Simulation of Neutron Background with Mokka

ILC – LDC – TPC

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Neutron Sources at the ILC

Main beam dump and beamstrahlung dump

- huge amounts of neutrons after every BX
- but: far away from the detector

Electron-positron pairs from beamstrahlung scattering

- smash into forward calorimeters and quadrupoles
- create neutrons inside the detector
- main source of neutron background for the TPC

Radiative Bhabha scattering and various other processes

- probably negligible due to larger production distance

Effects of Neutrons

In the TPC

- short tracks from recoil protons (hydrogen)
- tracks from beta decay (15 min mean life)
- additional primary ions, field distortions

In other detectors

- radiation damage to silicon sensors
- many random low-energy hits

General phenomena

- low-energy “neutron gas” floods the whole detector
- ping-pong-like bouncing, channelling effects

Simulation Tools

Guinea Pig

- simulates beam-beam interaction
- generates e^+e^- pair particles

Brahms

- simulates interaction of particles with the detector
- based on Geant 3 (no more development), Fortran

Mokka

- successor of Brahms, still under development
- but: based on Geant 4 (state of the art), C++

Physics Lists

`PhysicsList` (Mokka built-in)

- doesn’t support neutron production at all

`LCPhys` (dedicated Linear Collider physics list)

- newer versions support neutron production
- but: uses poor models for low energies (up to now)

`PhysicsListNeutrons` (extended `PhysicsList`)

- enables electro-nuclear processes
- uses high-precision neutron models (`QGSP_HP`)
- features scattering and moderation of neutrons

Mokka Geometry Drivers

Existing geometries describe the forward region poorly

- only elementary beam tube, mask, and calorimeters
- quadrupole fields are missing completely
- no support for a crossing angle

New geometry drivers for the forward region

- generalised beam tube (straight or X-shaped)
- more detailed mask (absorbers, support, magnets, . . .)
- simplified calorimeters (homogeneous, non-sensitive)
- better magnetic fields (solenoid, serpentine, quadrupole)

Mokka Geometry Data

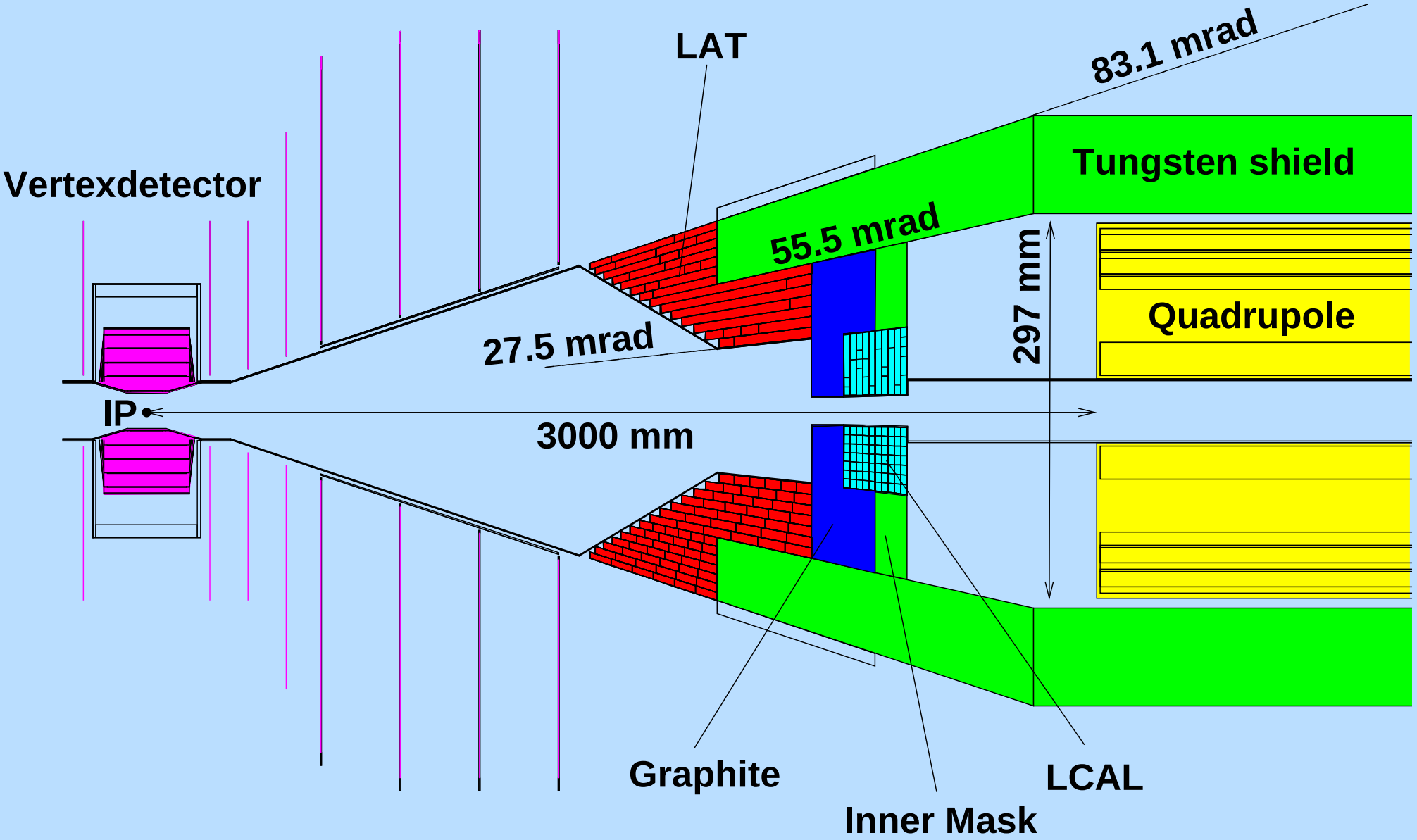
Mokka uses a data-driven geometry model

- actual geometry data is kept in a MySQL database
- driver reads the values and constructs the detector geometry at runtime

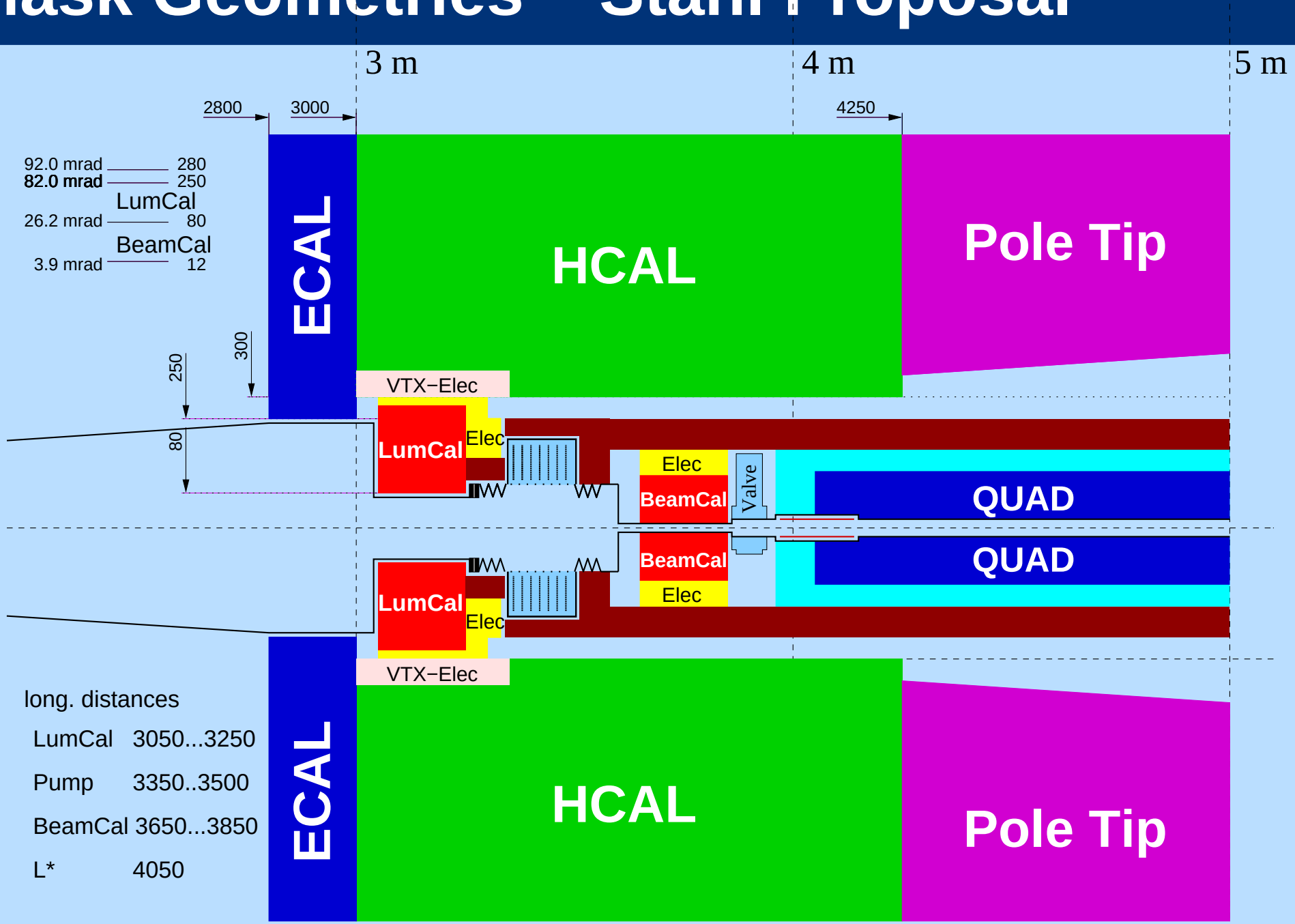
Three datasets for the forward region have been implemented (based on TDR-like model “D10”)

- TDR layout (LAT and LCAL, $L^* = 3.00\,\mathrm{m}$)
- Stahl proposal (LumCal and BeamCal, $L^* = 4.05\,\mathrm{m}$)
- modified Stahl proposal with 20 mrad crossing angle

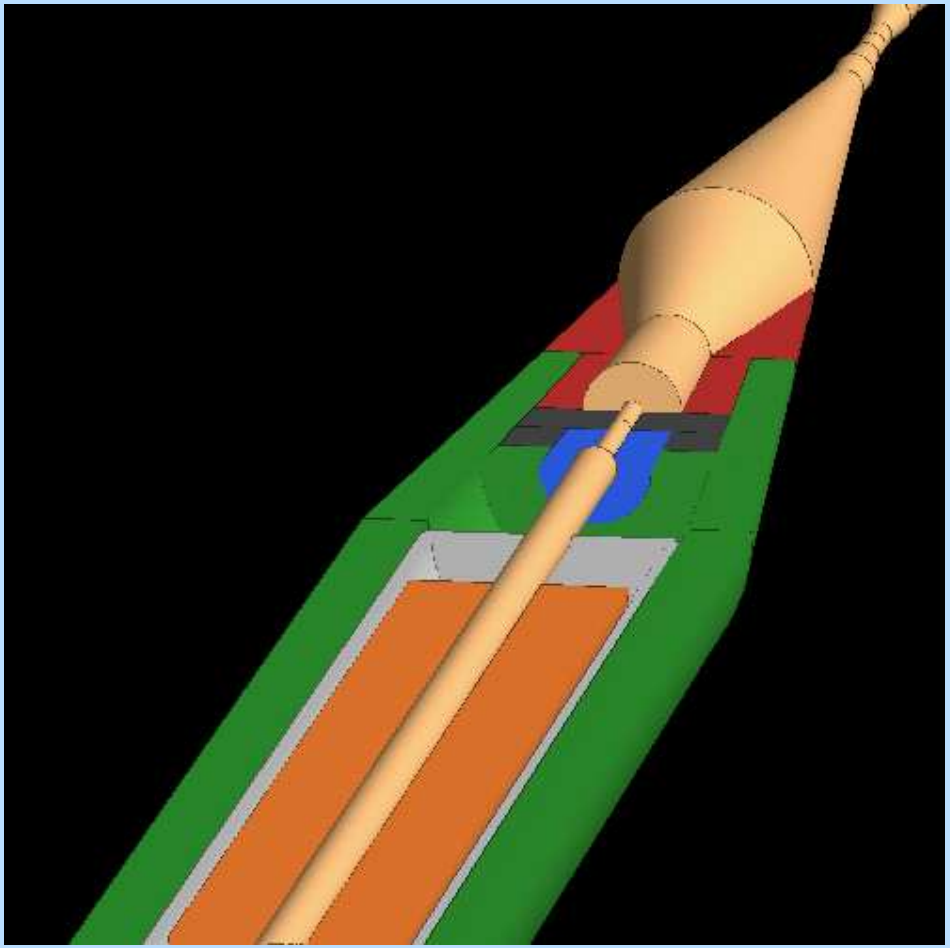
Mask Geometries – TDR Layout



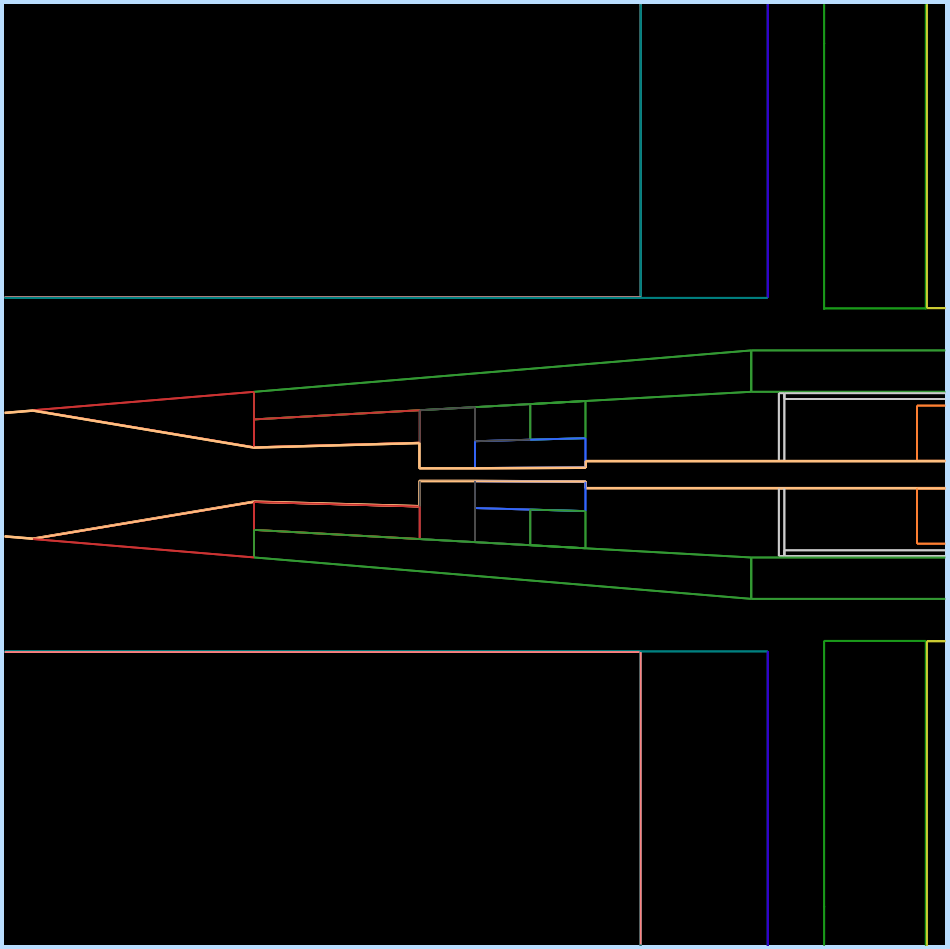
Mask Geometries – Stahl Proposal



Mokka Geometries – TDR Layout

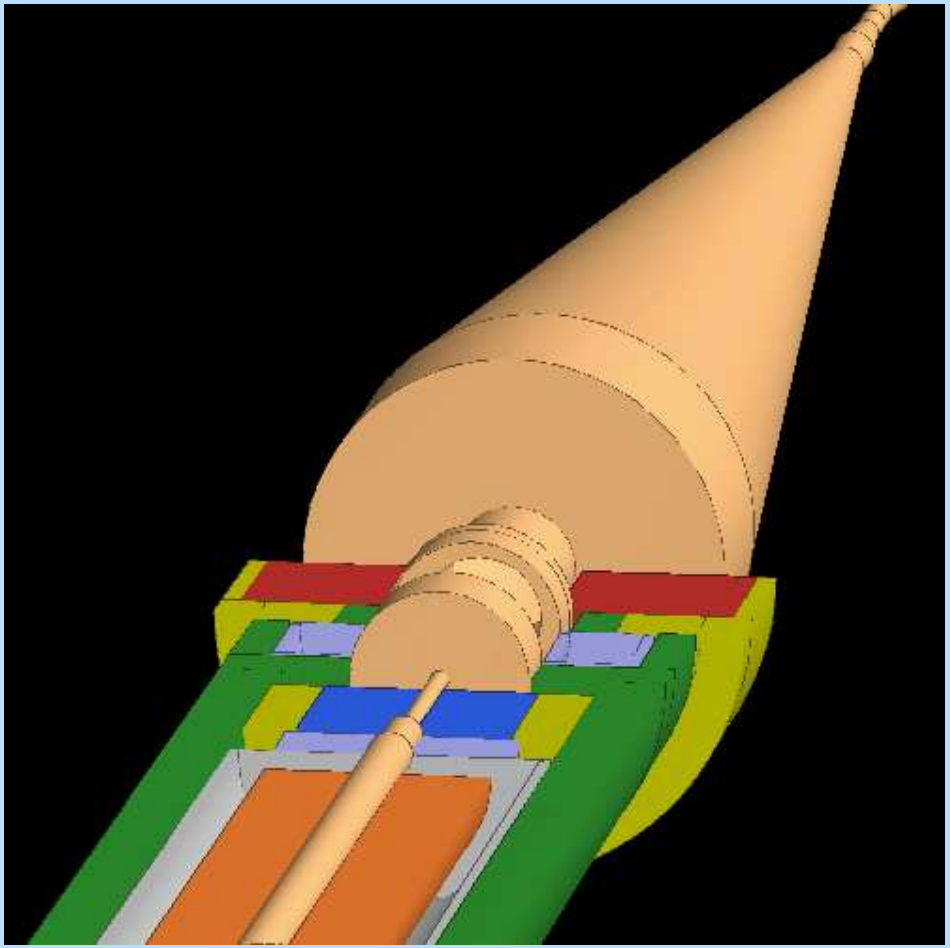


red: LAT, blue: LCAL

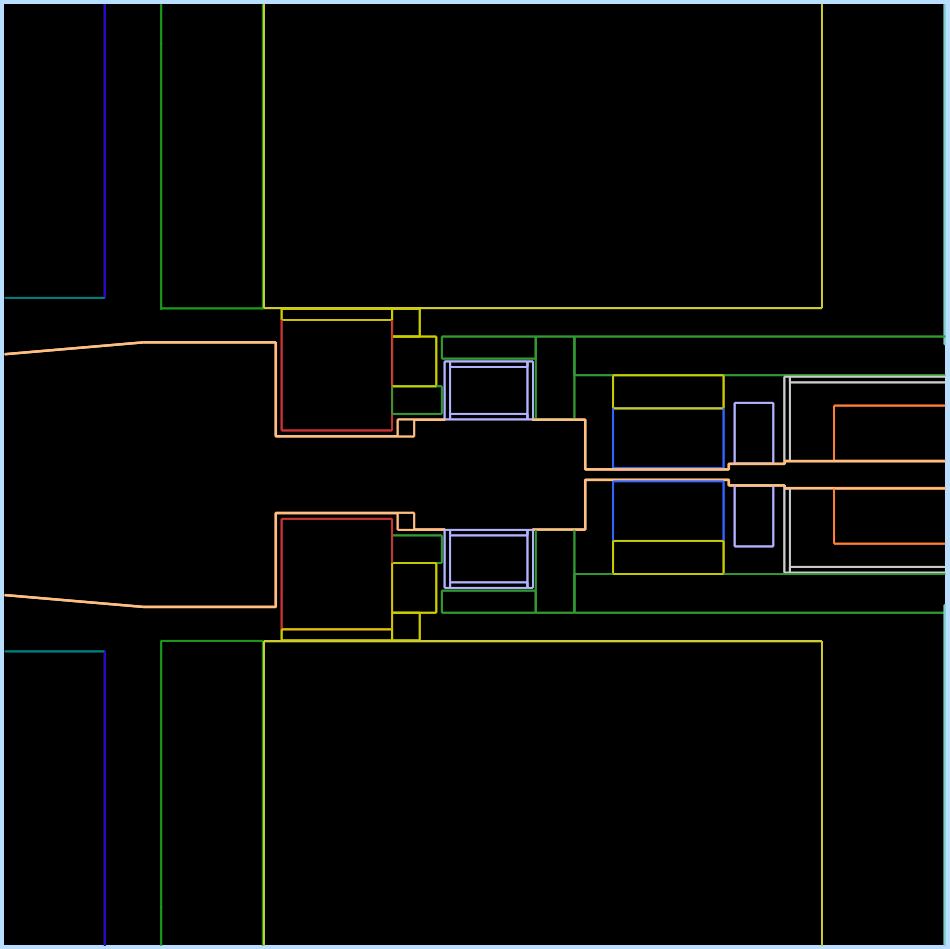


center: z = 2.2 m

Mokka Geometries – Stahl Proposal

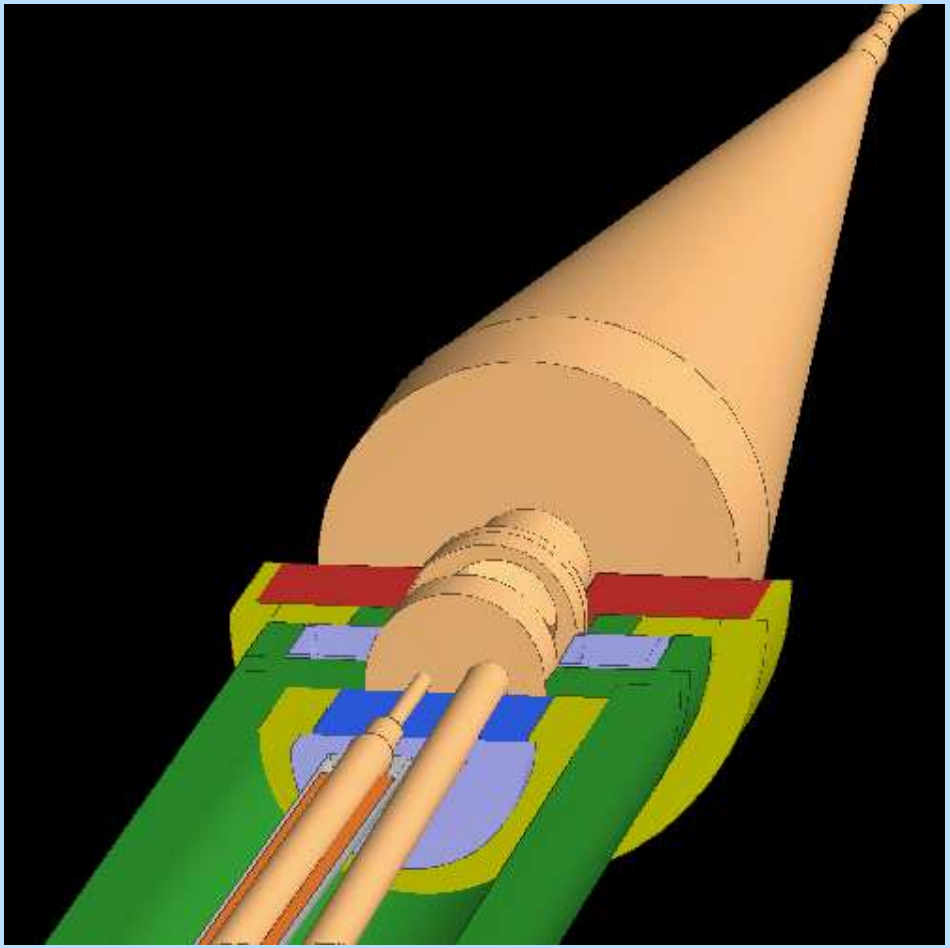


red: LumCal, blue: BeamCal

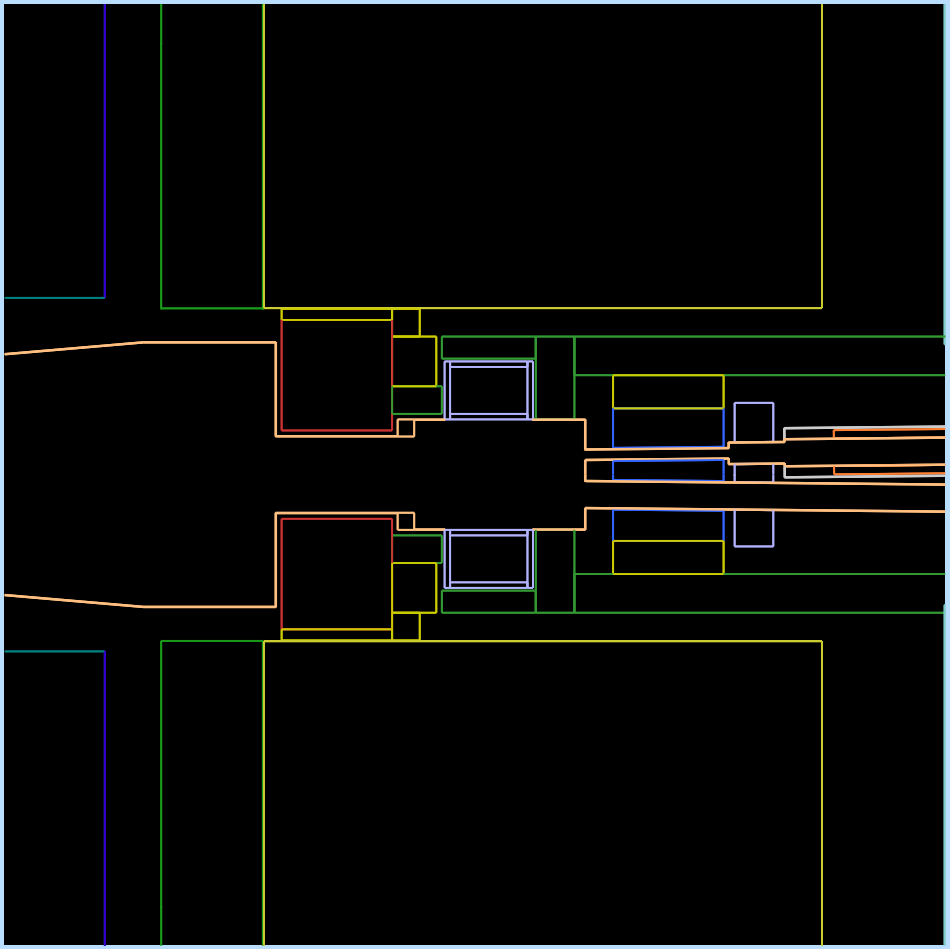


center: z = 3.4 m

Mokka Geometries – Crossing Angle



crossing angle: 20 mrad



center: z = 3.4 m

Mokka Plugins – Little Helpers

Plugins allow modular customisation of Mokka

- hooks to Geant 4 steps, tracks, events, and runs
- any other custom initialisation (e. g. new commands)

Visualisation Plugin

- project events into a plane (*xy*, *xz*, *yz*, *rz*)
- assign custom colours to particles
- hide particles (neutrinos, neutrals, selected)

Magnetic Field Plugin

- pick $\vec{B}(\vec{x})$ from the command line (for debugging)

First Results

Simulation

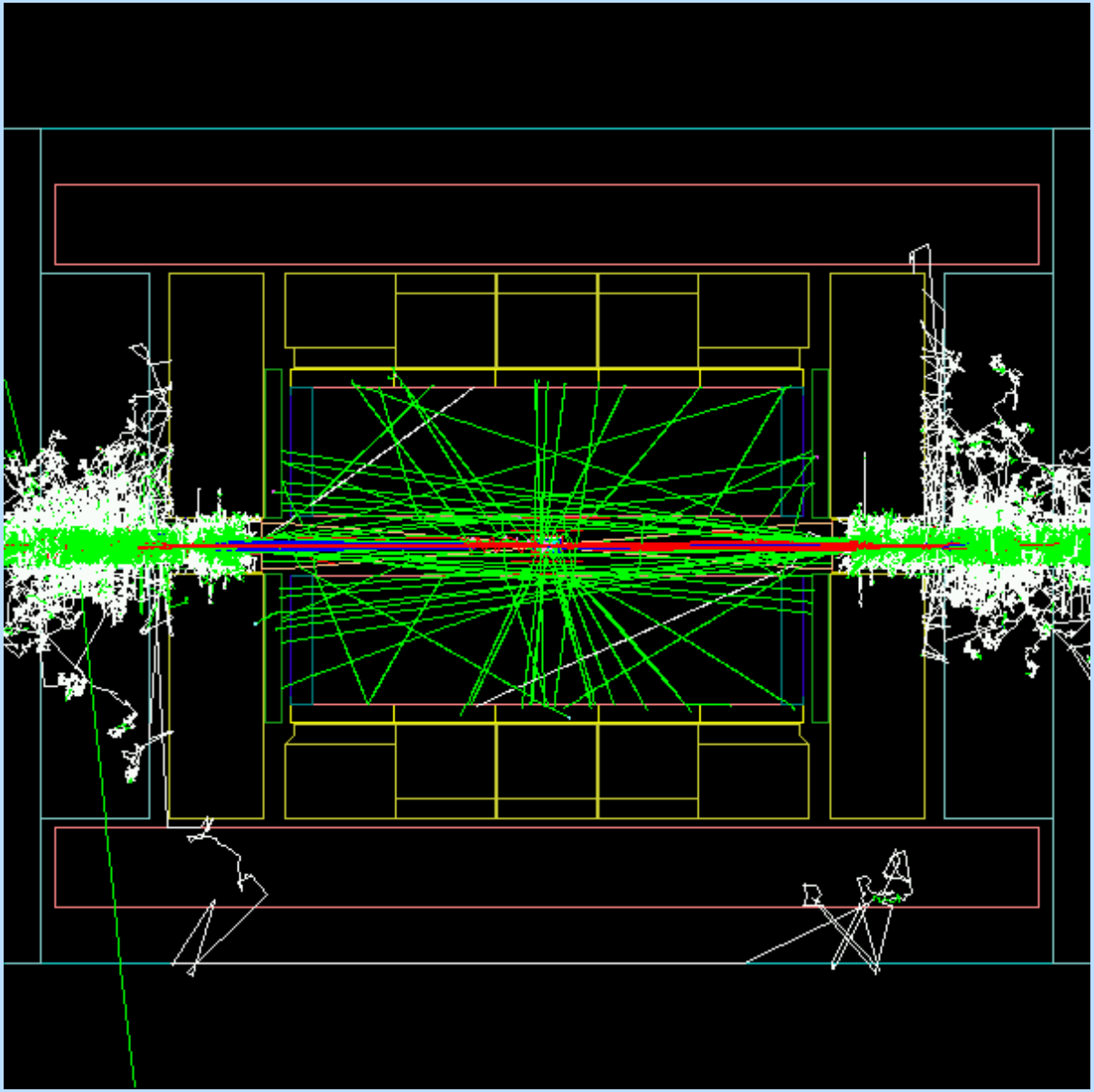
- pairs from one BX (130 000 particles)
- physics list with neutron production
- geometry from Stahl proposal, head-on
- TPC filled with pure Argon (for now)
- standard production and energy cuts

Analysis

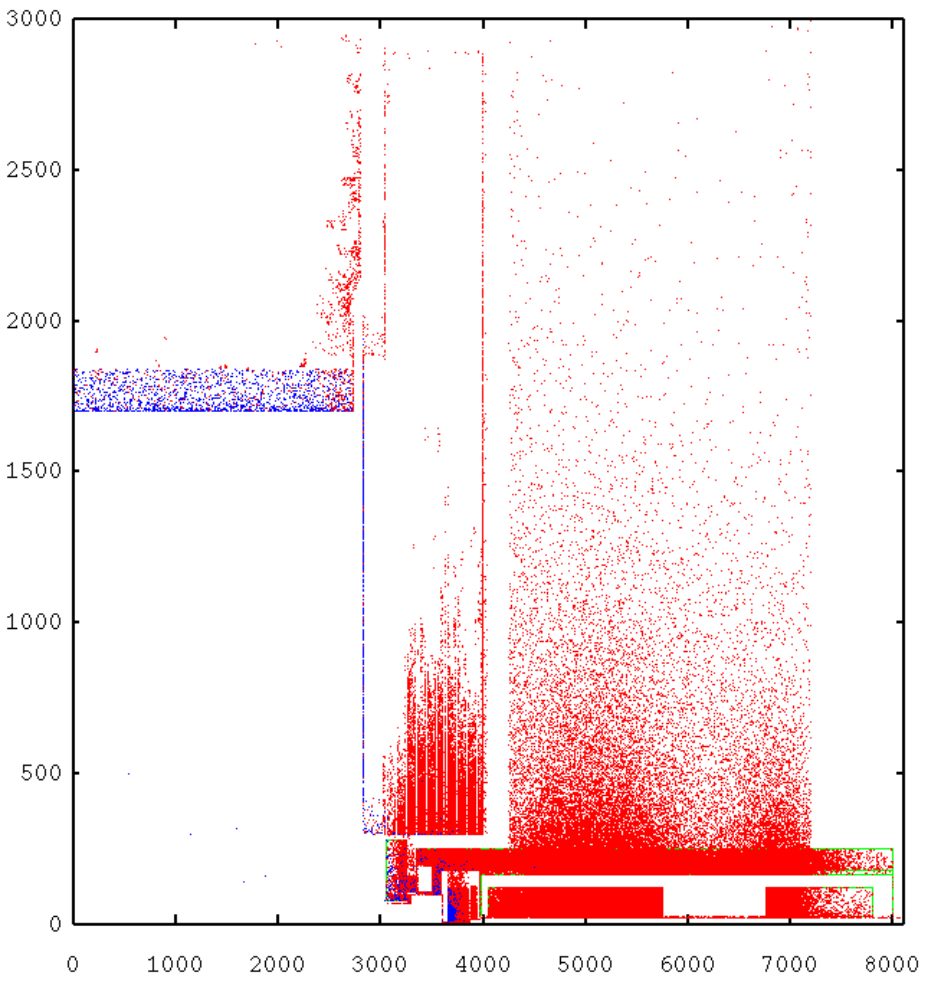
- where are neutrons produced?
- which of these reach the TPC?

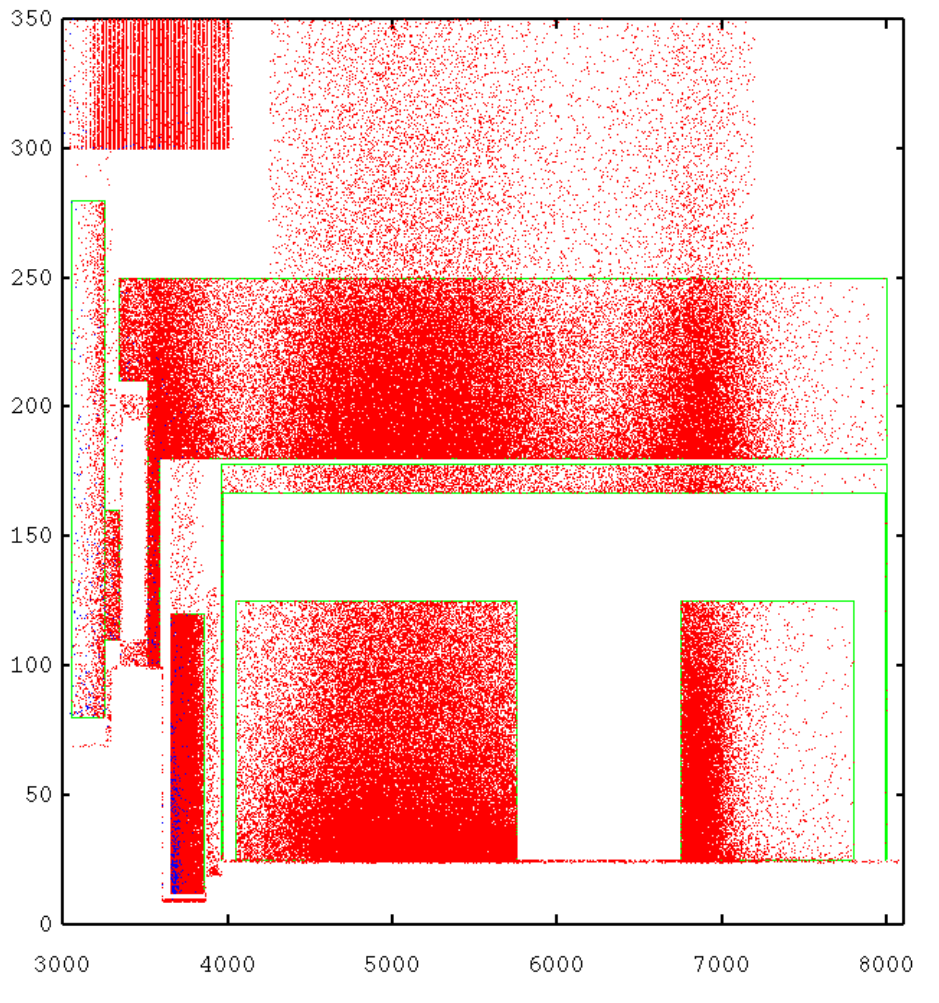
Example Events

- 1000 particles ($\approx$ 1/100 BX)
- projected onto *rz* plane
- neutrons shown in white colour



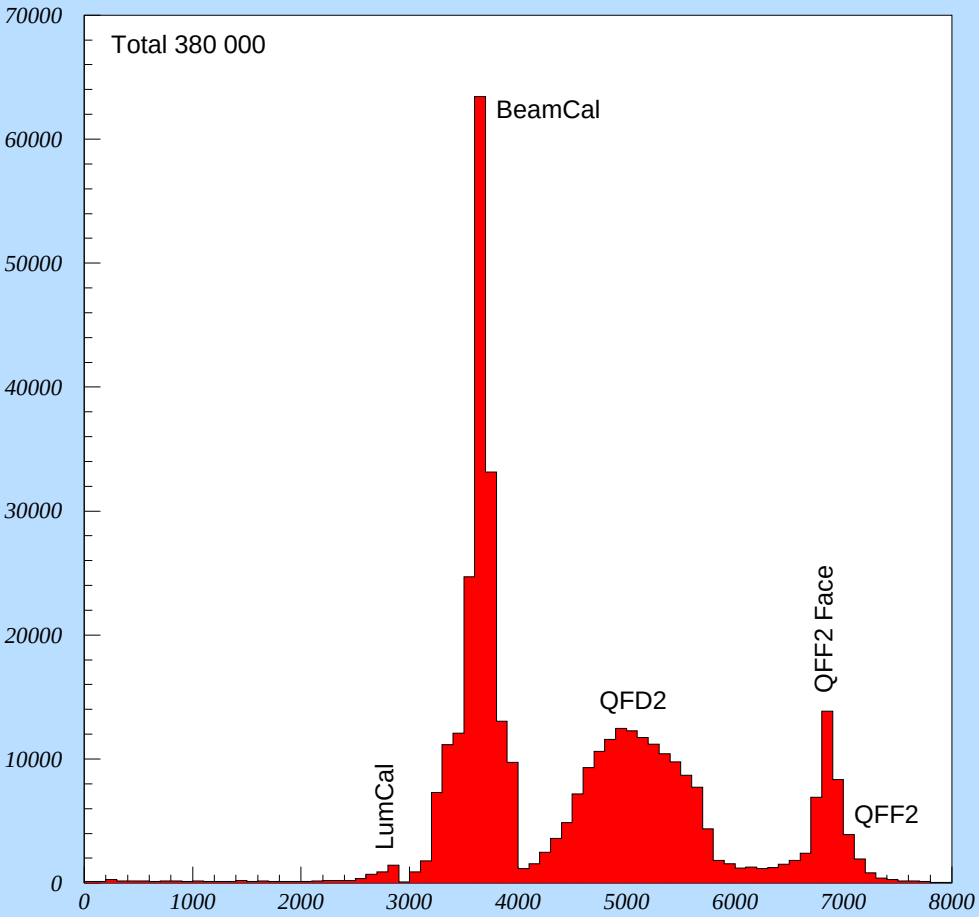
Neutron Production – Cross Section



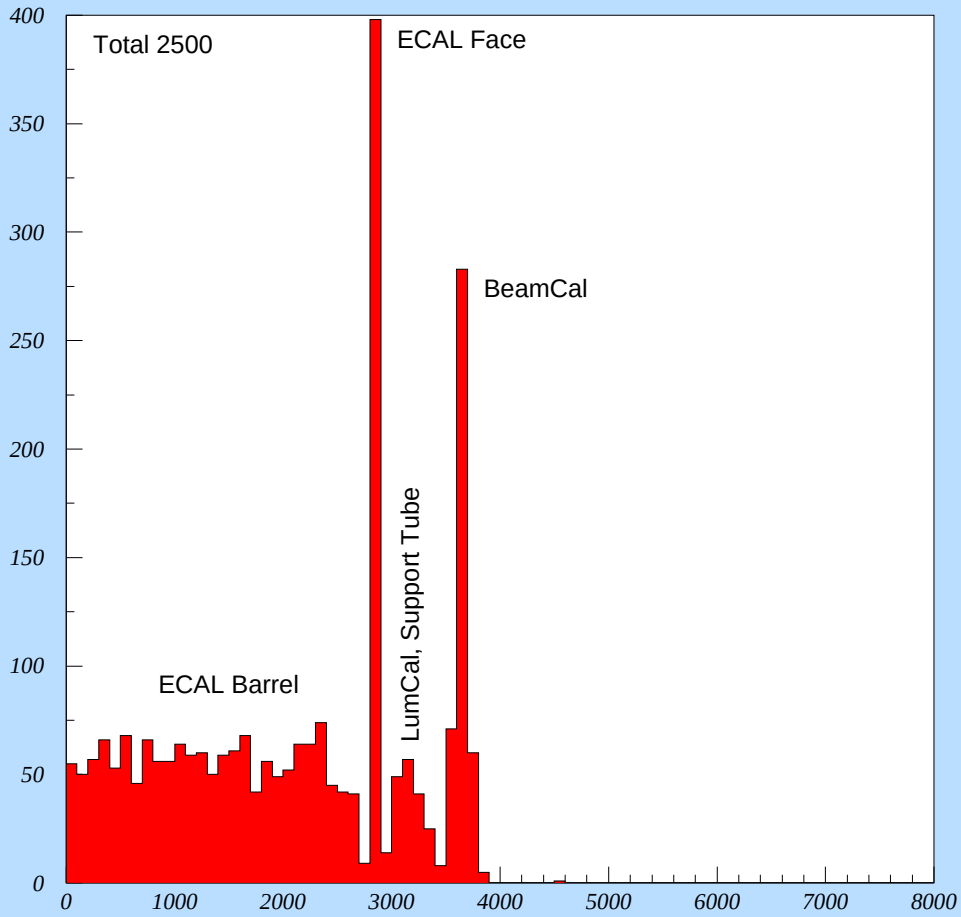


Origins of neutrons (blue ones reach the TPC)

Neutron Production – Distances



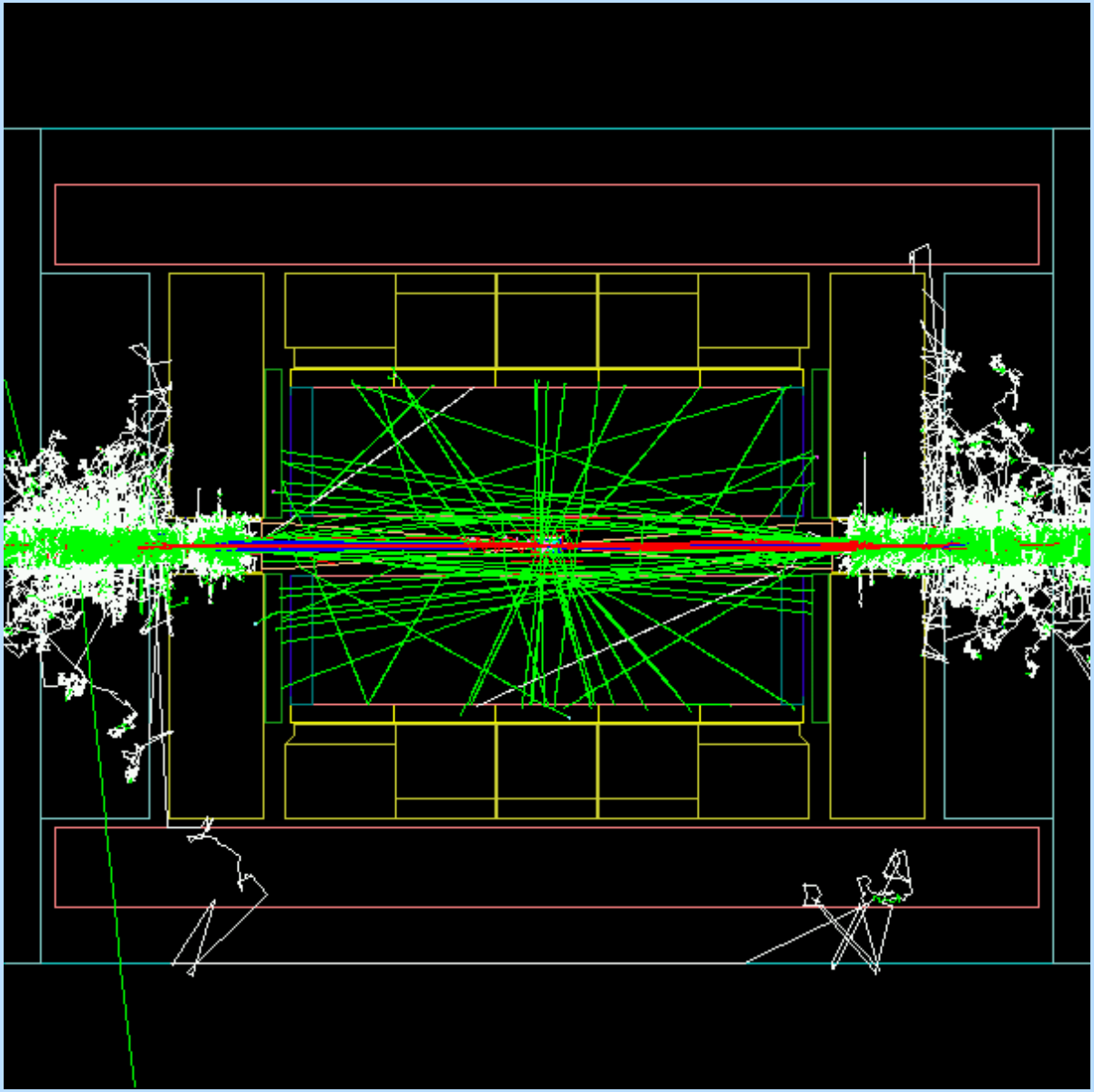
Origins of neutrons. . .



. . . reaching the TPC

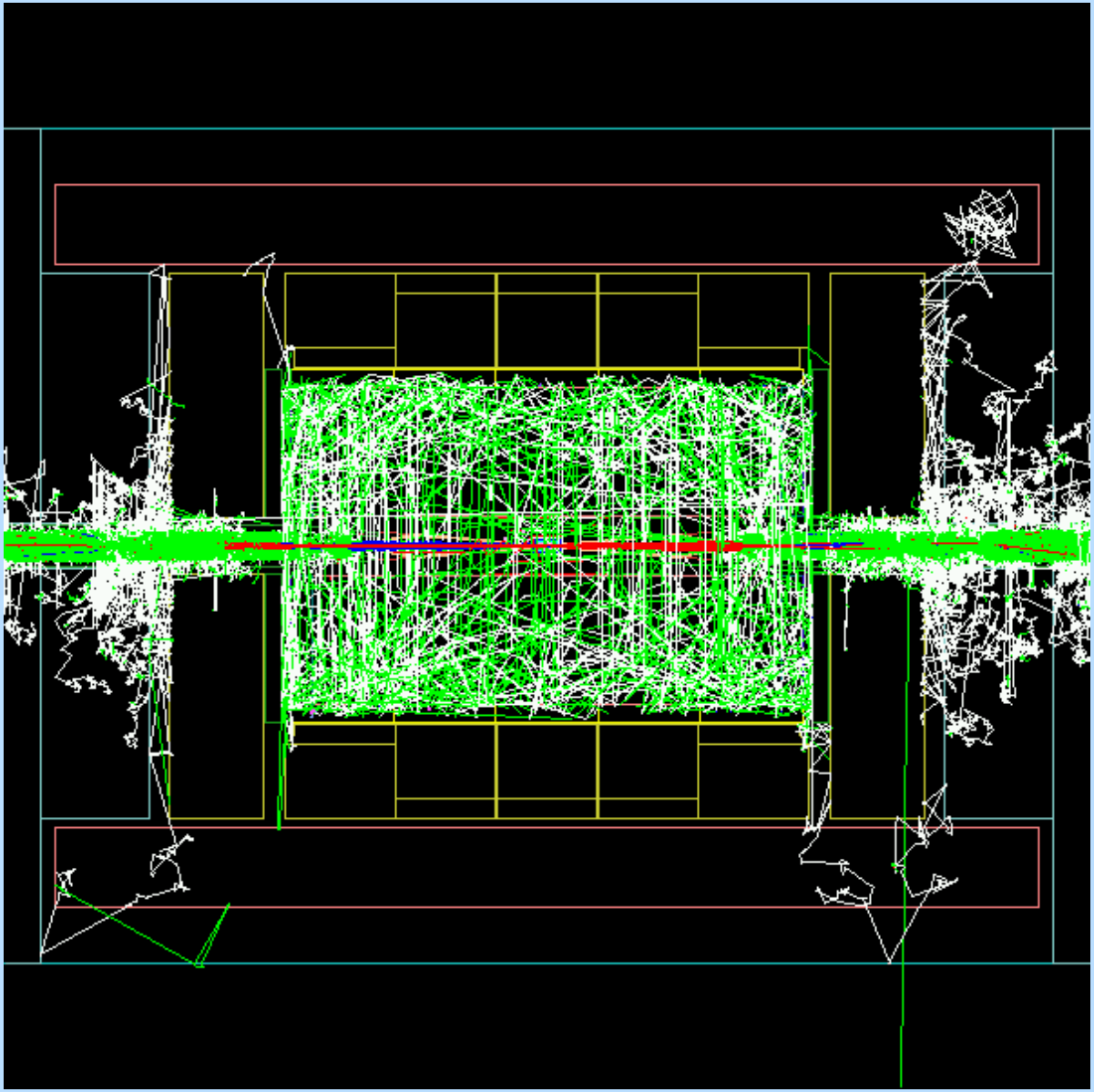
Example Events – Stahl Proposal

- 1000 particles (≈ 1/100 BX)
- Stahl proposal, head-on



Example Events – TDR Layout

- same particles
- TDR layout
- neutrons are produced inside the TPC volume
- neutrons create photons in the calorimeters
- preliminary!
- to be compared with G. Wagner



Next Steps

More detailed analysis

- energy spectrum of neutrons
- neutron production details

Further studies

- effects of different geometries
- influences of gas mixtures in the TPC
- background hits in the subdetectors
- comparison with earlier results

Mokka development

- arbitrary visualisation cuts? (with OpenGL)