Simulations of Neutron Background in an ILC TPC using Geant 4

First Results from Mokka

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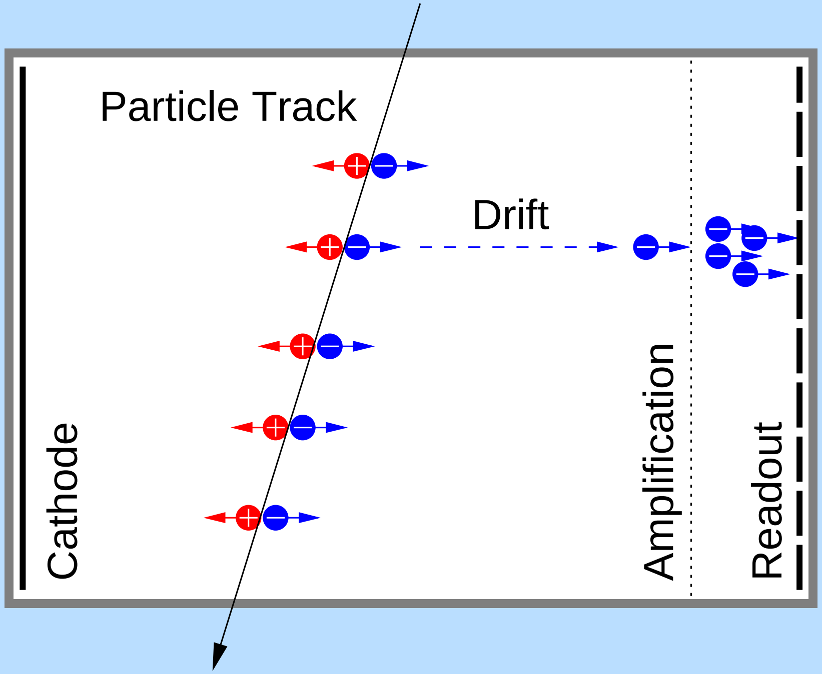
TPC – Time Projection Chamber

Principle of operation



- large chamber filled with gas
- tracks from ionising particles drift in a hom. electric field
- signals are amplified and read out at the endplates
- $r\varphi$ measured directly, z from drift time ("projection")

Advantages of a TPC

- good point resolution (goal: $\sigma_{r\varphi} \approx 100\,\mu m$, $\sigma_z \approx 1\,mm$)
- large number of 3D points, robust pattern recognition
- minimum of material in front of calorimeters

Effects of Neutrons

In the TPC

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

In other detectors

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

General issues

- the closer created to the IP, the more dangerous!
- bouncing, channelling, thermalisation

Simulation Tools

Guinea Pig

- simulates beam-beam interaction
- generates (among others) e^+e^- pair particles

Brahms

- simulates interaction of particles with the detector
- based on old Geant 3, Fortran

Mokka

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

Geant 4 Physics Lists in Mokka

`PhysicsList` (Mokka built-in)

- doesn’t support neutron production at all

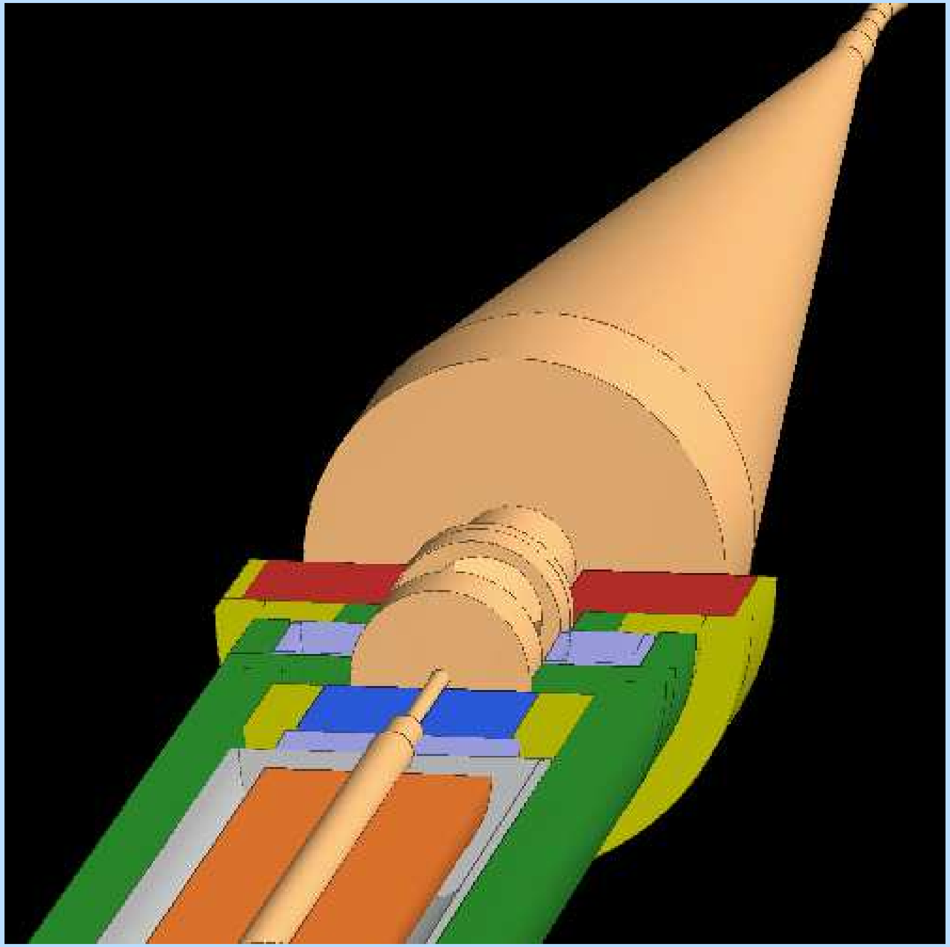
`LCPhys` (dedicated Linear Collider physics list)

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

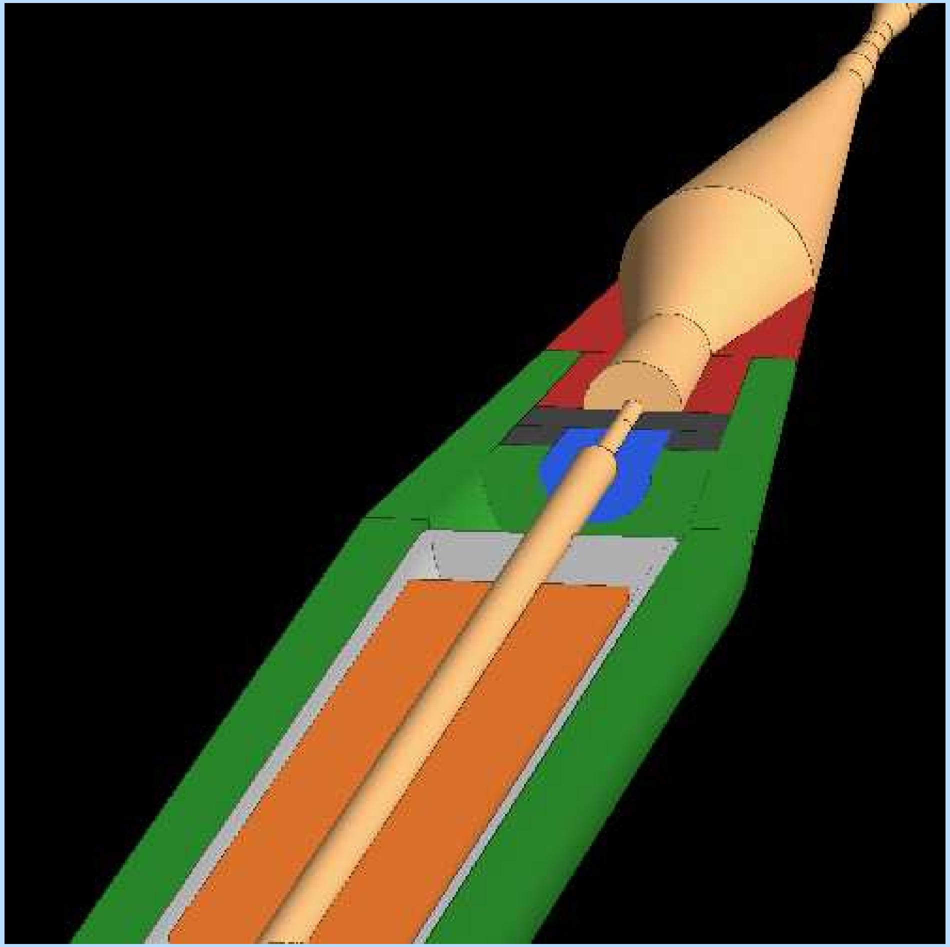
`PhysicsListNeutrons` (extended `PhysicsList`)

- enables electro-nuclear processes (`EM_GNPhysics`)
- uses high-precision neutron models (`QGSP_HP`)
- features scattering, moderation, interactions with gas

Geant 4 Detector Geometries in Mokka



Stahl proposal
($L^* = 4.05\,\mathrm{m}$)



TDR layout
($L^* = 3.00\,\mathrm{m}$)

First Results

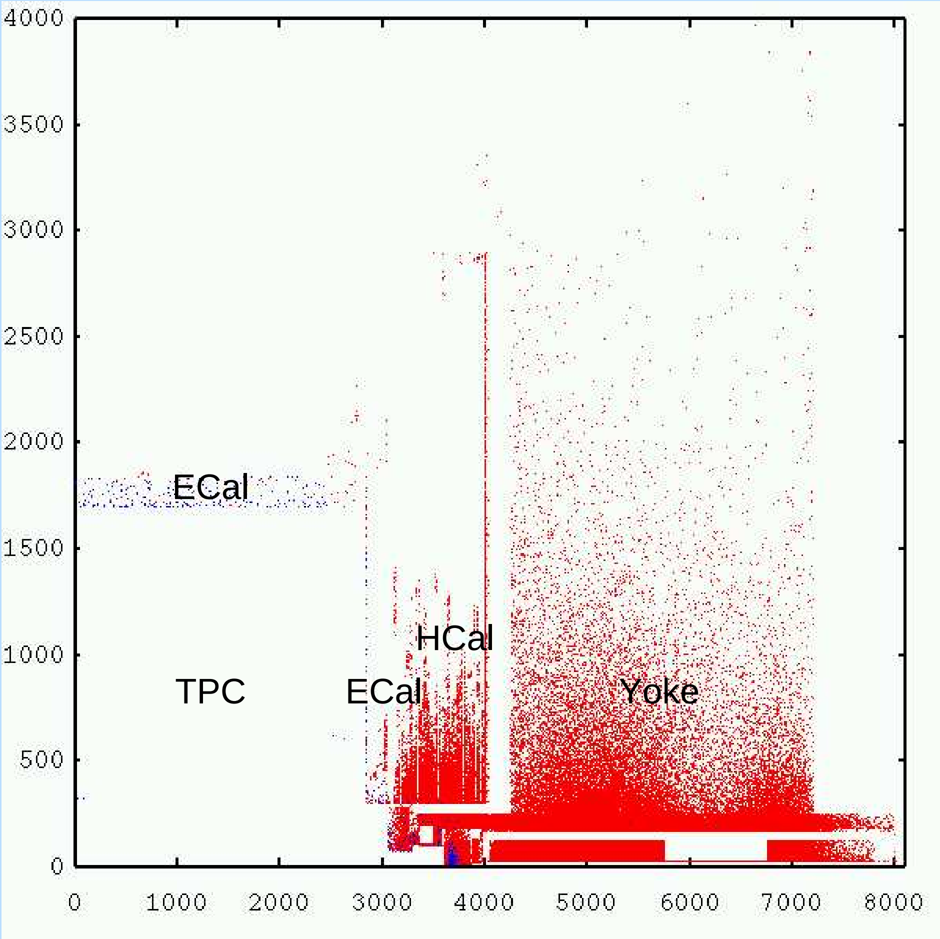
Simulation

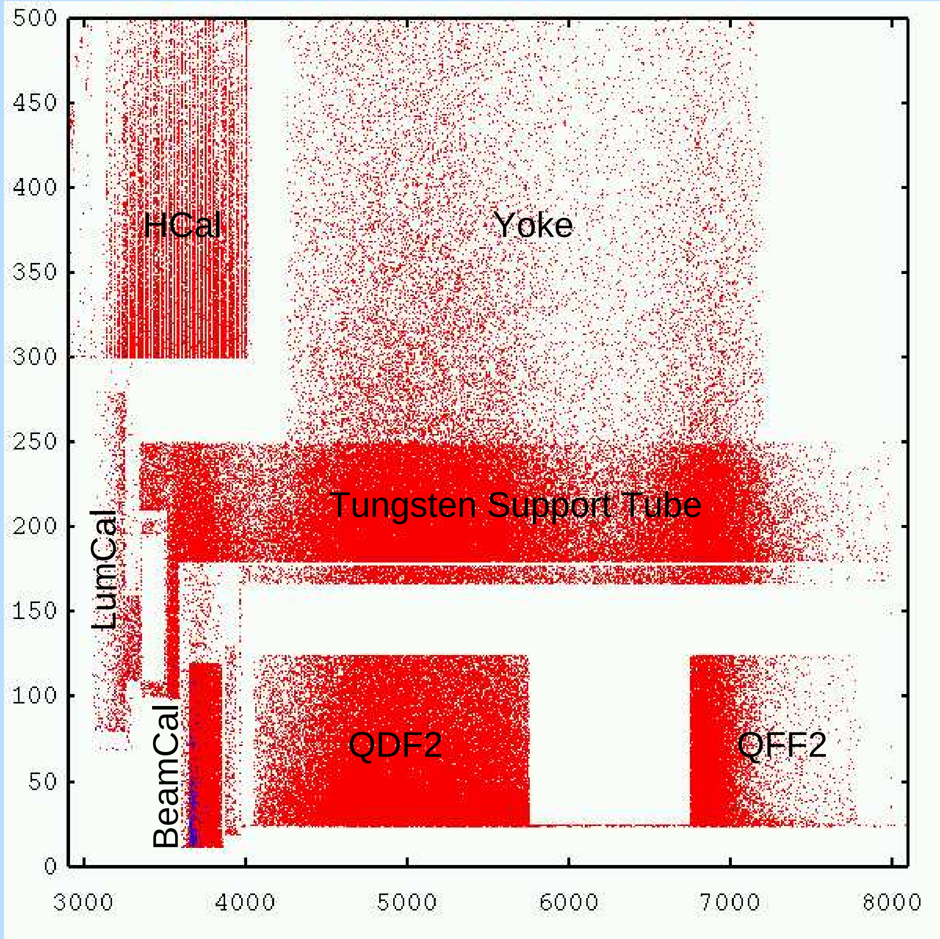
- pairs from one BX (130 000 particles)
- physics list with neutron production
- geometry from Stahl proposal, head-on
- TPC filled with TDR gas (93% Ar, 5% CH_4, 2% CO_2)
- standard production and energy cuts, no TPC cut

Analysis

- where are neutrons produced?
- which of these reach the TPC?
- what energies do they have?

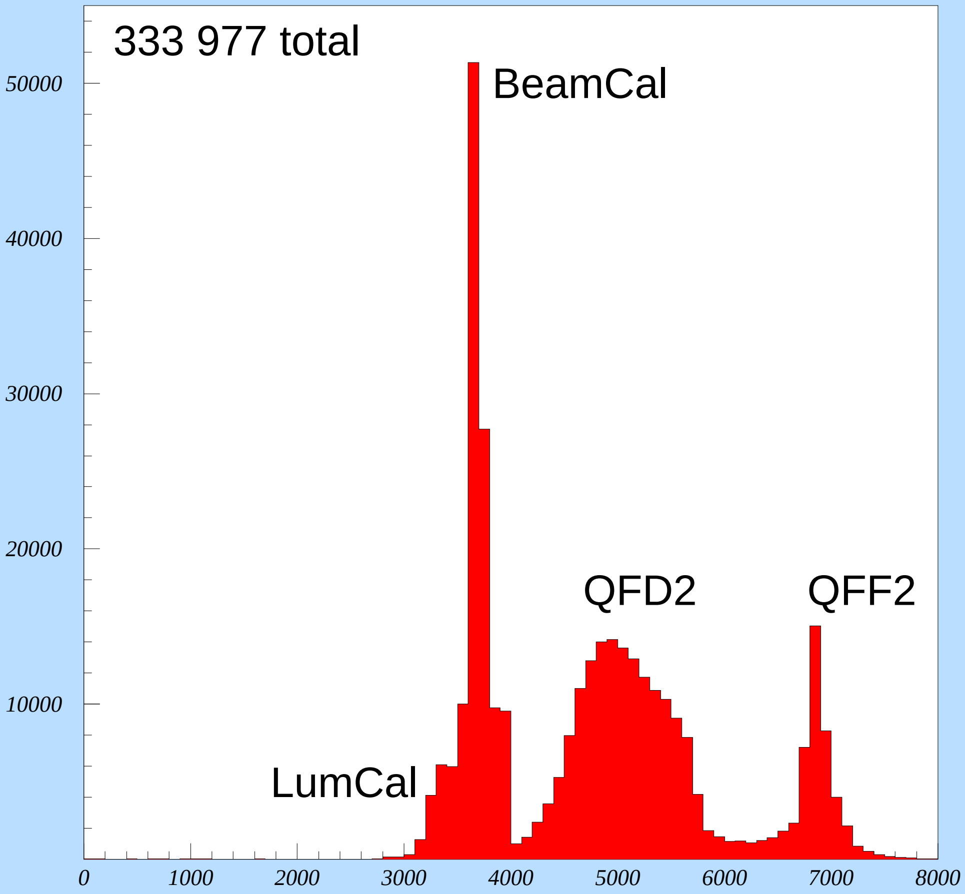
Neutron Production – Cross Section



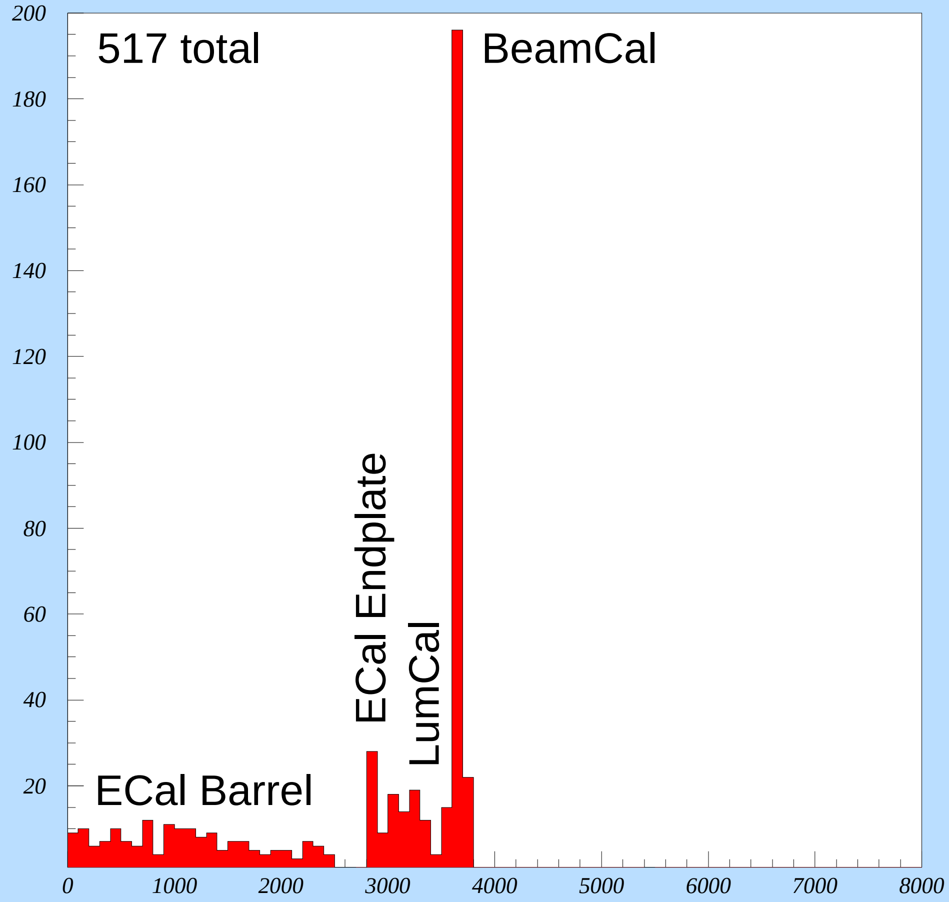


Origins of neutrons (blue ones reach the TPC)

Neutron Production – Distances

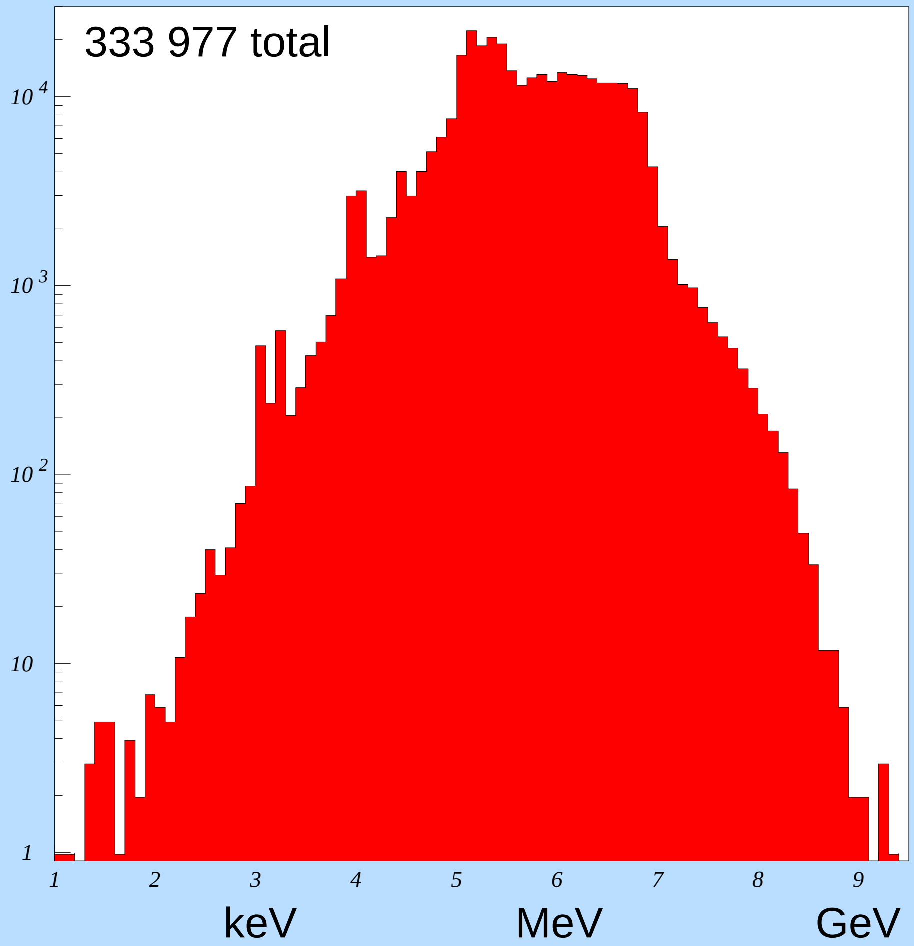


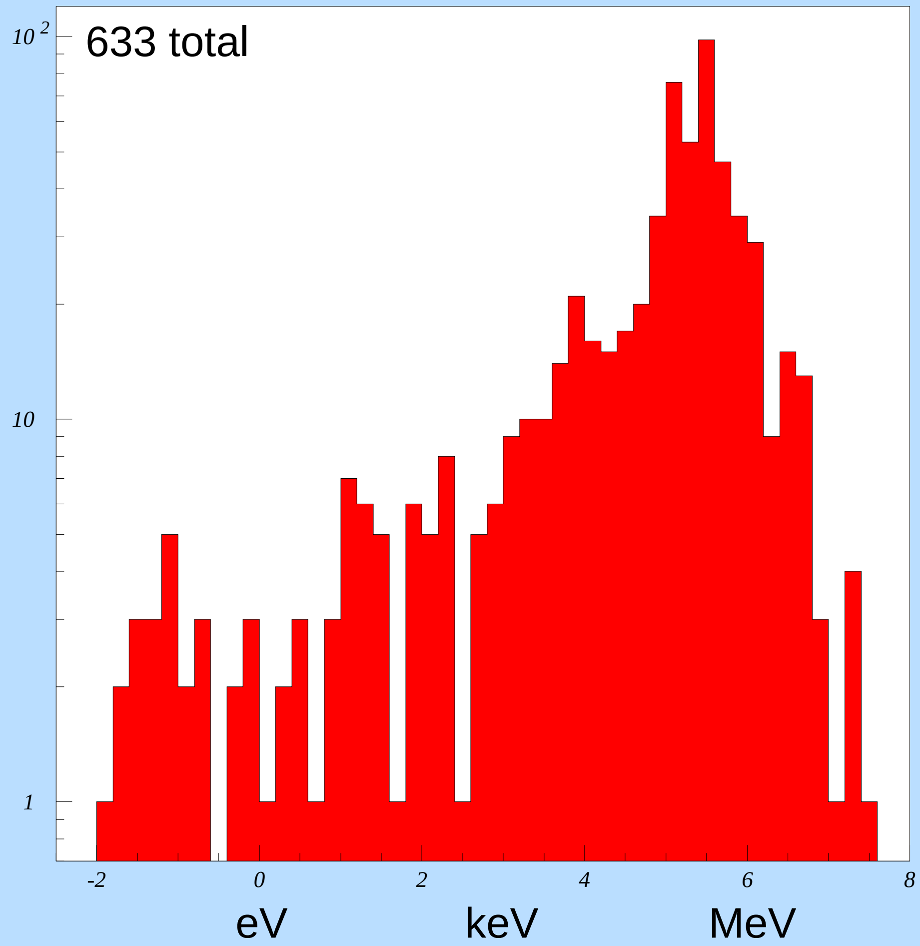
Origins of neutrons. . .



. . . reaching the TPC

Neutron Production – Energies

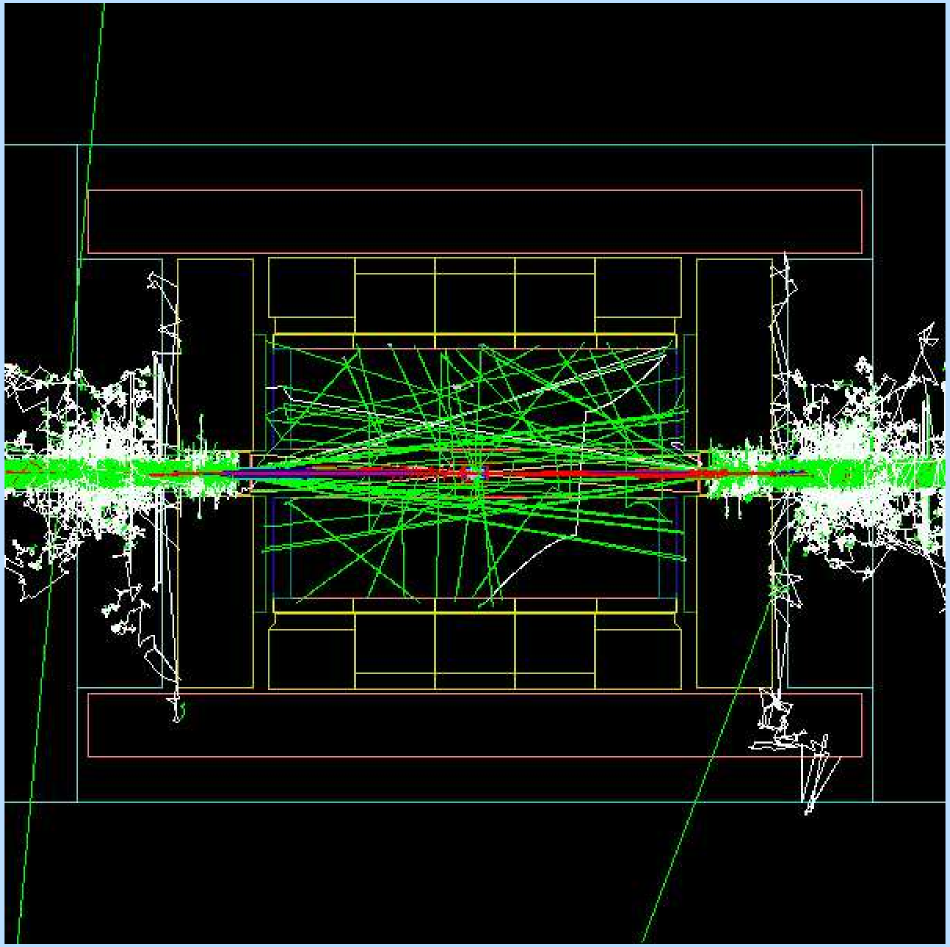


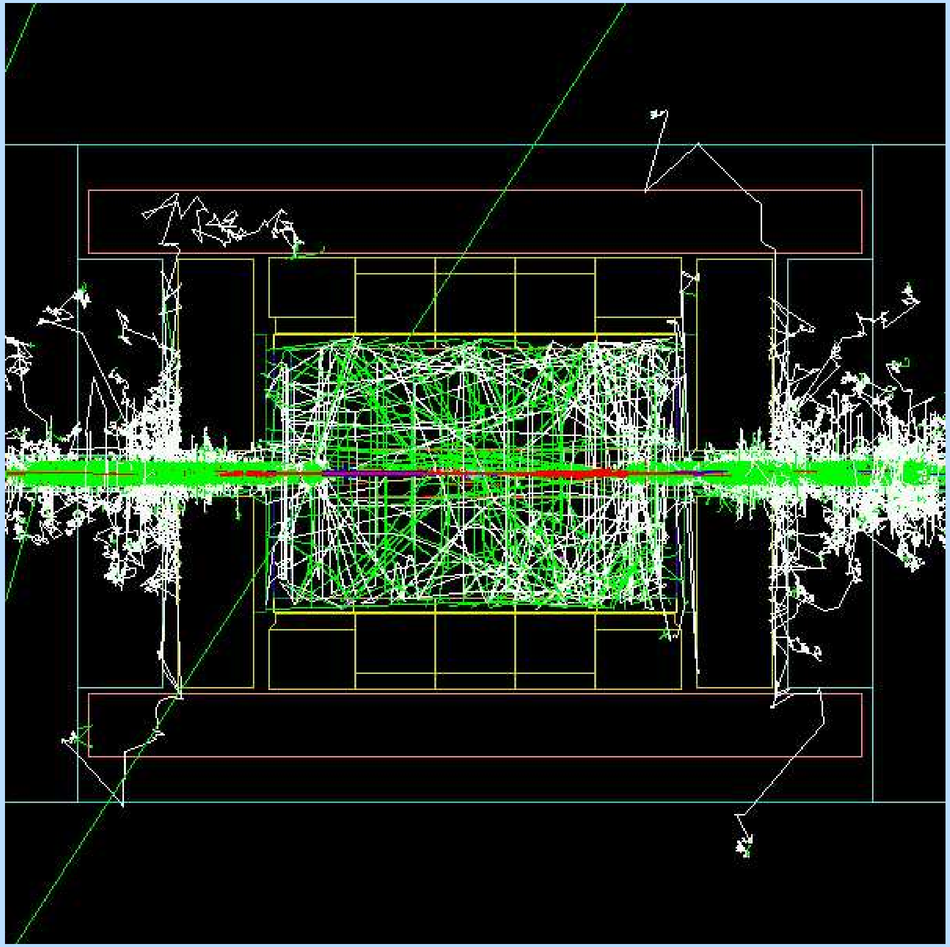


Energies of neutrons. . .

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

Comparison Stahl vs. TDR – Events





Stahl proposal TDR layout

Tracks created by 1000 pair particles (≈ 1/100 BX)

Comparison Stahl vs. TDR – Numbers

	Stahl	TDR
Total neutrons per BX	333977	413286
Neutrons reaching TPC	517	10959
Bouncing neutrons	20%	20%
Total TPC hits	5361	9881

Only preliminary!

- simulation of one single BX – need more statistics
- how many hits are caused by neutron scattering?

Outlook

Next steps:

- comparison with earlier results (G. Wagner)
- better understanding of Geant 4 mechanisms (particle creation, tracking, killing)
- better handling of low-energy neutrons down to thermalisation (fall back to Fluka?)
- simulation of neutron diffusion and decay
- simulations with different gas mixtures

Final goal:

- estimate of all background tracks in the TPC at a given time (with superposition of 160 BX)