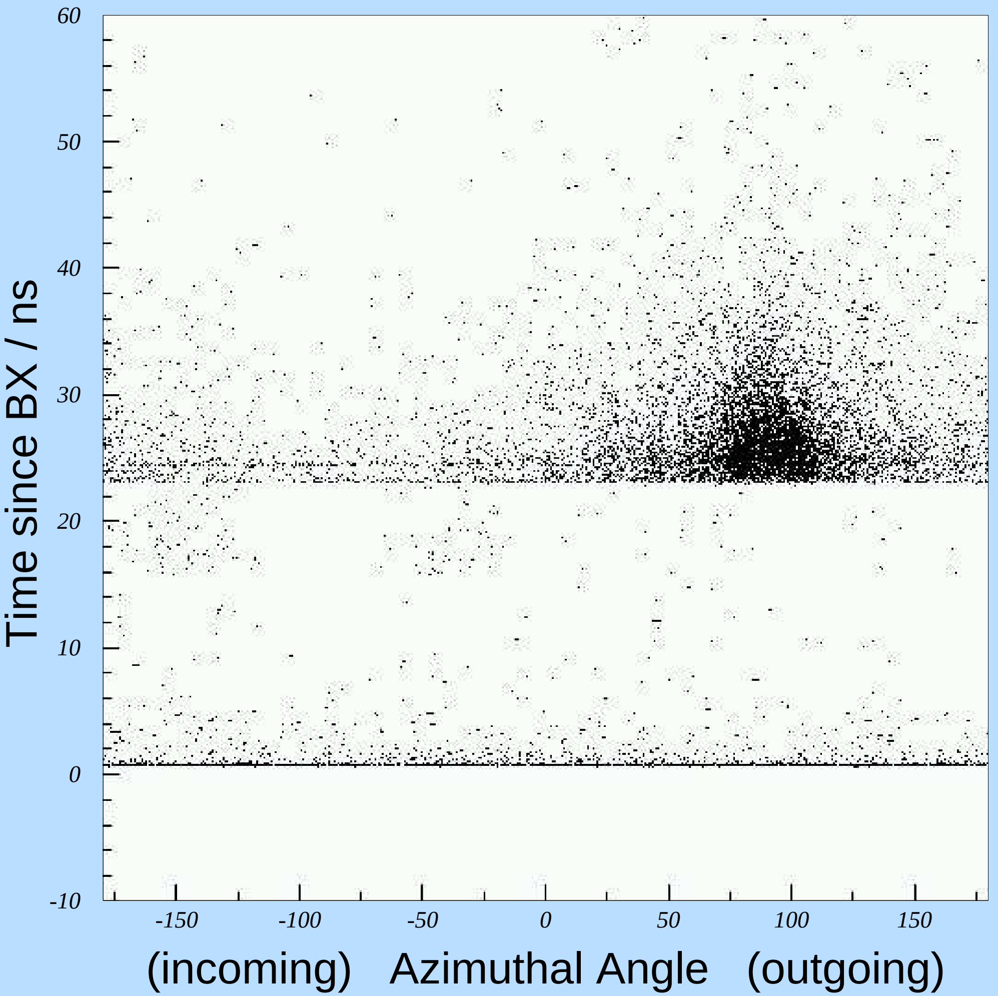
20 mrad, DID

FTD Hits – phi-t-Plane

Mokka hits on the innermost FTD (overlay of 100 BX)



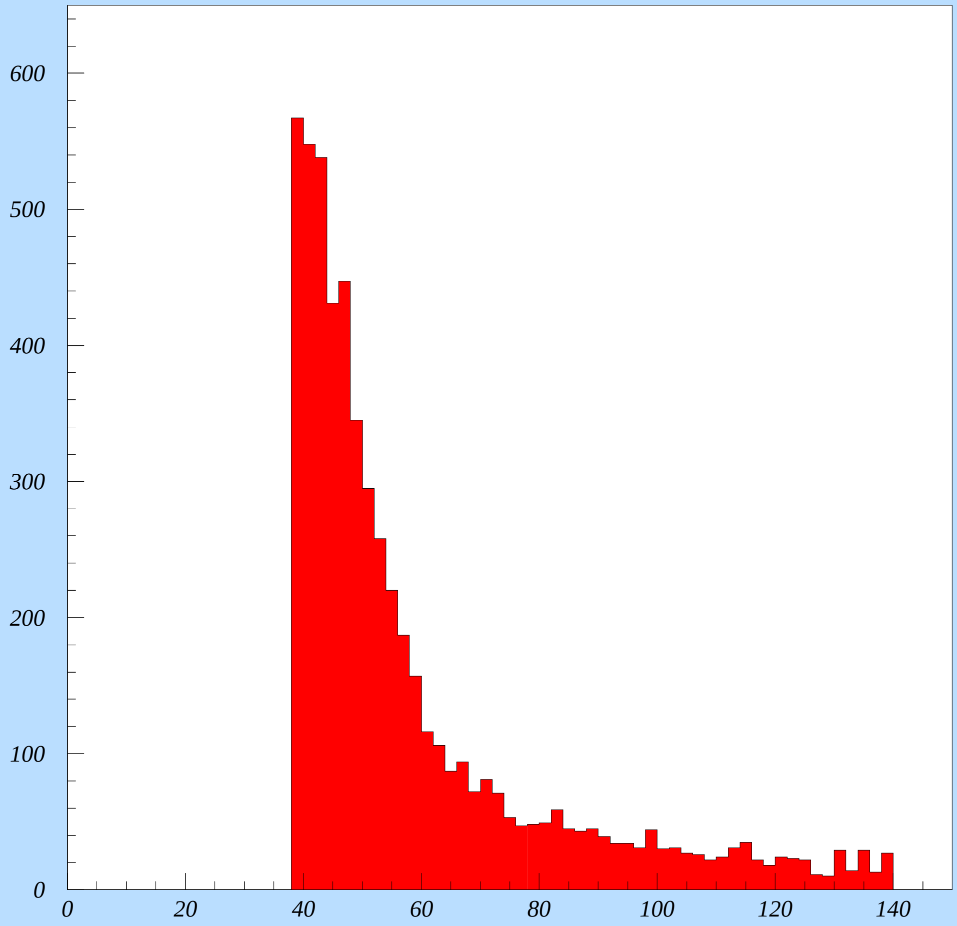
2 mrad



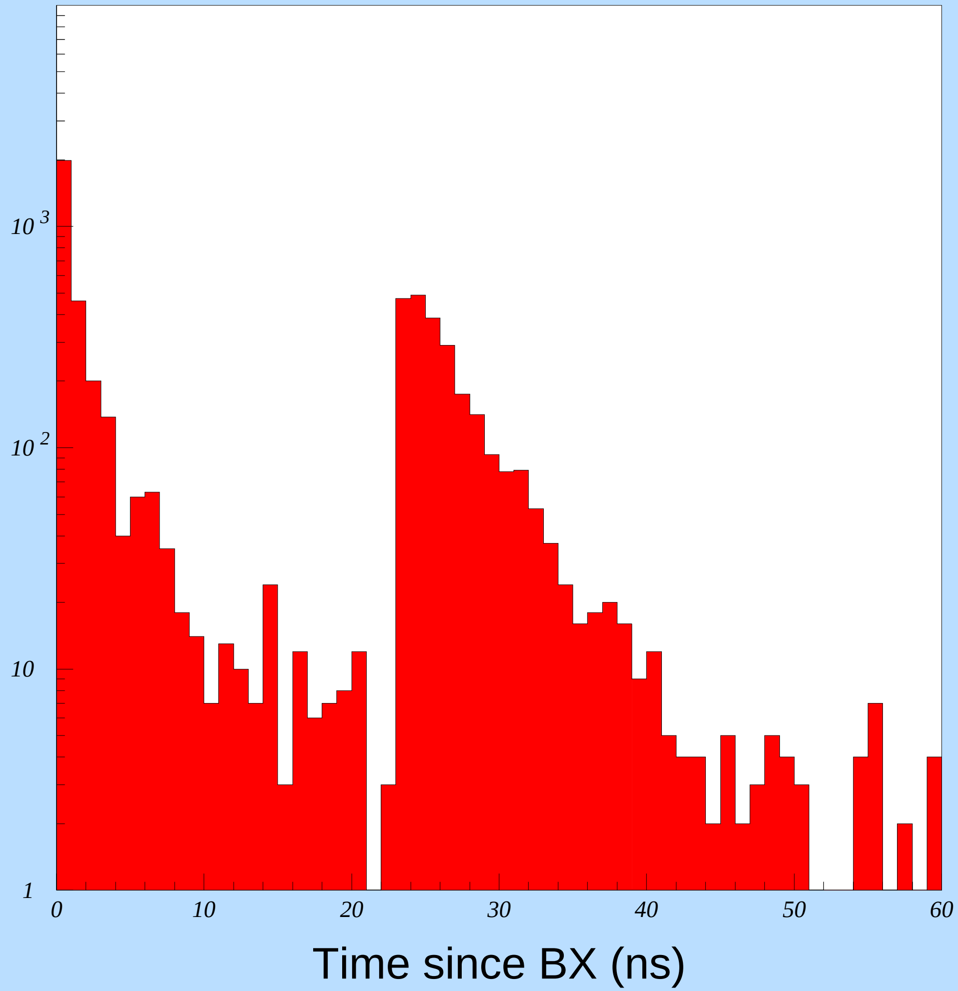
20 mrad, DID

FTD Hits – Radius and Time

Mokka hits on the innermost FTD (overlay of 100 BX)



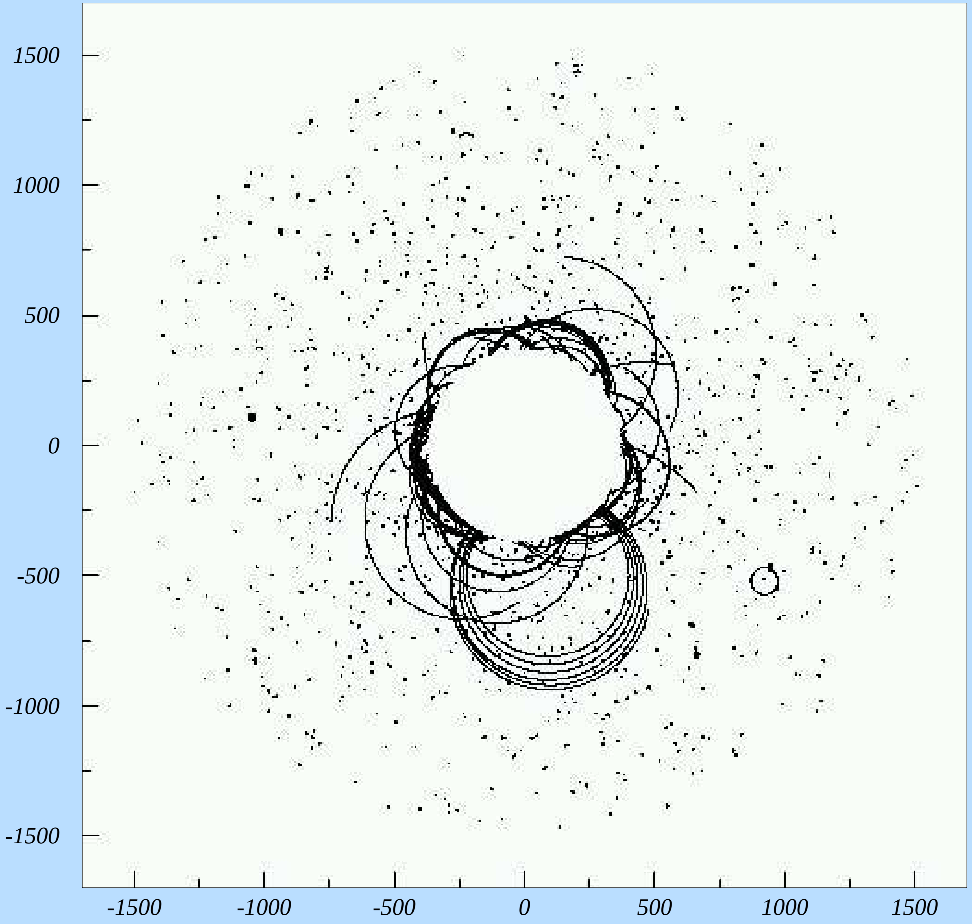
Radial distribution, 2 mrad



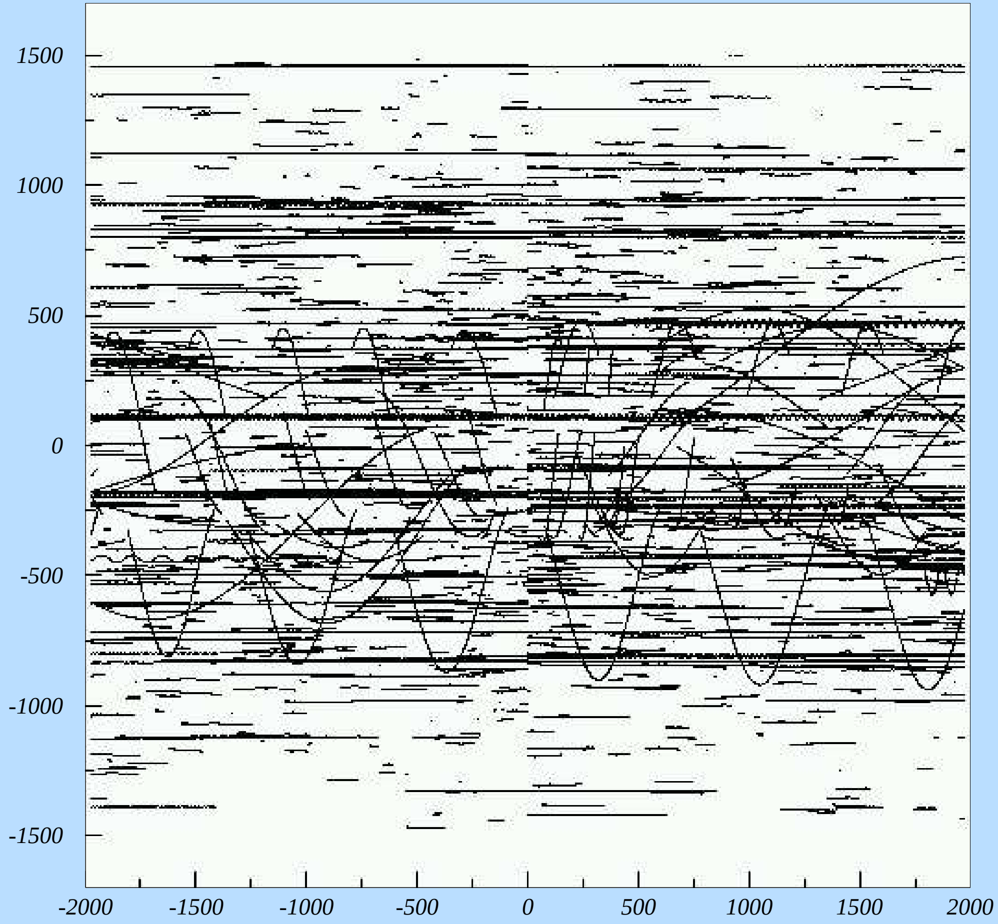
Time structure, 2 mrad

TPC Hits (Not Your Problem)

Mokka hits in the TPC (overlay of 100 BX)

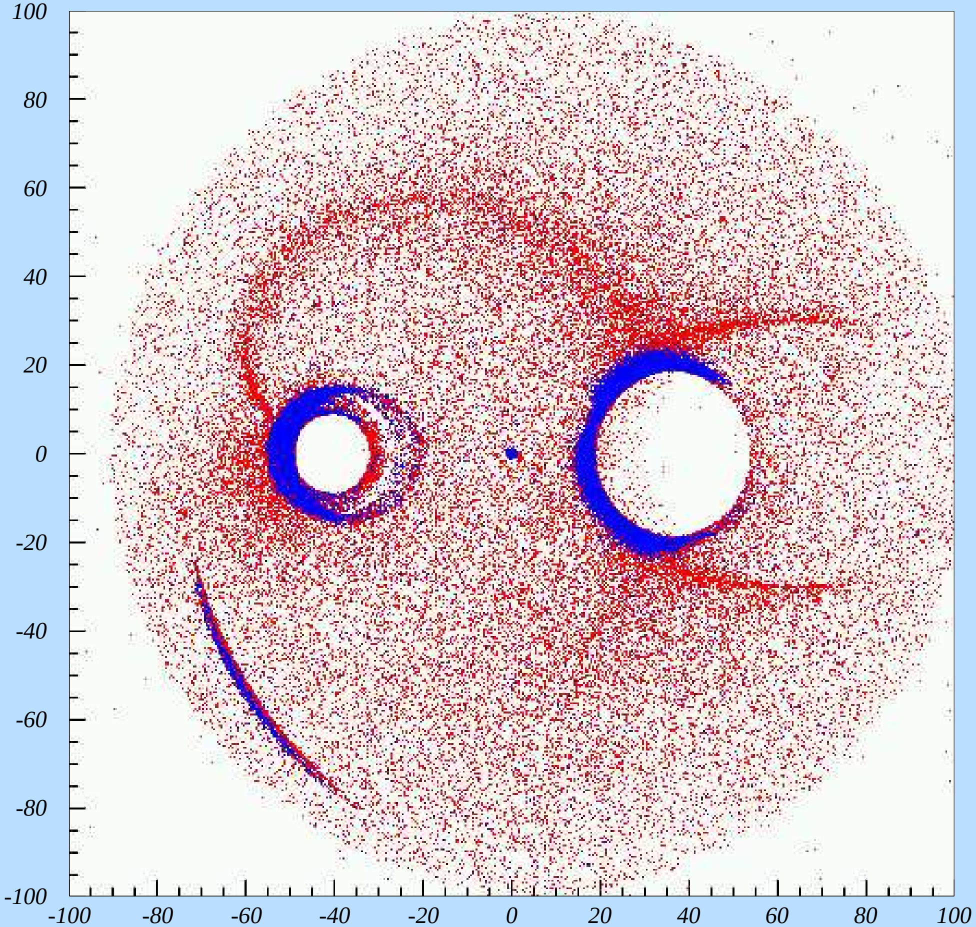


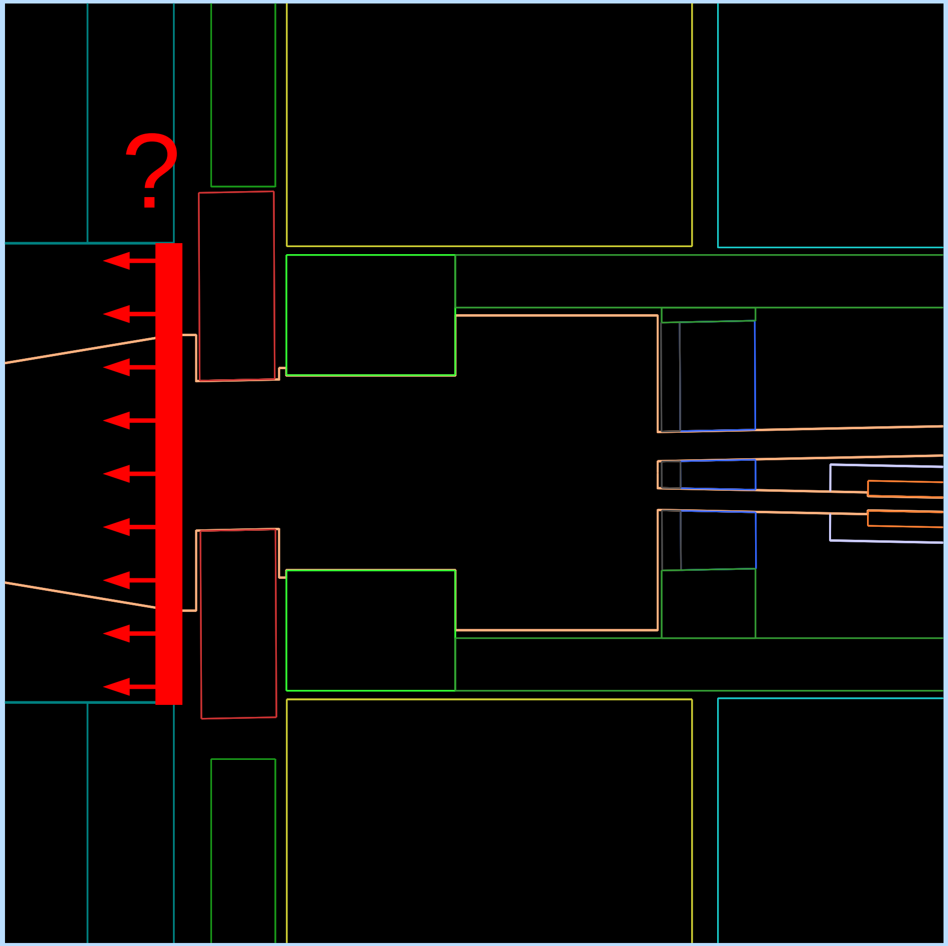
Front view, 2 mrad



Side view, 2 mrad

Backscattering Sources





Origins of electrons (red) and positrons (blue) which . . .

. . . go through this surface in front of the LumiCal

Summary and Outlook

Backscattering is a significant contribution

- may be reduced by optimisation of geometries
- work is in progress (in collaboration with FCAL)
- small modifications (e. g. radii) can have large effects

Simulation effort is going on

- this talk contains data from 1 CPU-year
- jobs were run on the Grid (3 days on $\approx$ 120 nodes)
- the parameter space is large and multi-dimensional

Further runs are planned

- different geometries, beam parameters, . . .

Summary and Outlook

Other background sources

- backscattering from losses in the extraction line
- beam halo from the main linac
- can be studied with tools like BDSim

Background signals in the VTX (and friends)

- crossing angle (plus the DID field) can cause asymmetries and hot spots
- background hits have a clear time structure
- draw your own conclusions – you are the experts
- beware: background studies are no percent business!