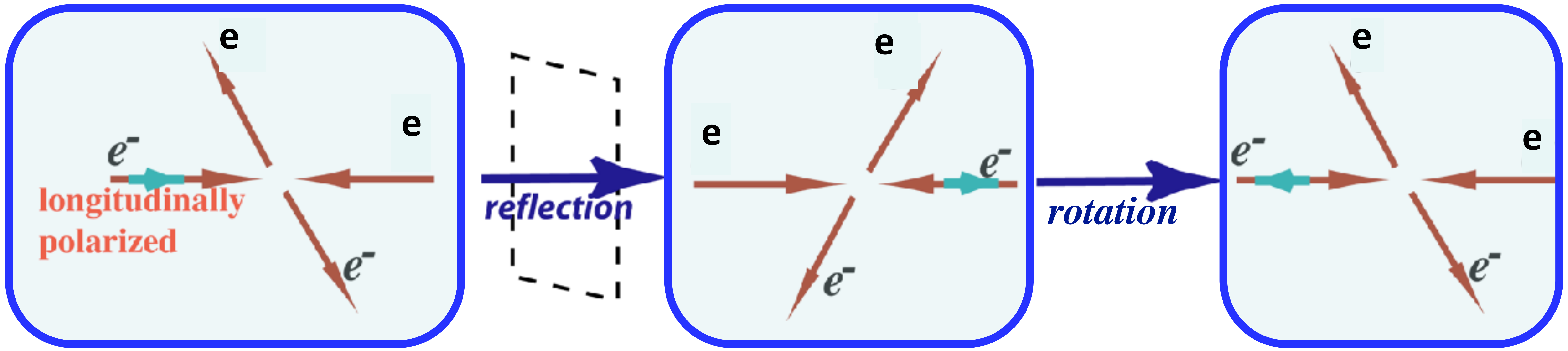
MOLLER Experimental Apparatus Overview

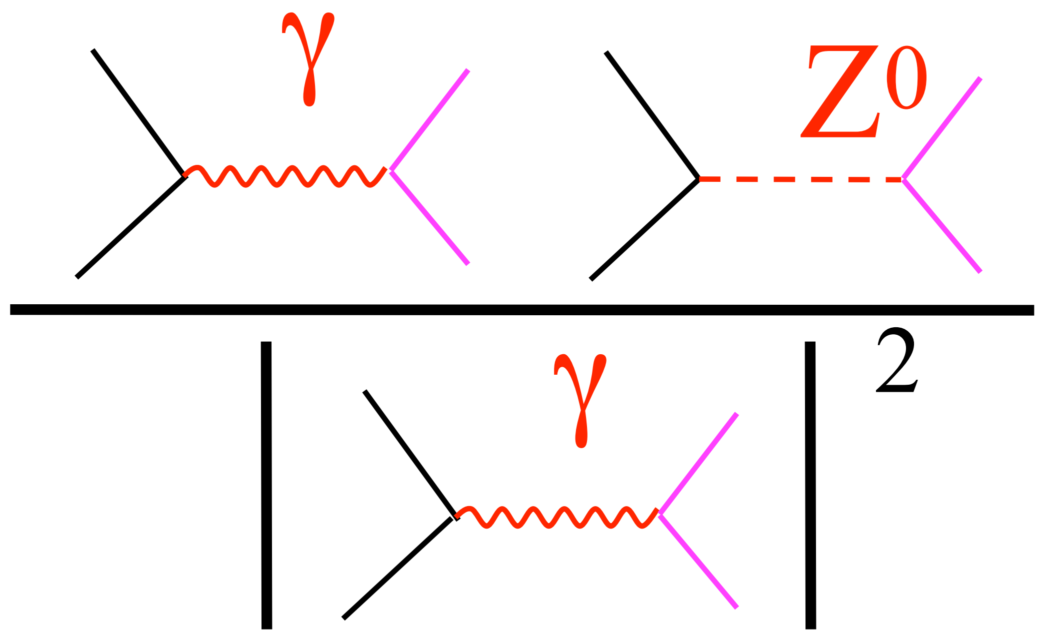
Kent Paschke

Electron Scattering and Parity-Violation



- Incident beam is longitudinally polarized
- Change sign of longitudinal polarization
- Measure fractional rate difference

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} \sim$$

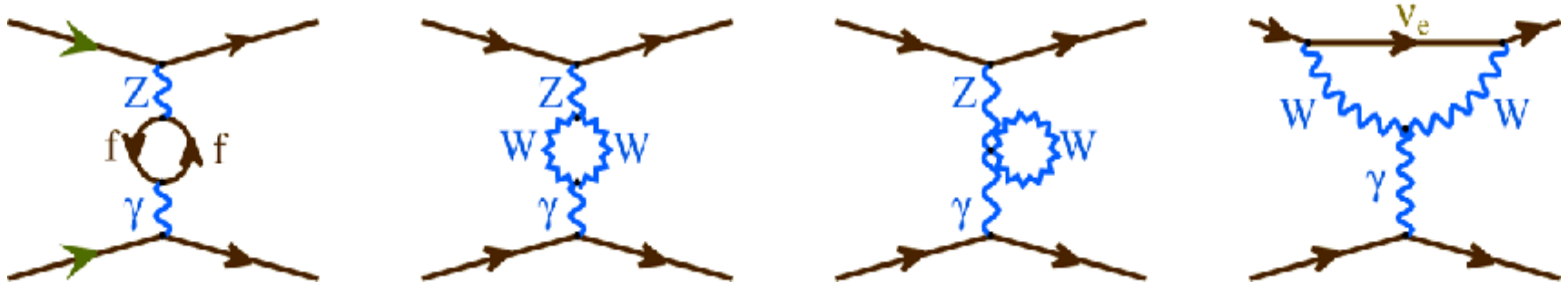


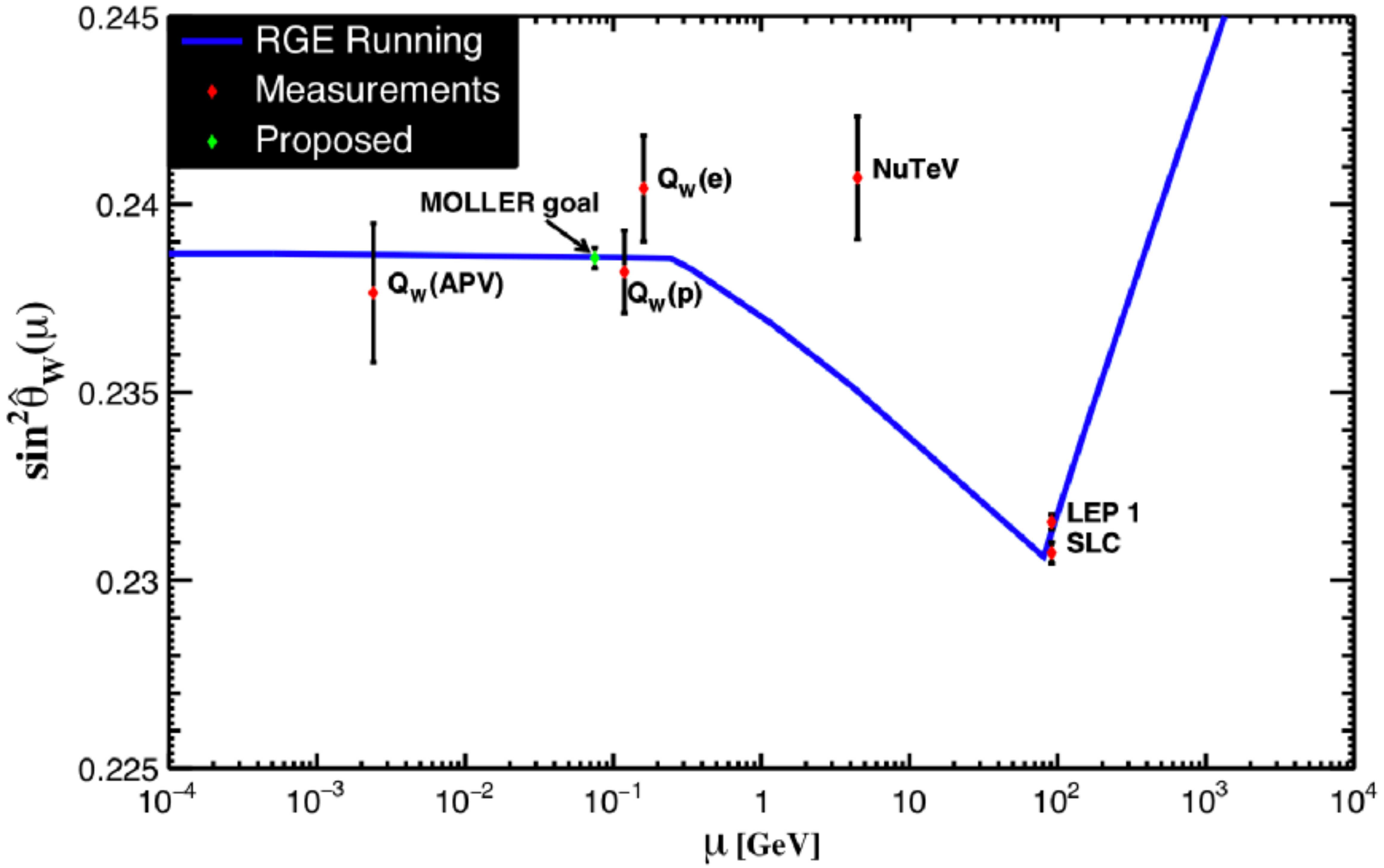
$$\propto \frac{|\mathcal{M}_Z|}{|\mathcal{M}_\gamma|}$$

Measuring ee elastic (Møller) scattering

$$A_{PV} \propto Q_W^e = 1 - 4\sin^2\theta_W$$

The Weak Mixing Angle





Renormalization scheme defines $\sin^2\theta_W$ at the Z-pole.

γ-Z mixing and other diagrams are absorbed into the coupling constant

At the Z-pole - measuring properties of the SM Z^0 boson

Off the Z-pole, low-energy measurements are sensitive to (new) parity-violating interactions

$\delta(\sin^2\theta_W) = \pm\ 0.00024$ (stat.) $\pm\ 0.00013$ (syst.) ⇨ ***~ 0.1%***

Matches best collider (Z-pole) measurement!

MOLLER

parity-violation in $e^- e^-$ elastic scattering

$A_{PV} = 35.6$ ppb

$\delta(A_{PV}) = 0.73$ parts per billion

$\delta(Q^e_W) = \pm\, 2.1\,\%\,(stat) \pm 1.0\,\%\,(syst)$

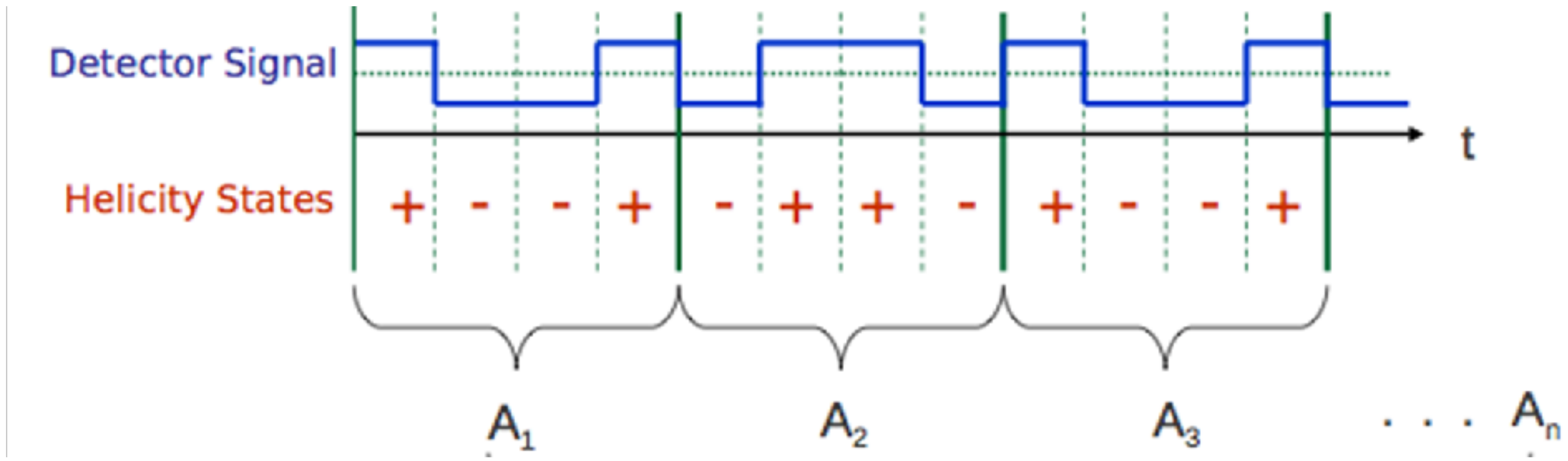
signal rate: 135 GHz

run time: 8200 hours

~3×10^{18} electrons detected

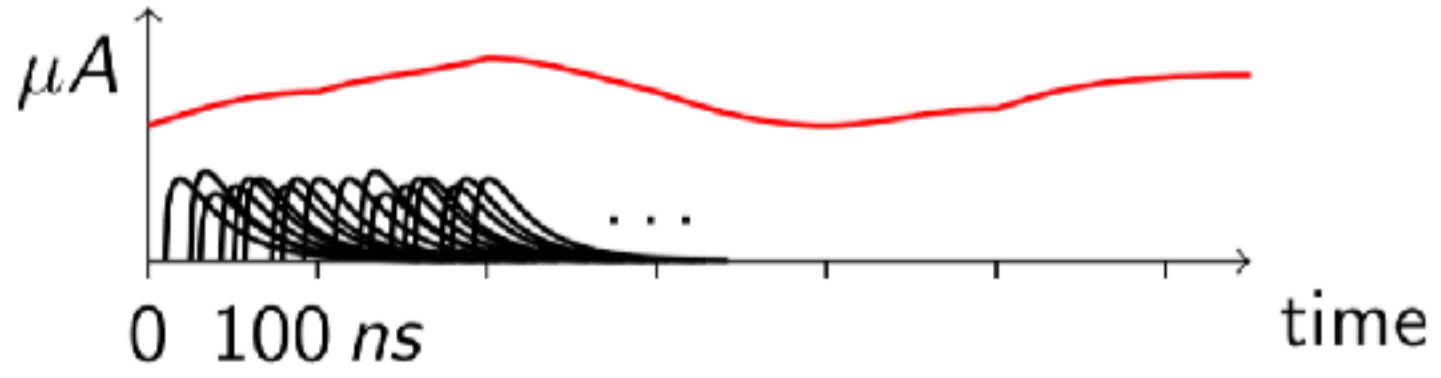
Measuring this small asymmetry

Rapid (2kHz) helicity reversals



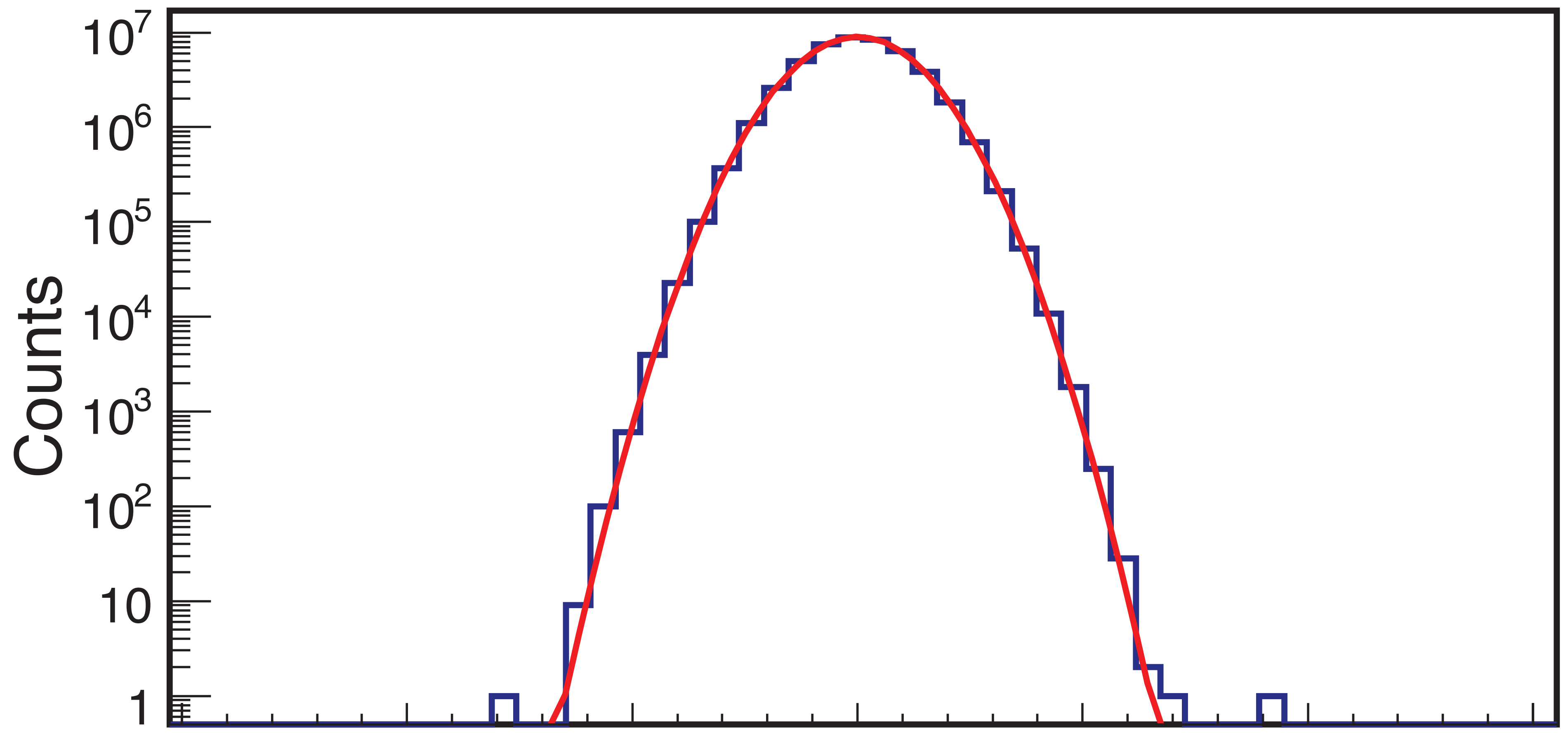
Place a detector where it sees the Møller scattered electron

Analog integrate detector current



Form an asymmetry over the helicity reversal

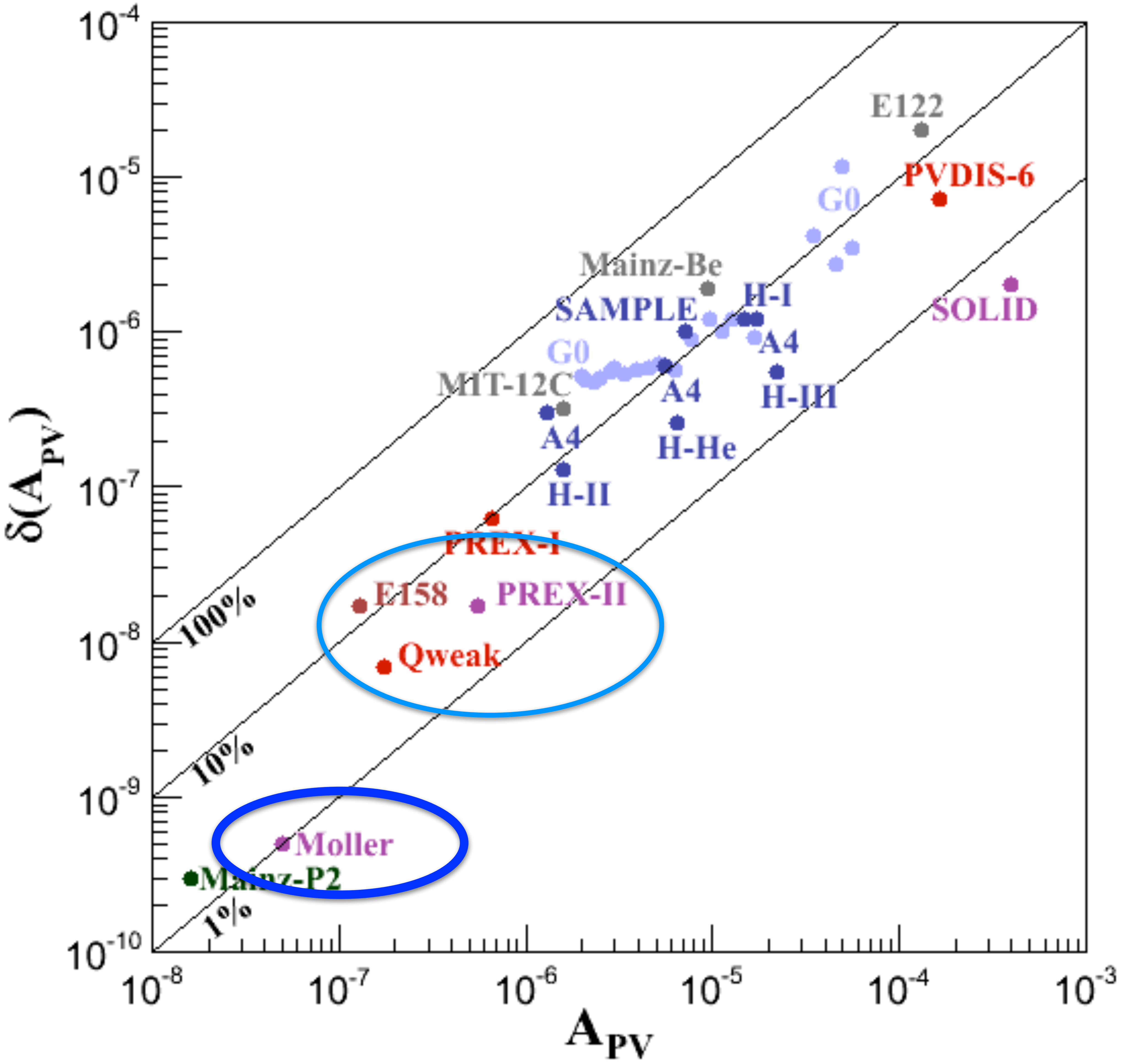
Measure to 0.01% at 1 kHz, repeat for a year straight



Specialized experimental techniques

- Precise spectrometer to separate signal
- Low noise electronics
- Precise beam control and measurement
- …

High Precision

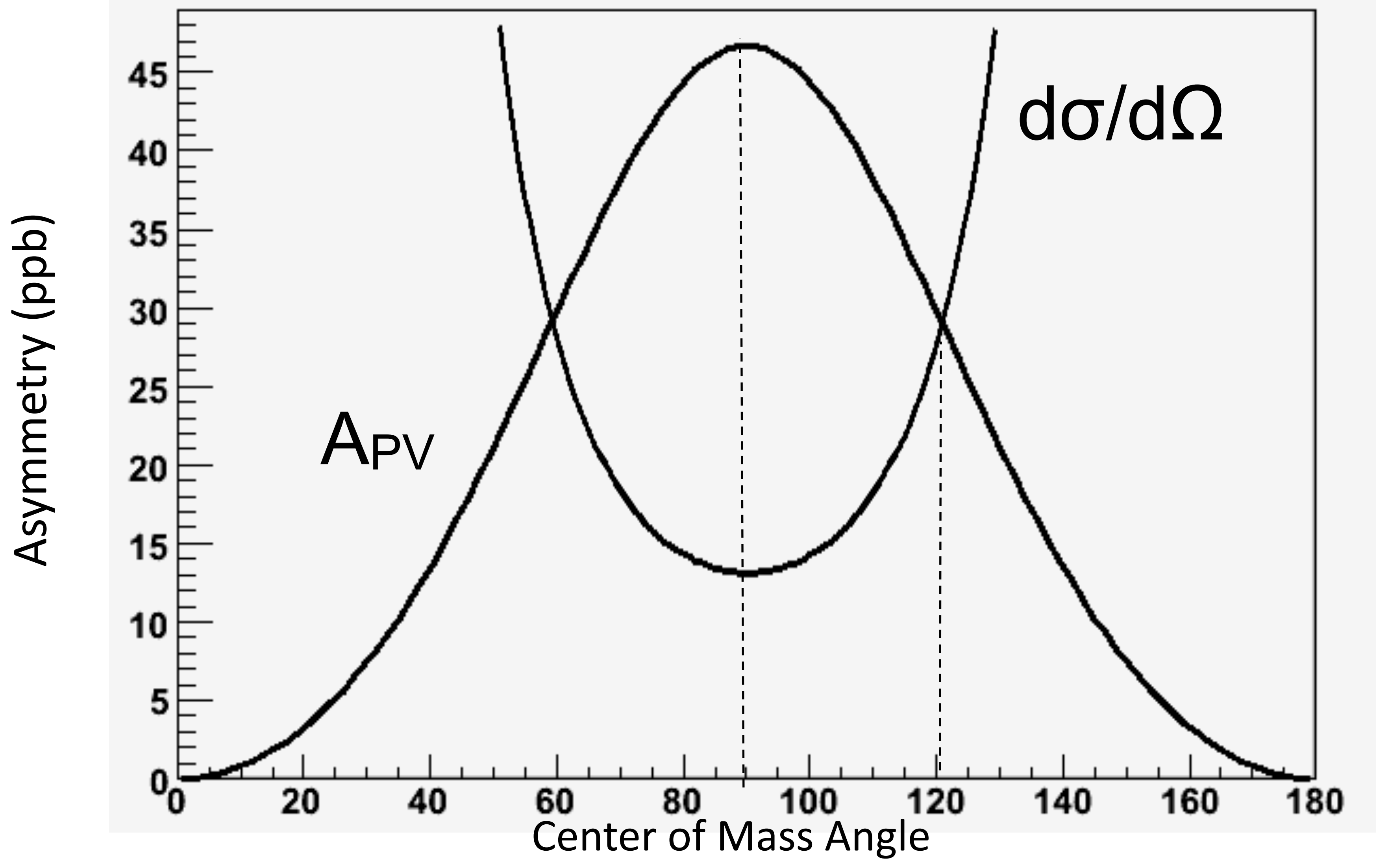


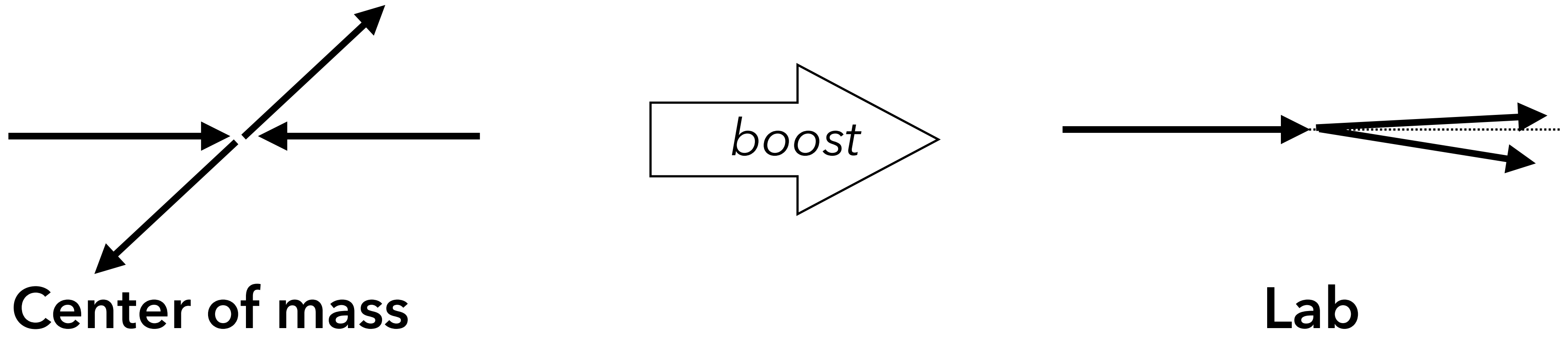
Experimental Overview

Figure of Merit

$$A_{PV} = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L} = mE\frac{G_F}{\sqrt{2}\pi\alpha}\frac{4\sin^2\theta}{(3+\cos^2\theta)^2}Q_W^e$$

Highest figure of merit at $\theta_{CM} = 90^\circ$

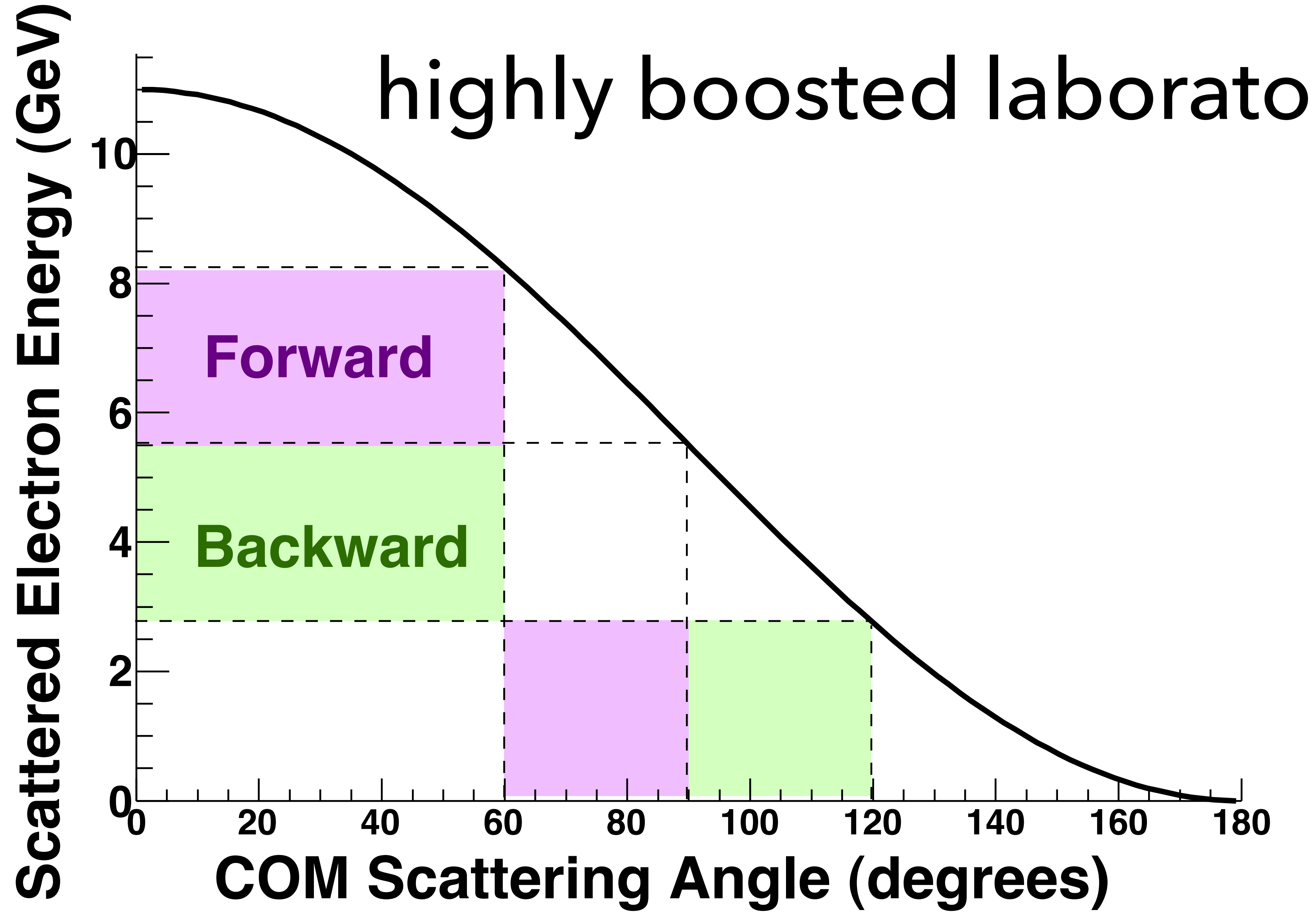




Identical particles.

Measure either forward or backward scattering.

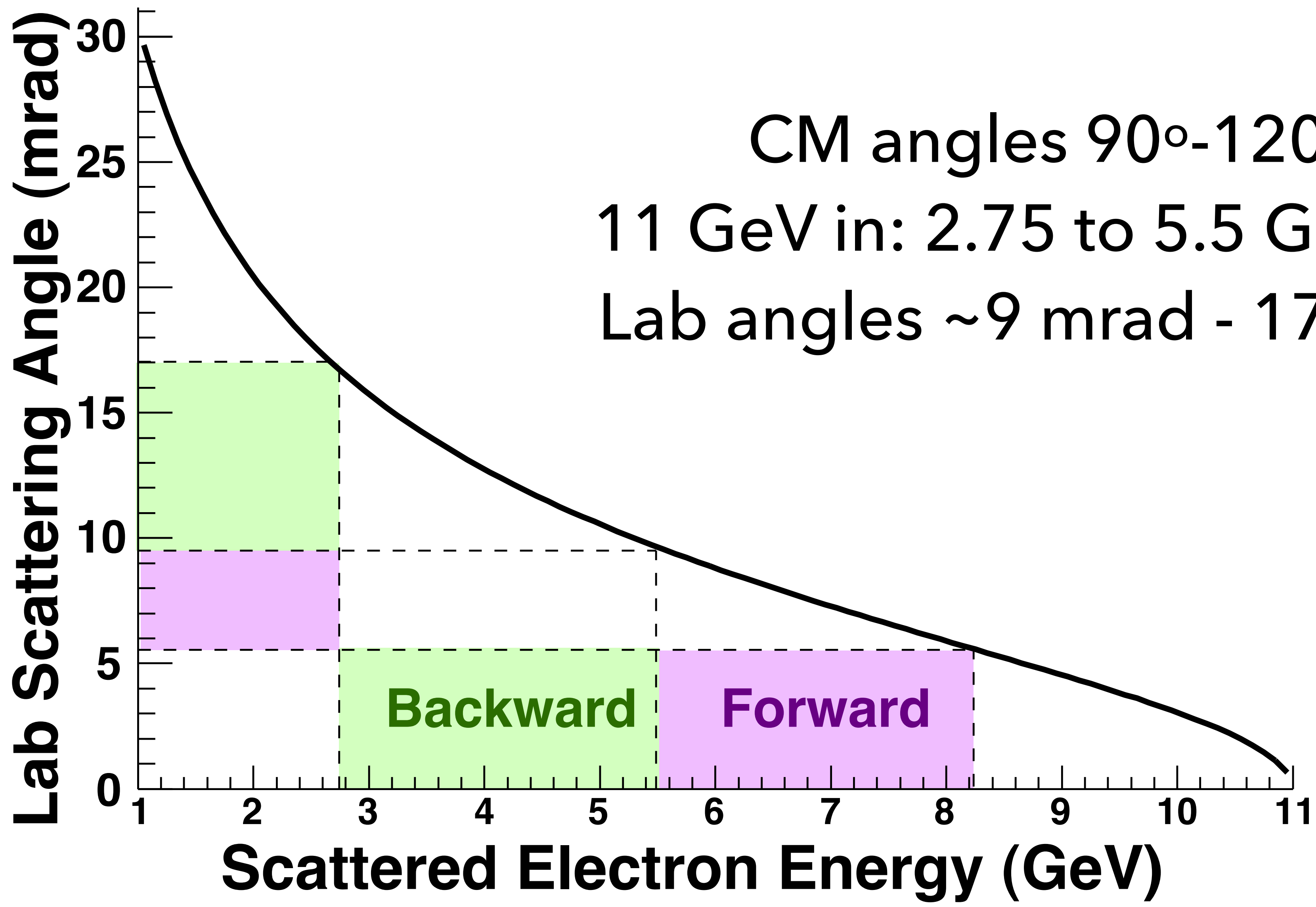
highly boosted laboratory frame



CM angles 90°-120°

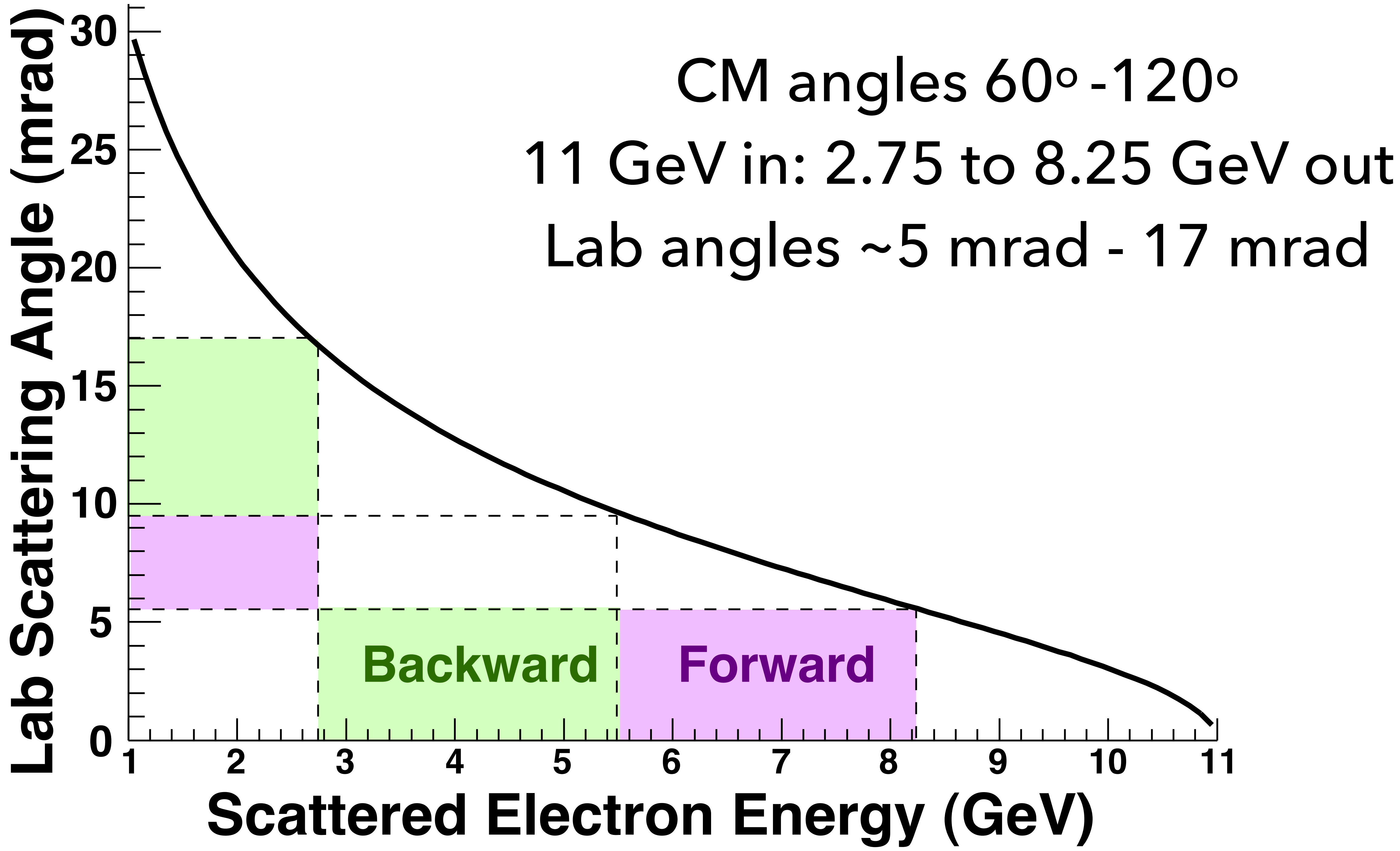
11 GeV in: 2.75 to 5.5 GeV out

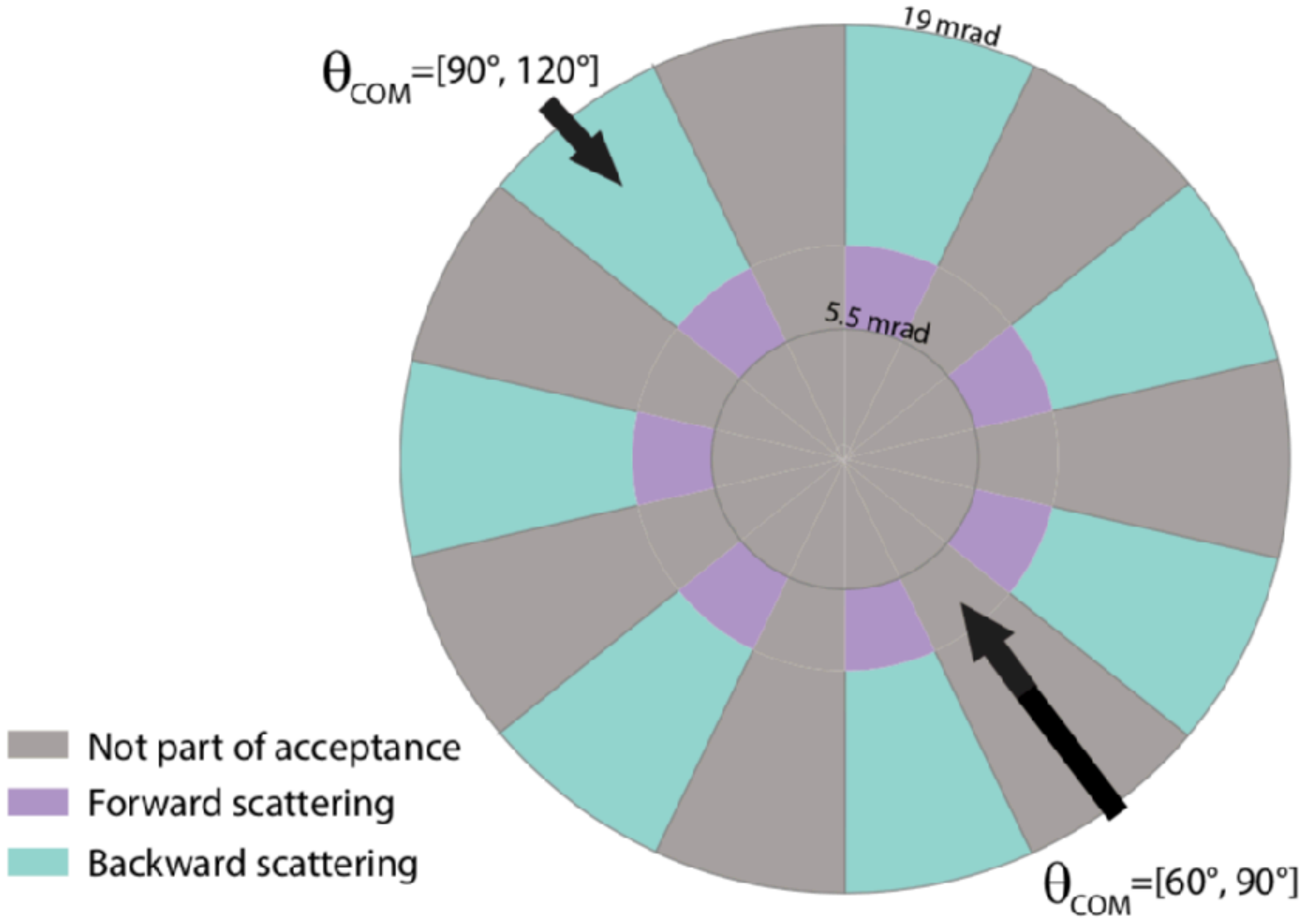
Lab angles ~9 mrad - 17 mrad



Identical Particles

Since you only need either the forward or the backward scatter, accept forward+backward for half the azimuth

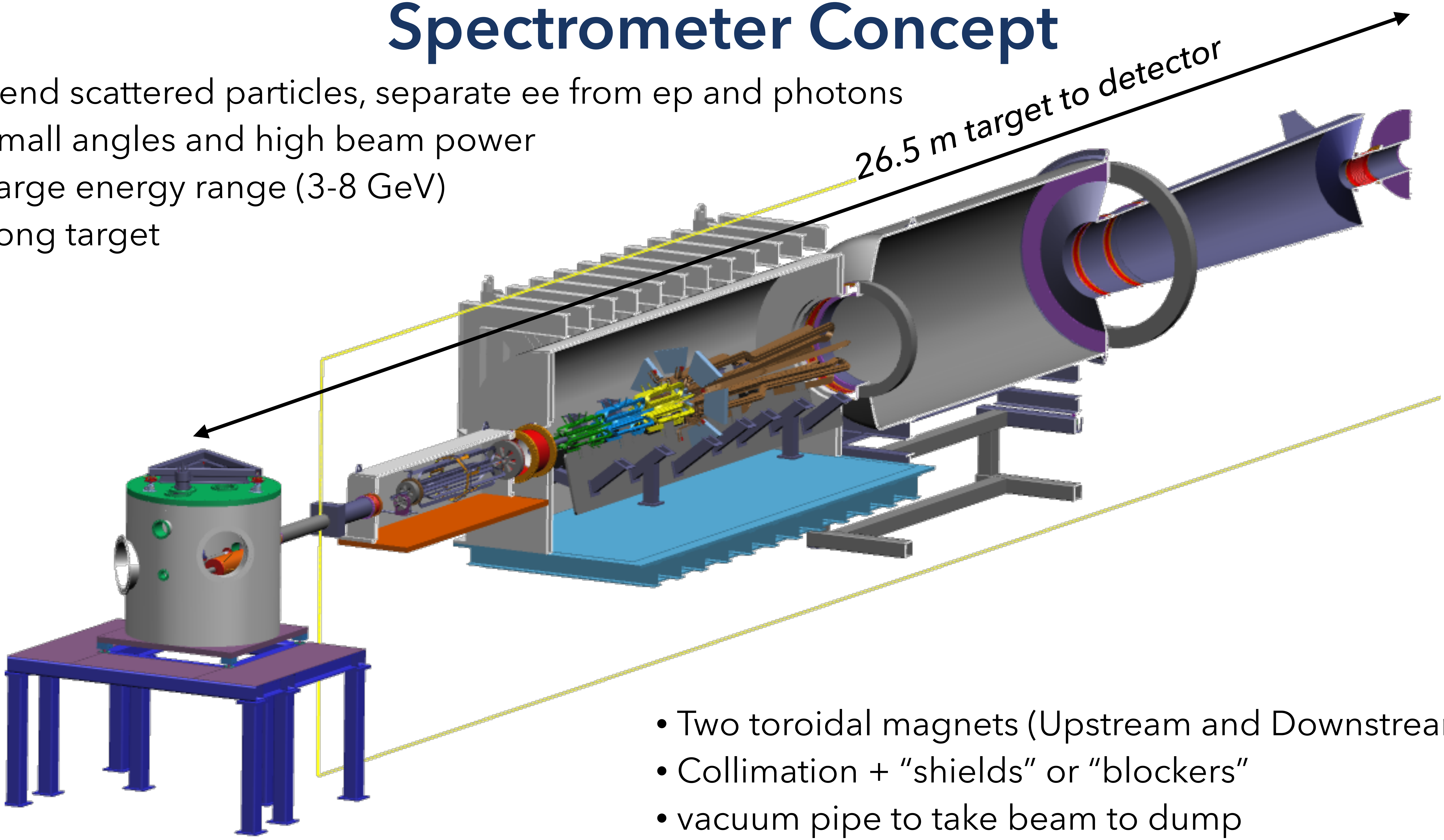




Unique concept allows for full azimuthal acceptance (effectively) even leaving space for coils but makes for a challenging design

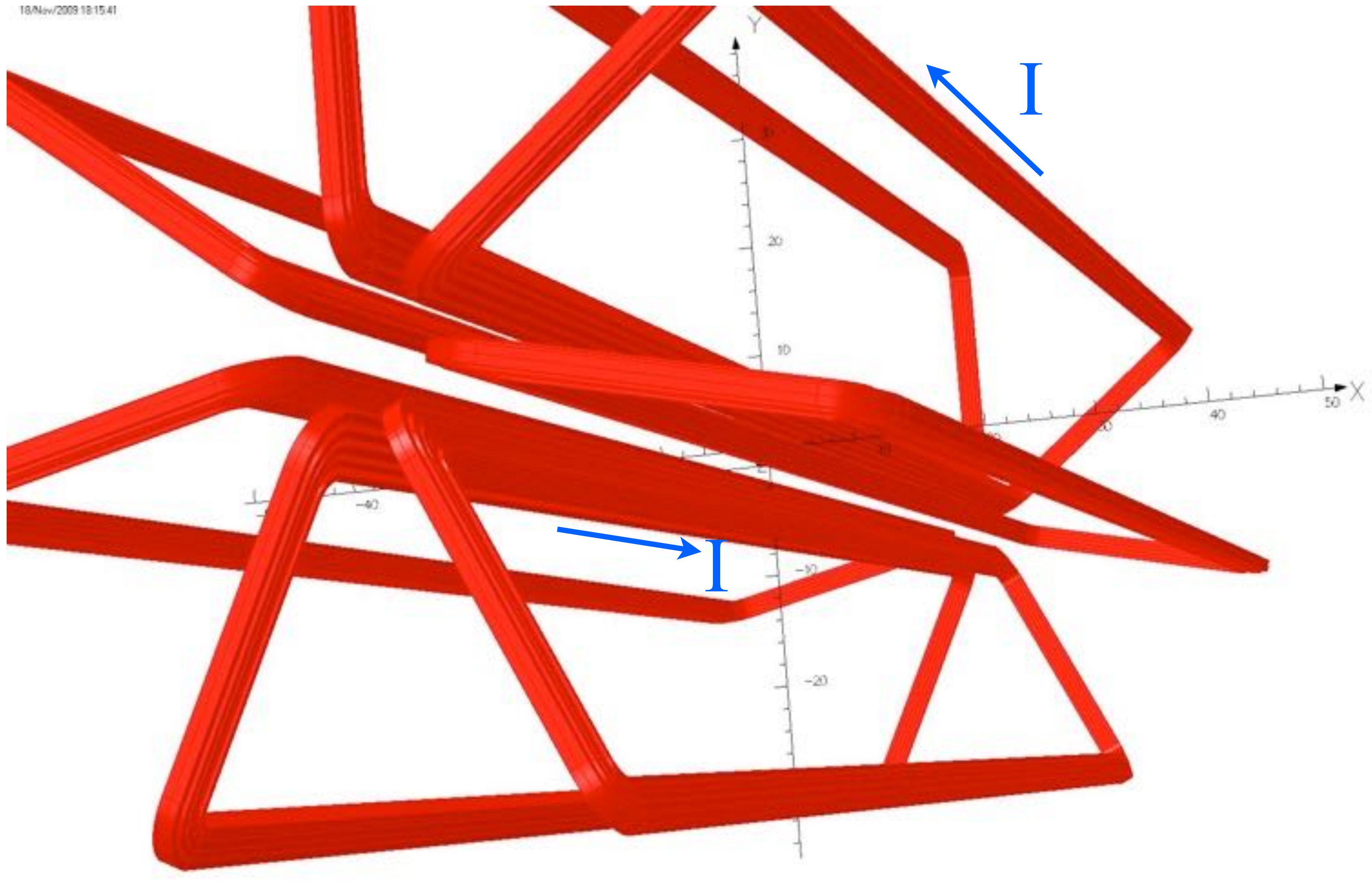
Spectrometer Concept

- Bend scattered particles, separate ee from ep and photons
- Small angles and high beam power
- Large energy range (3-8 GeV)
- Long target



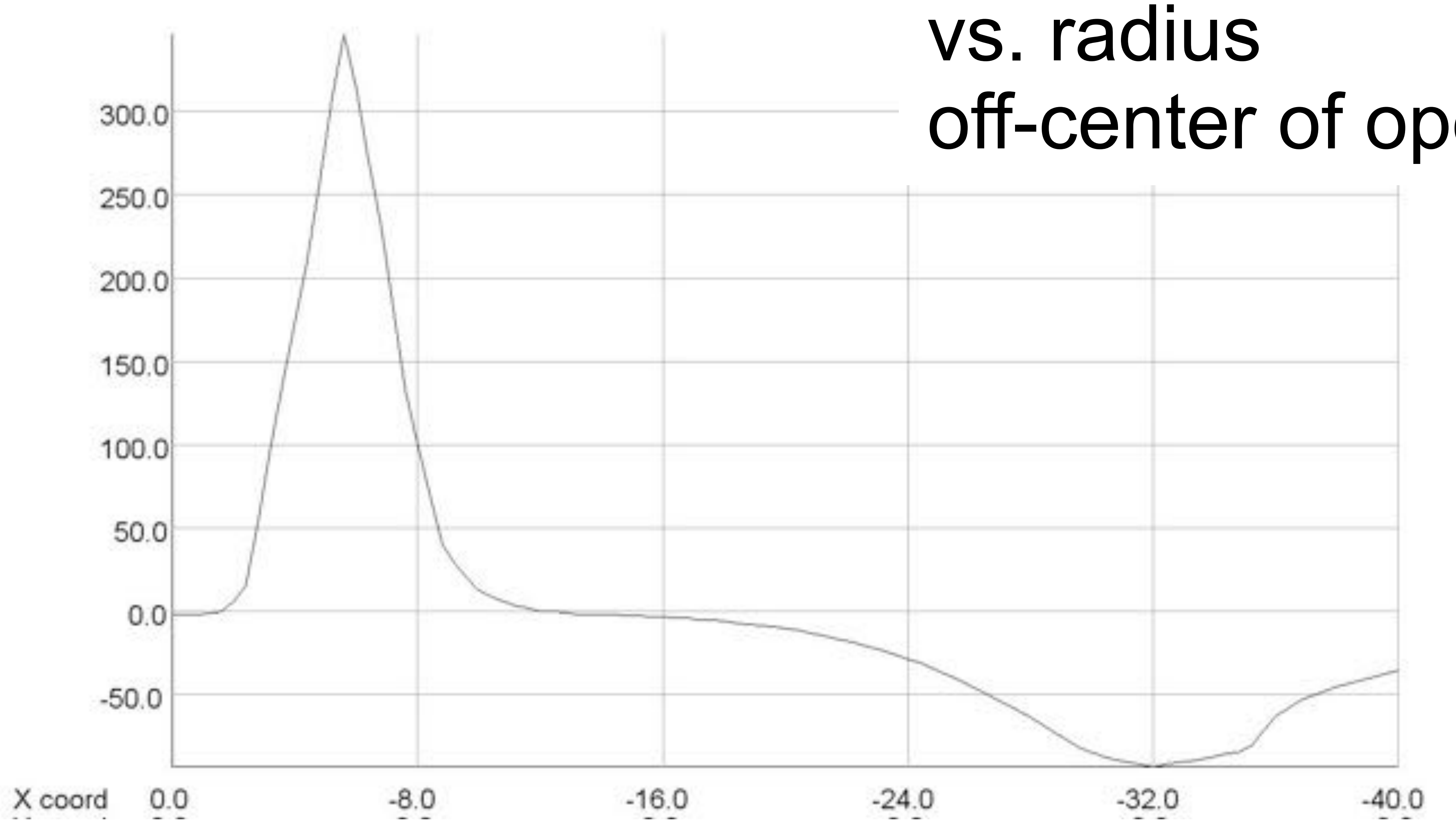
- Two toroidal magnets (Upstream and Downstream)
- Collimation + “shields” or “blockers”
- vacuum pipe to take beam to dump

Radial and Azimuthal Fields



Inner and outer edges of toroids have significant radial field components

Radial field component
vs. radius
off-center of open sector



repels electrons
from coil
“focussing”

attracts electrons
toward coils
“defocussing”

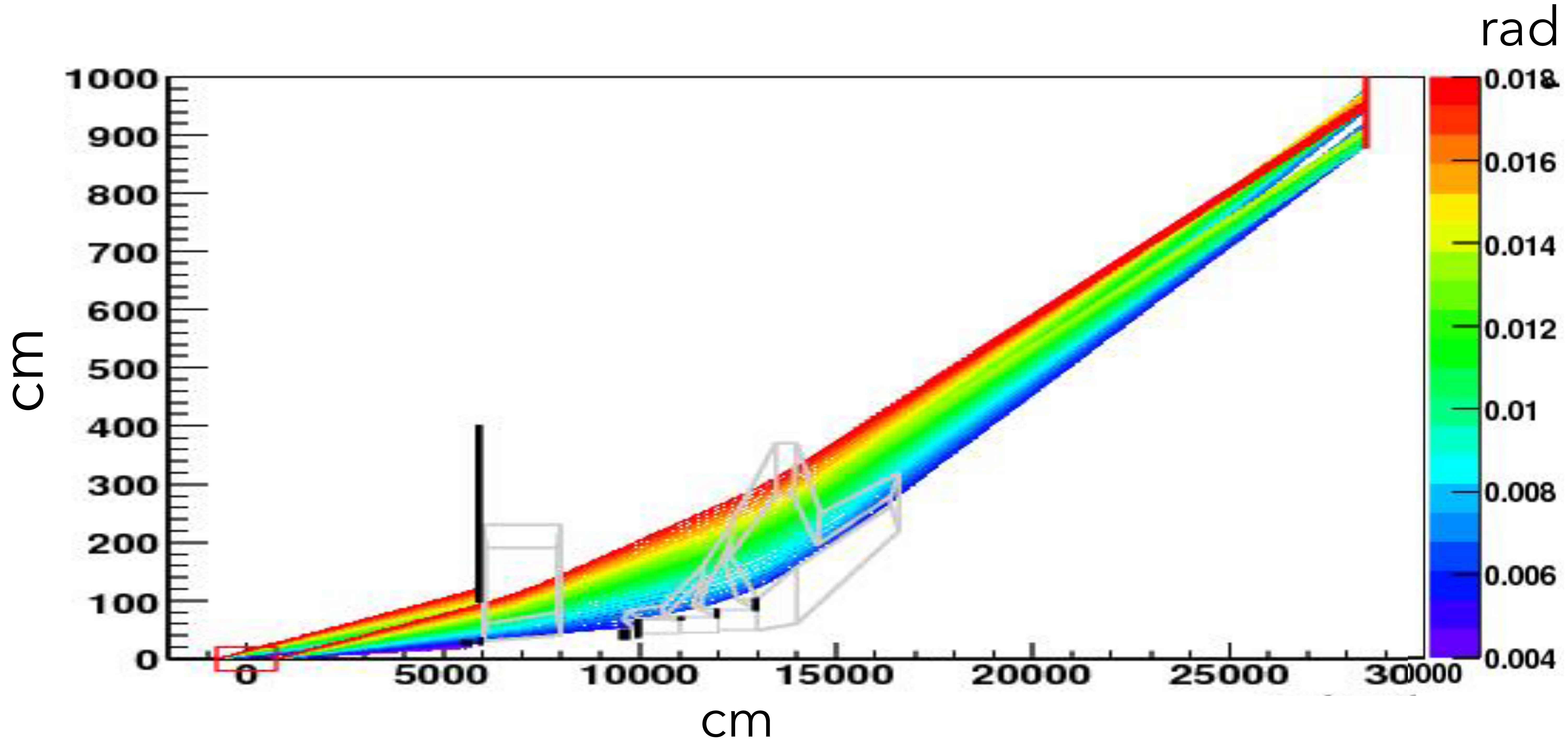
Effectively focuses or defocusses azimuthally!

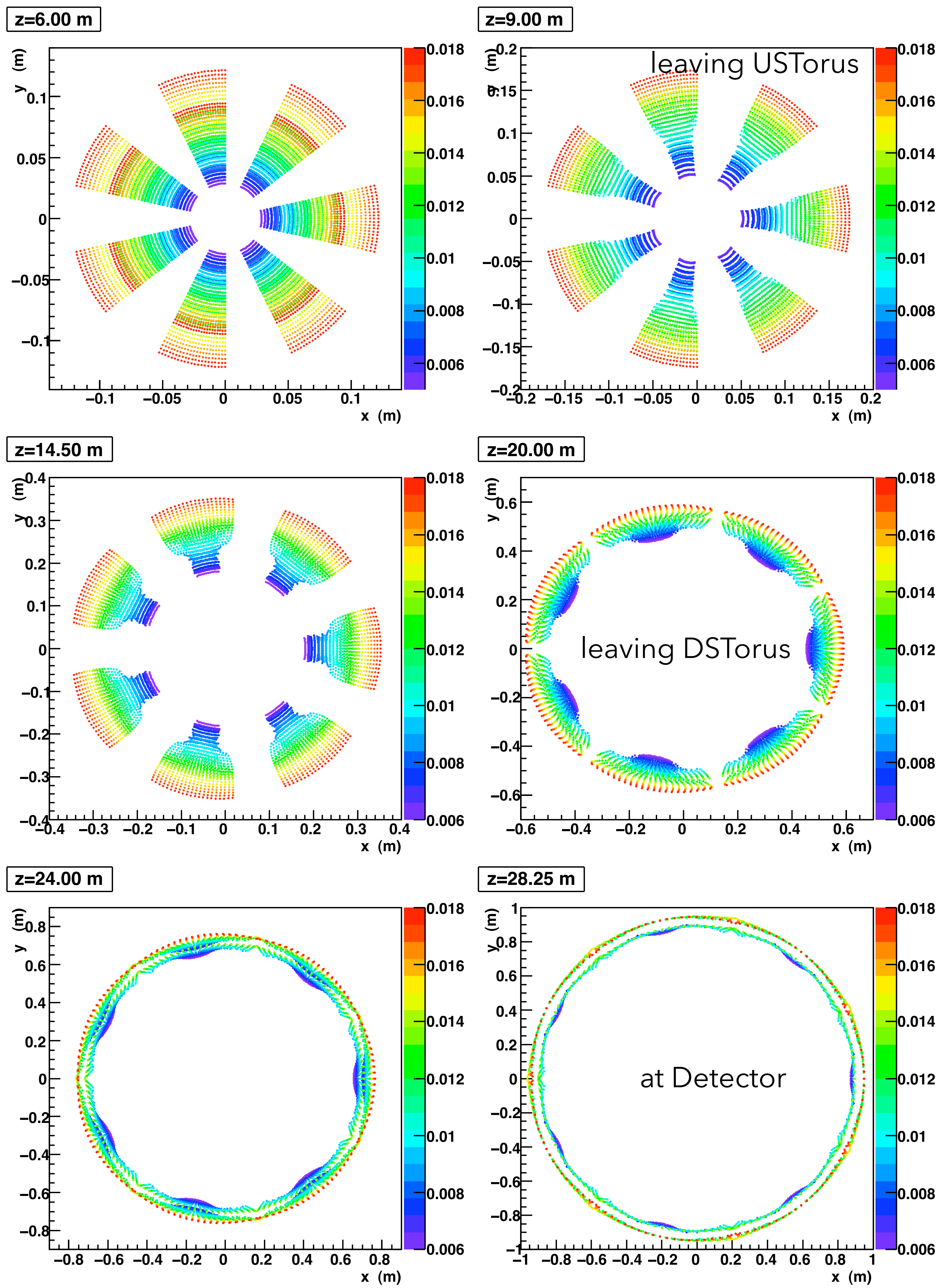
Magnet Concept

long and skinny

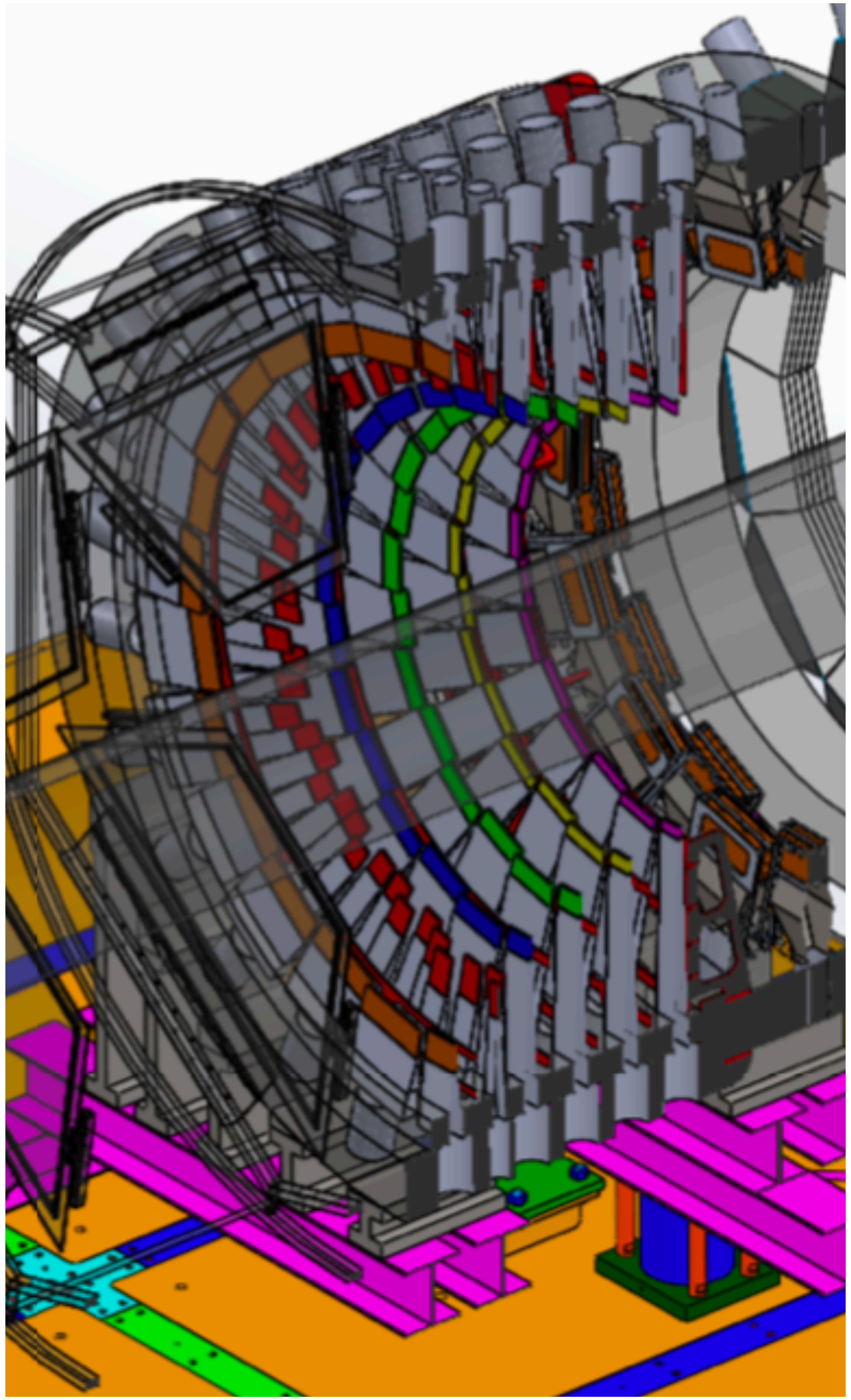
0.5 x 2m

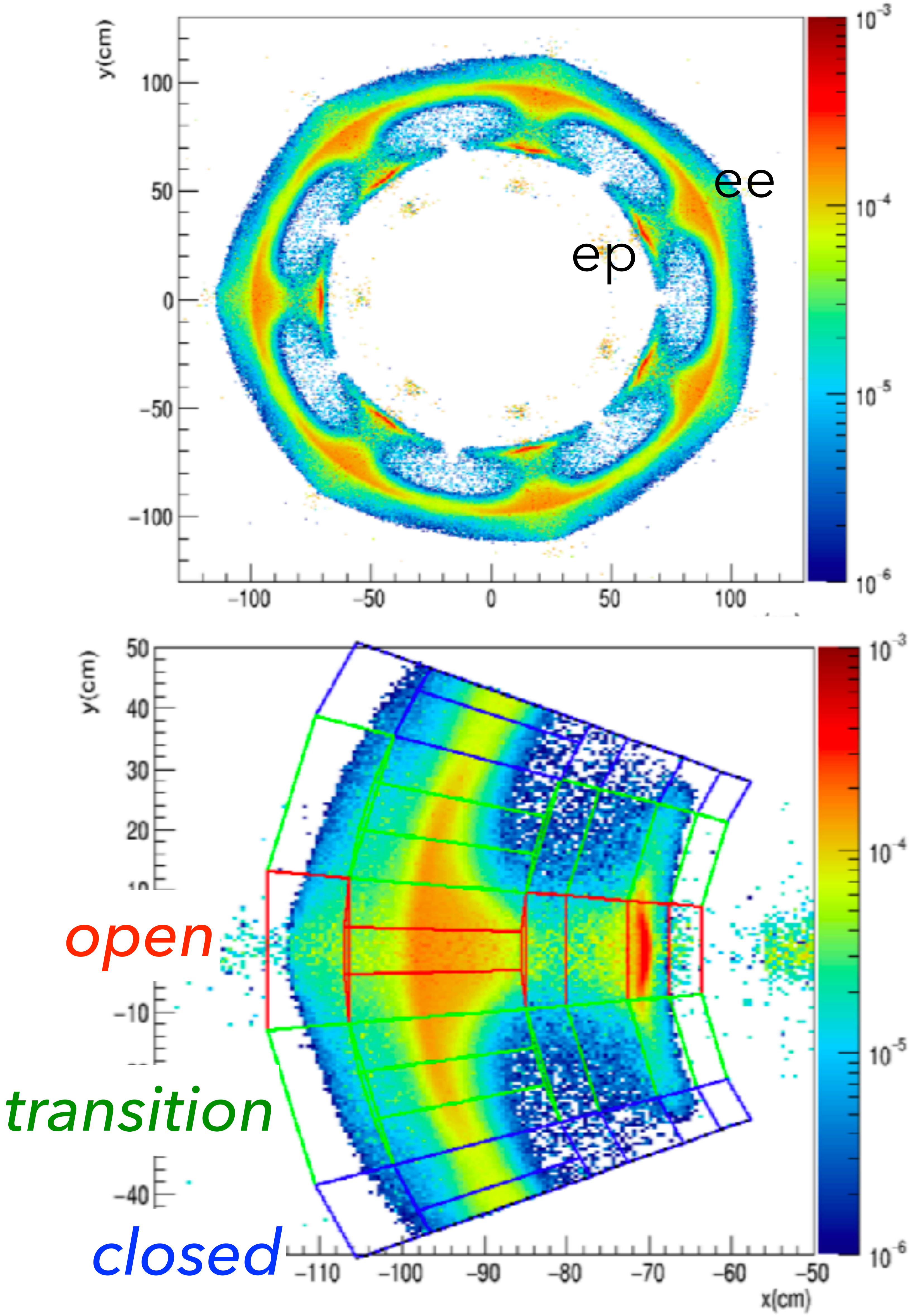
0.9 x 6.5m

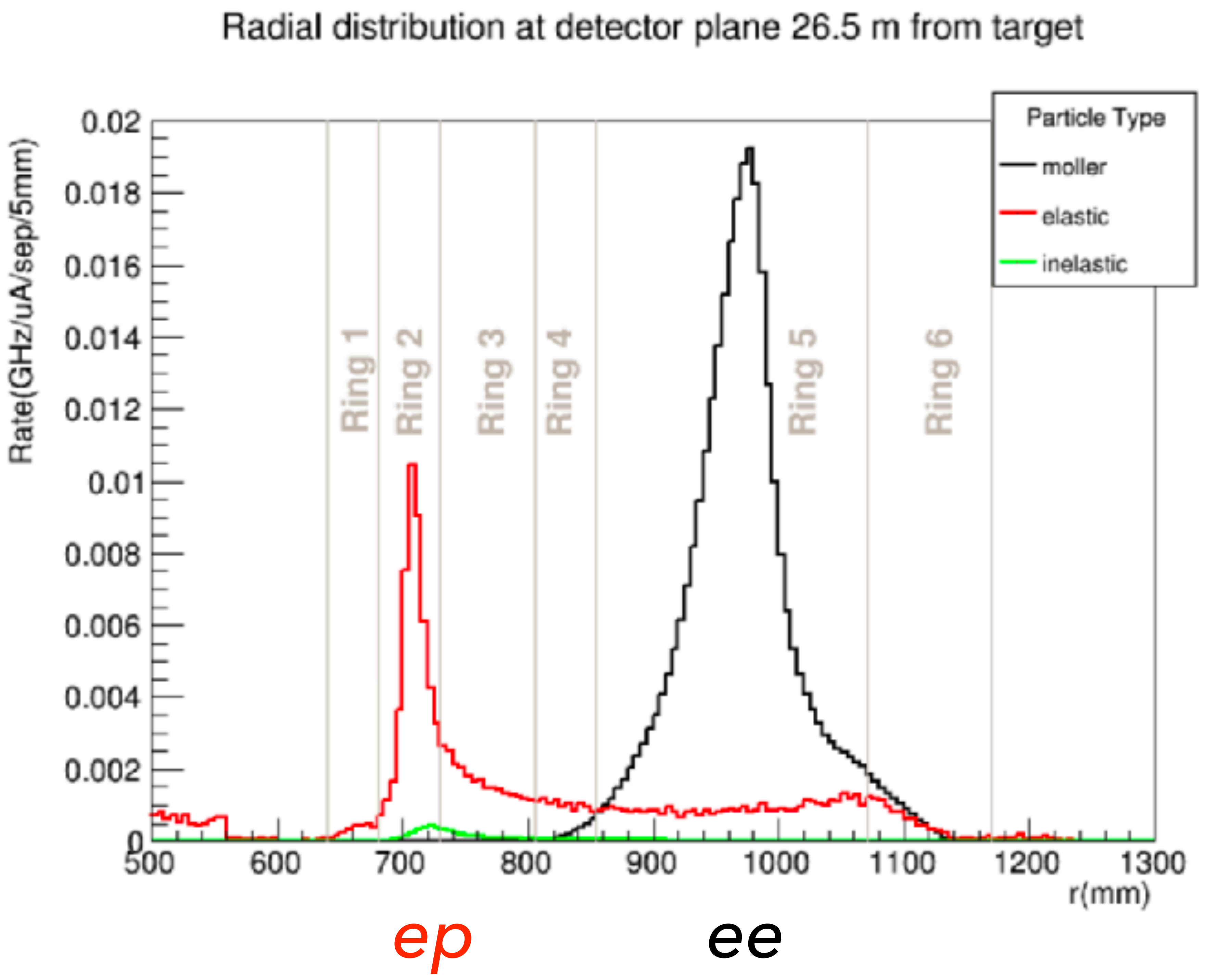




Main Detector

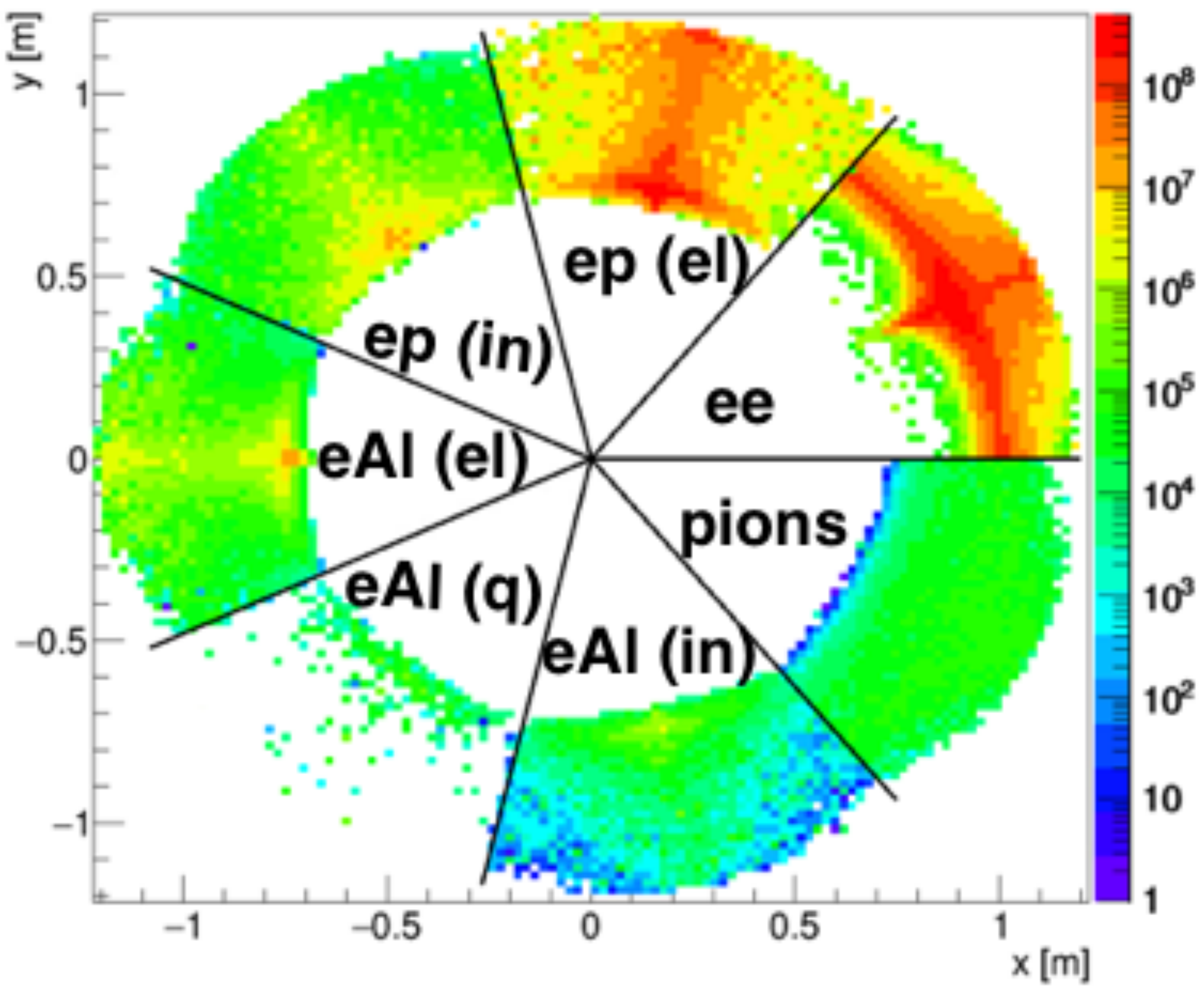






Backgrounds (irreducible)

Illustration with each septant a different fundamental background



There are various sources of backgrounds arising from scattering in the target that will pass through the spectrometer and arrive at the detector plane.

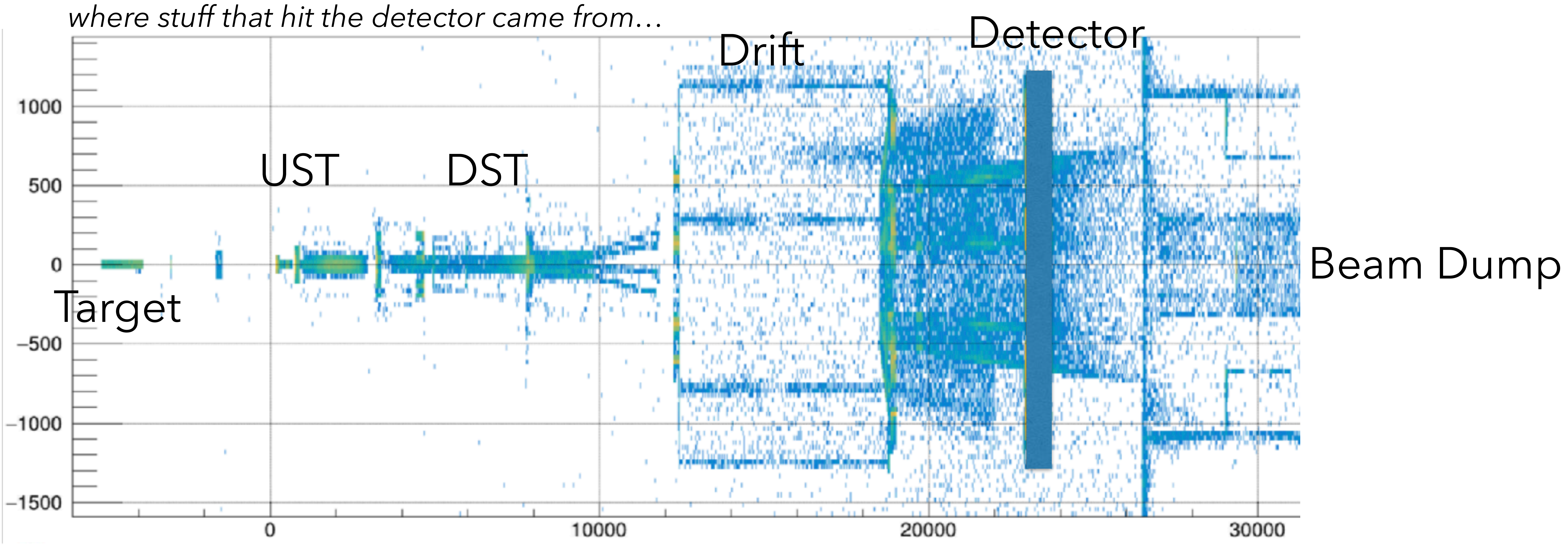
We must deconvolute the signal from the background using the segmented detector plane

Backgrounds (rescattering)

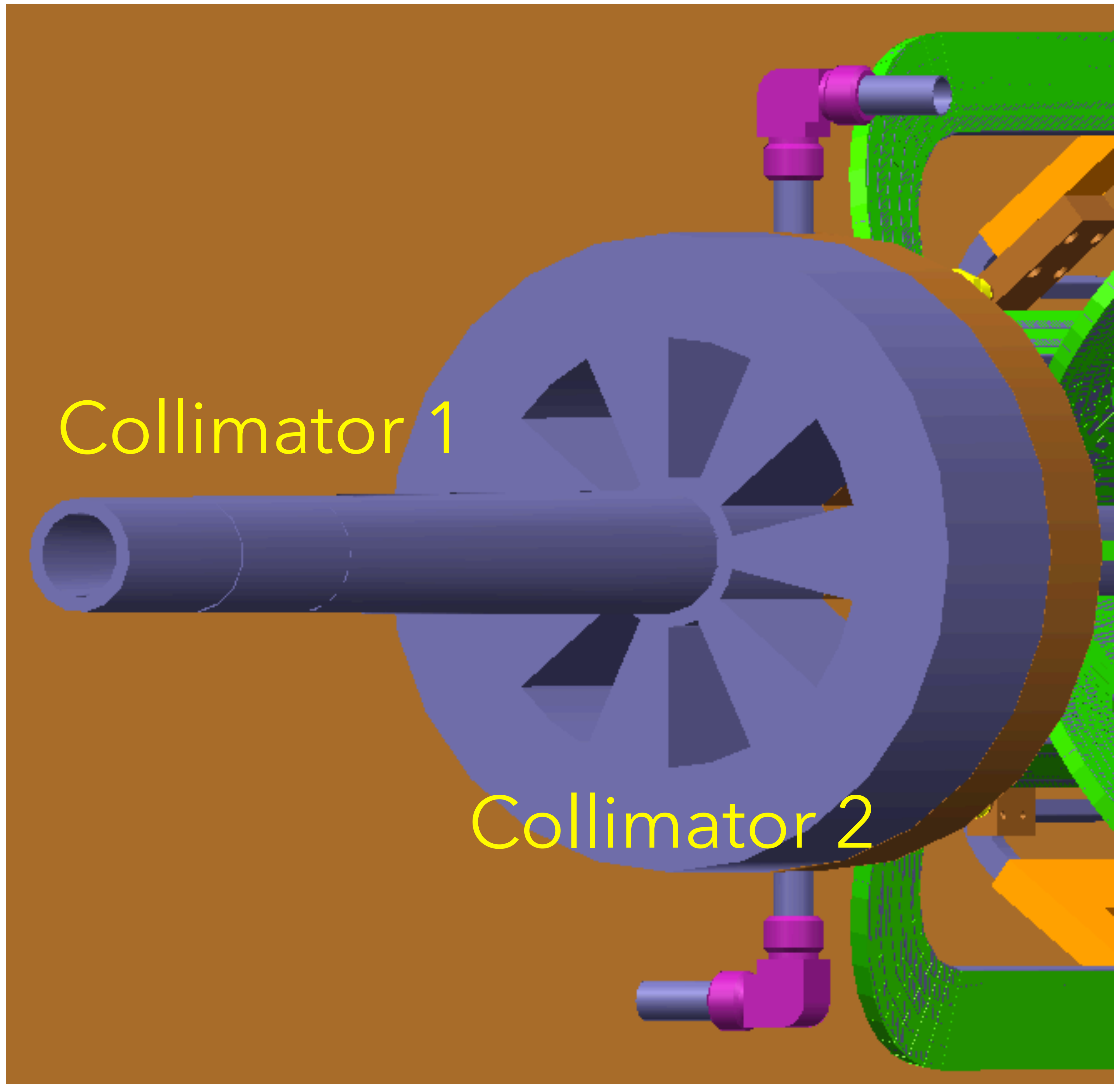
Other backgrounds aren't directly through the acceptance channel, but are

- from rescattering of the beam as it makes its way through the spectrometer to the dump
- from off-energy particles in the acceptance that rescatter from edges or surfaces, and go on to find the detector

where stuff that hit the detector came from…



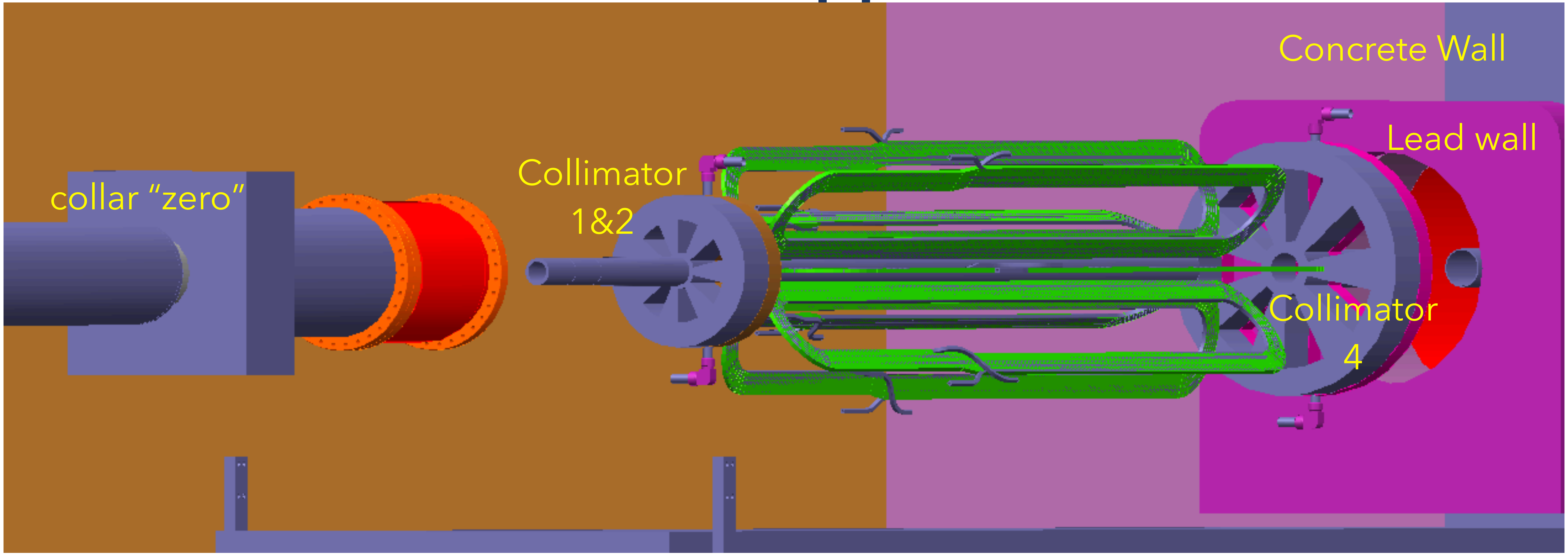
Beam Collimation

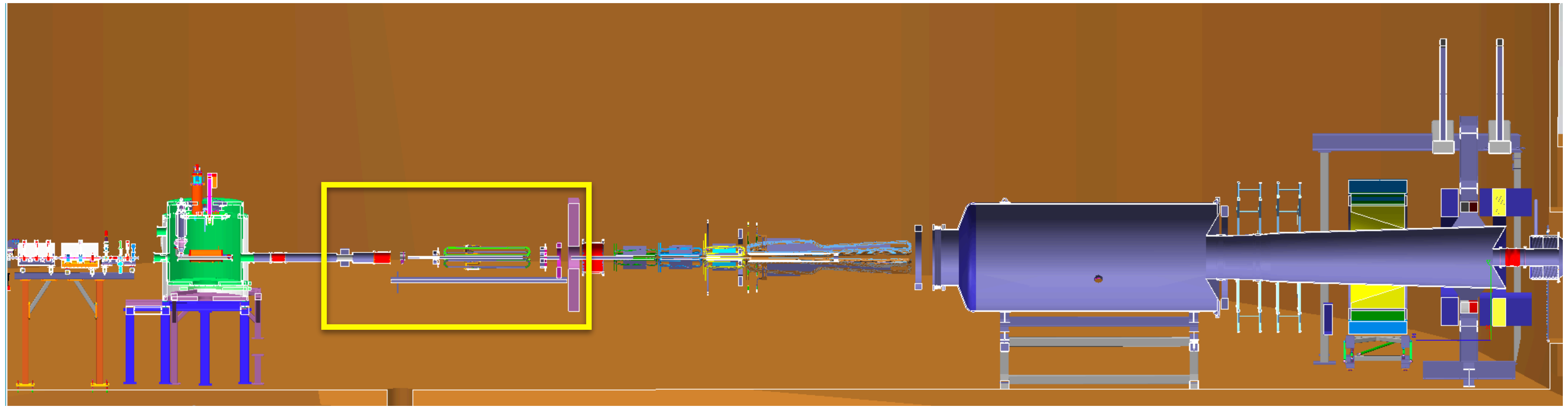


Collimator 1: long snout, collimates primary beam so what remains can go to the dump. ~3200 W

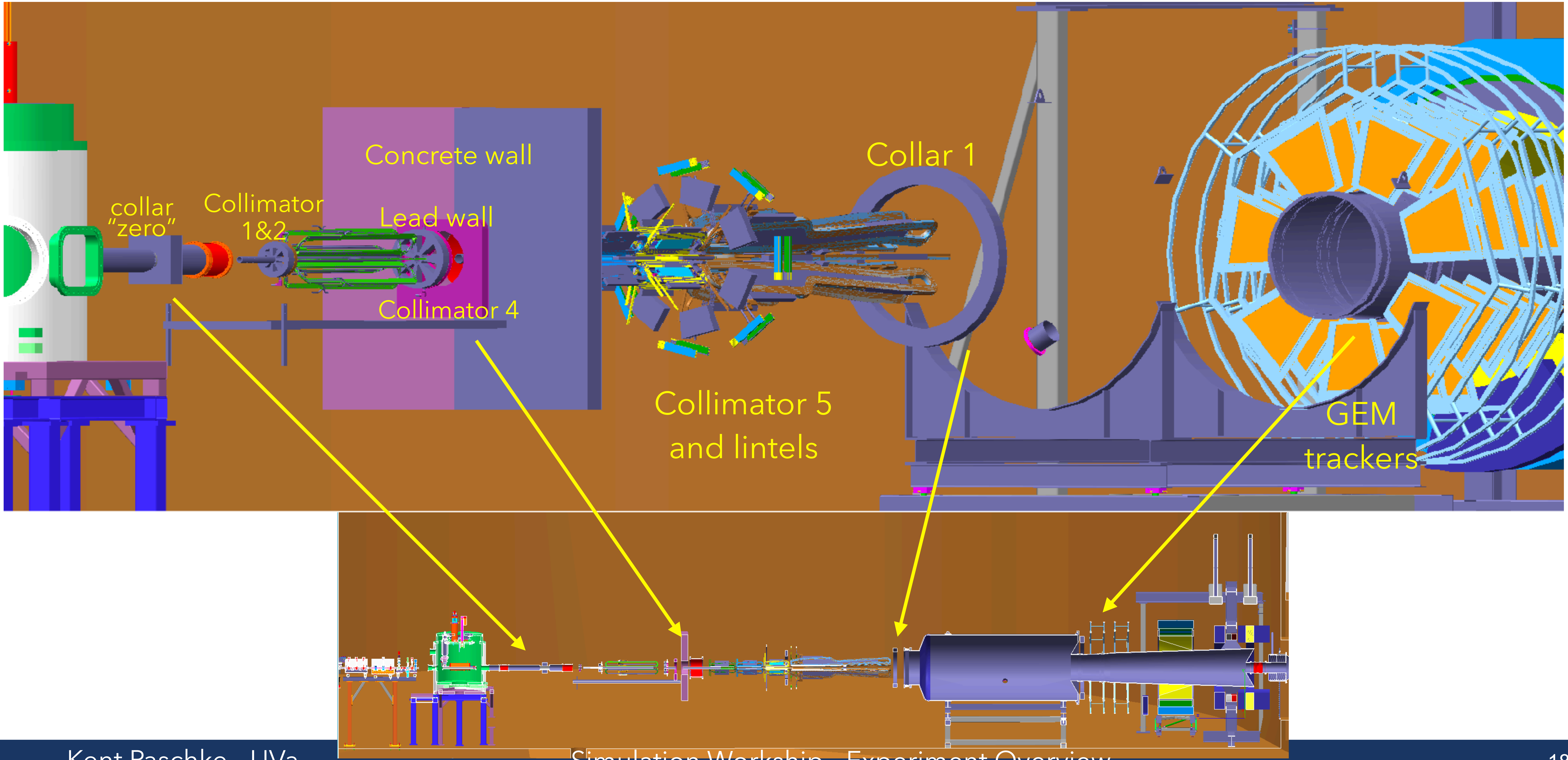
Collimator 2: wedges define the acceptance of the 7 septants

Walls, collars, and lintels supplement the collimation

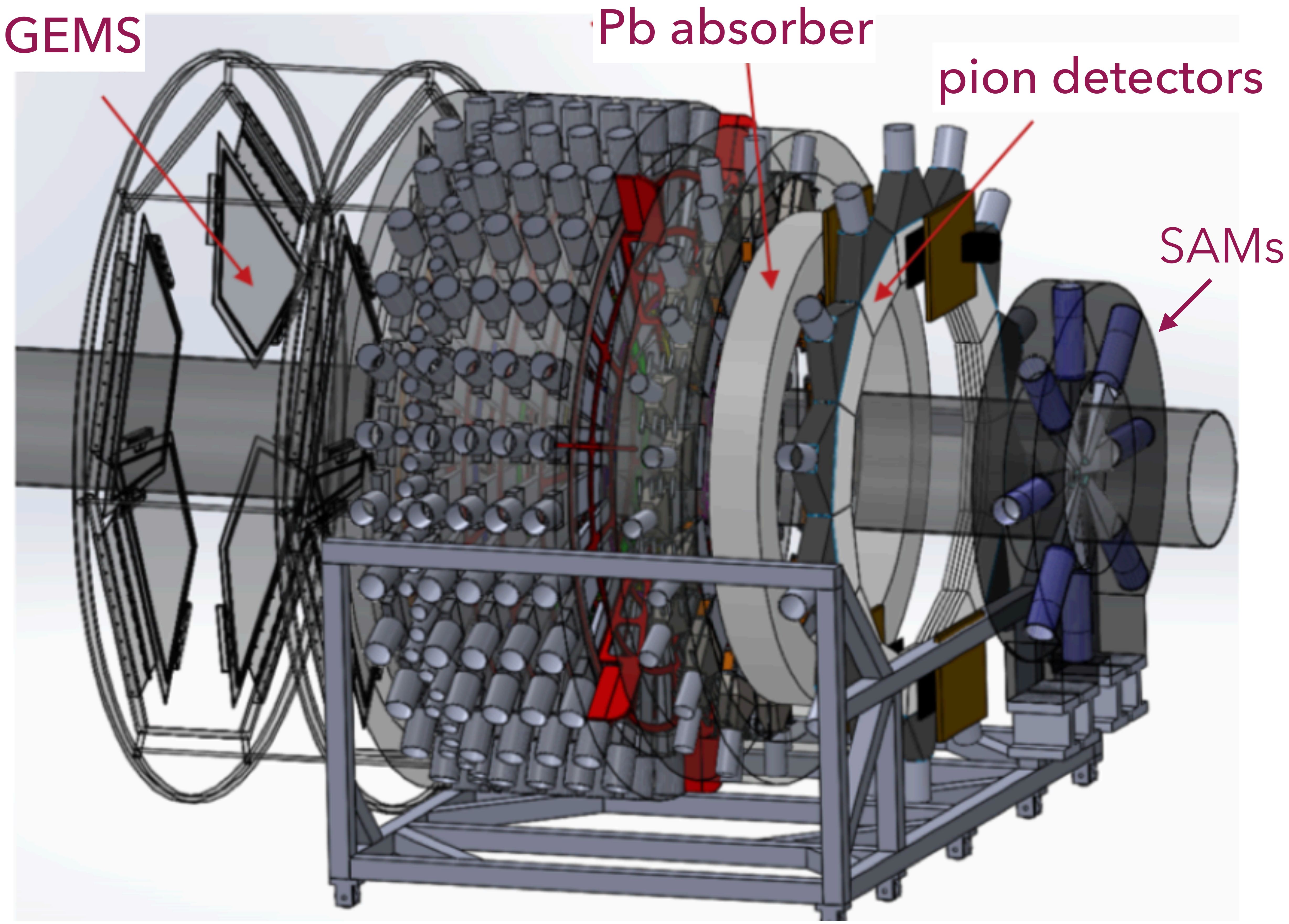




Walls, collars, and lintels supplement the collimation



More Detectors



Simulation Topics

Most everything we do falls in to one of these categories

- Radiation control for equipment (hall electronics) and personnel protection (boundary)
- Rescattering for control of measurement in main detector (or other detectors)
  - Edges, field imperfections…
  - rare events (e.g. ferromagnetic materials)
- Radiation estimates for radiation damage in apparatus (coils, o-rings)
- Maintain signal acceptance/interpretability throughout the final engineering
- Determining fabrication tolerances
- Detector optimization/design
- Physics extraction

This ~50M$ project is taking off, and engineering/design topics have our top priority

We're looking forward to having your help with this work!