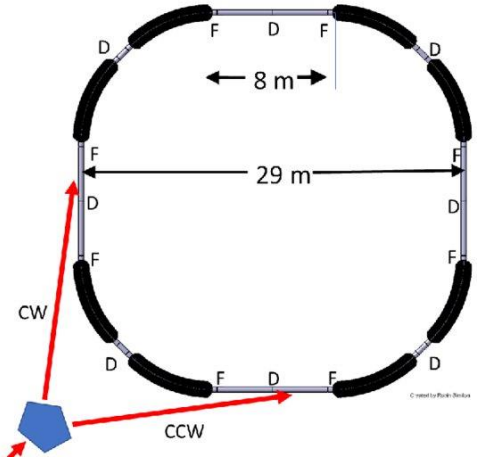
A silicon based polarimeter for pEDM searches

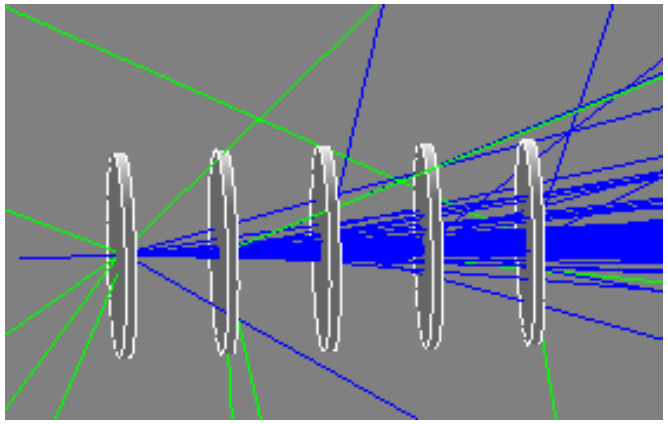
James Gooding

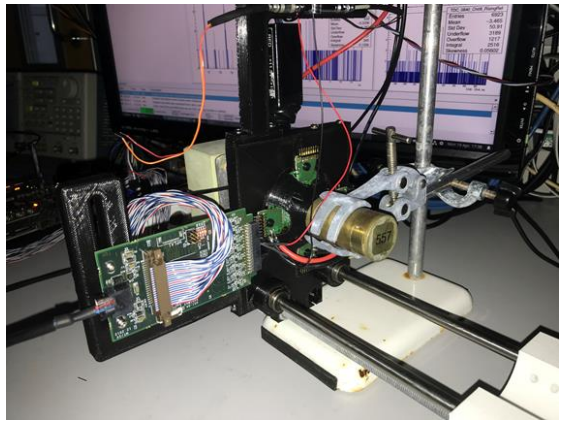
E. Vilella-Figueras, G. Casse, N. Rompotis

Contents of presentation

- Brief Overview
- Simulation
- Experimental





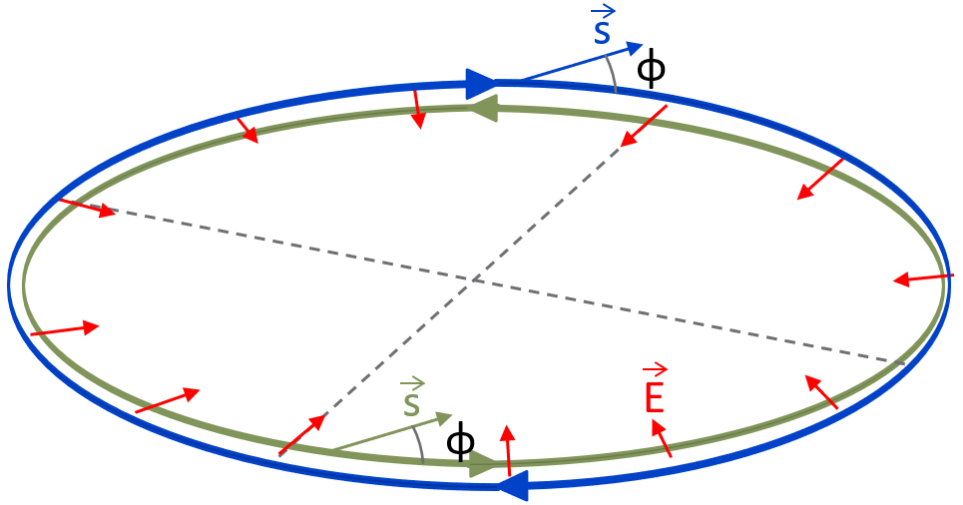


Overview of proton EDM

An EDM is caused by separation of permanent charges inside a particle

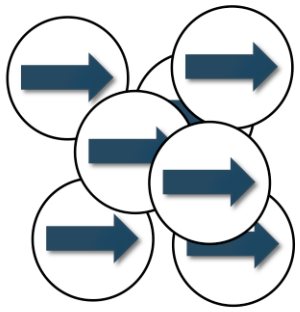
The standard model predicts proton EDM's at the level of 10^{-31} e.cm

Some BSM predict nucleon EDM's in the range 10^{-24} - 10^{-28} e.cm range

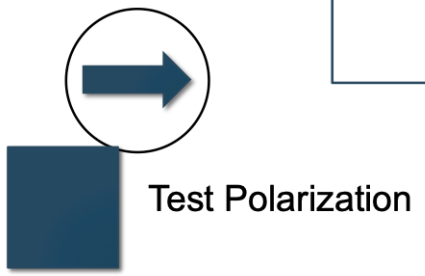


Sensitivity target

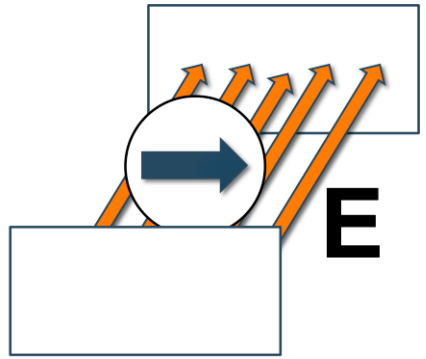
~ 10^{-29} e.cm



Polarize Beam



Test Polarization



Continuous E field
Interaction over ~ 1000 s

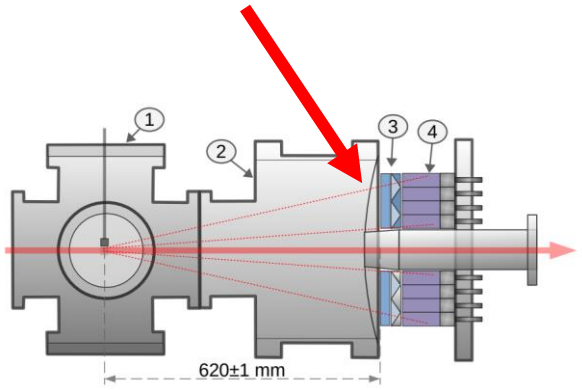
Continuous
Polarization
Measurement

JePo incompatibility

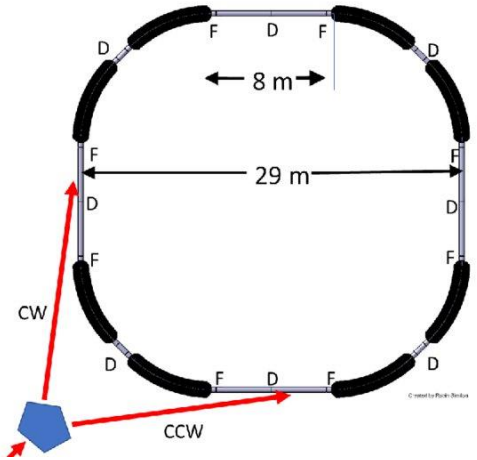
1. Material budget at lower energies
2. Forward angle detector

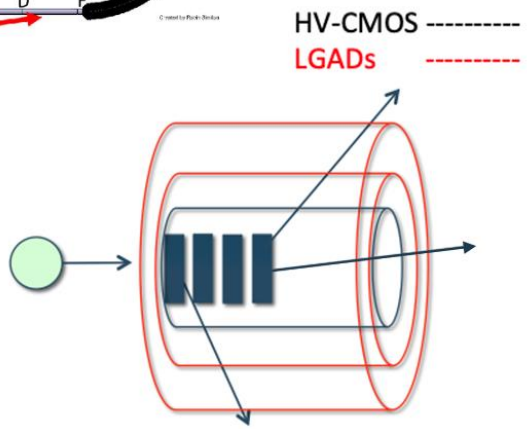
1	2	3
Precursor Experiment	Prototype Ring	All-electric Ring
dEDM proof-of-capability (orbit and polarization control; first dEDM measurement)	**pEDM proof-of-principle** (key technologies, first direct pEDM measurement)	**pEDM precision experiment** (sensitivity goal: 10^{-29} e cm)
270 MeV	**30-45 MeV**	**270 MeV**

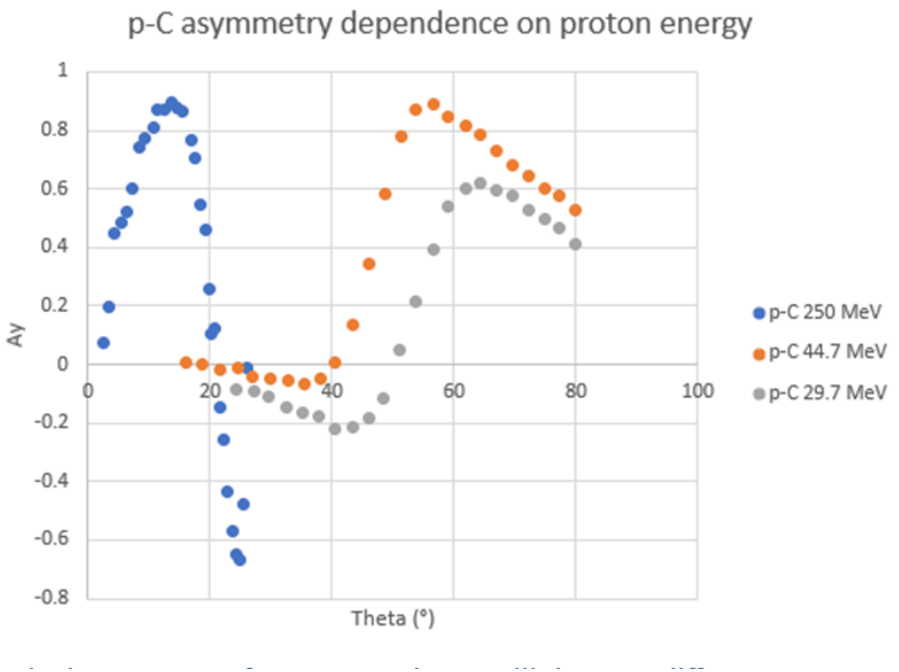
800µm Steel Beam Window



Angular acceptance 4 – 15 degrees

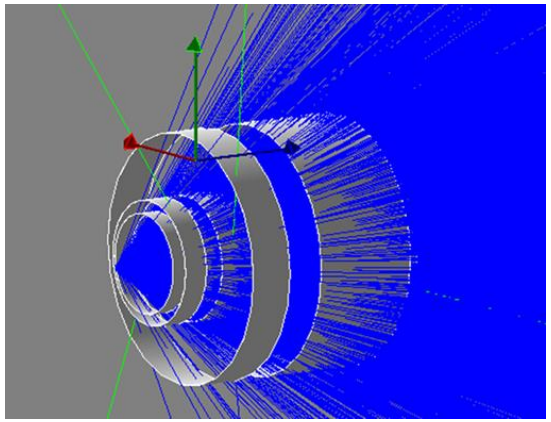


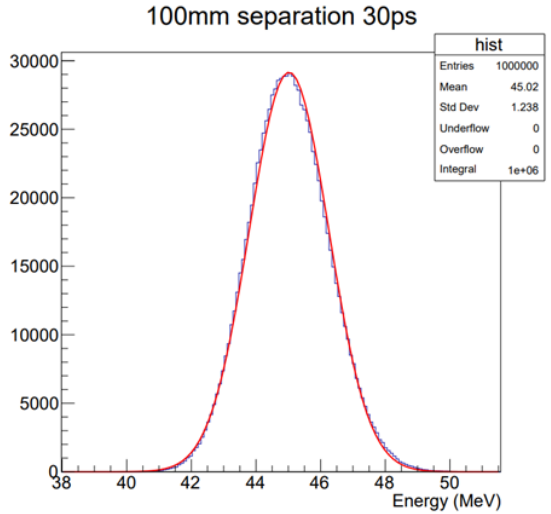


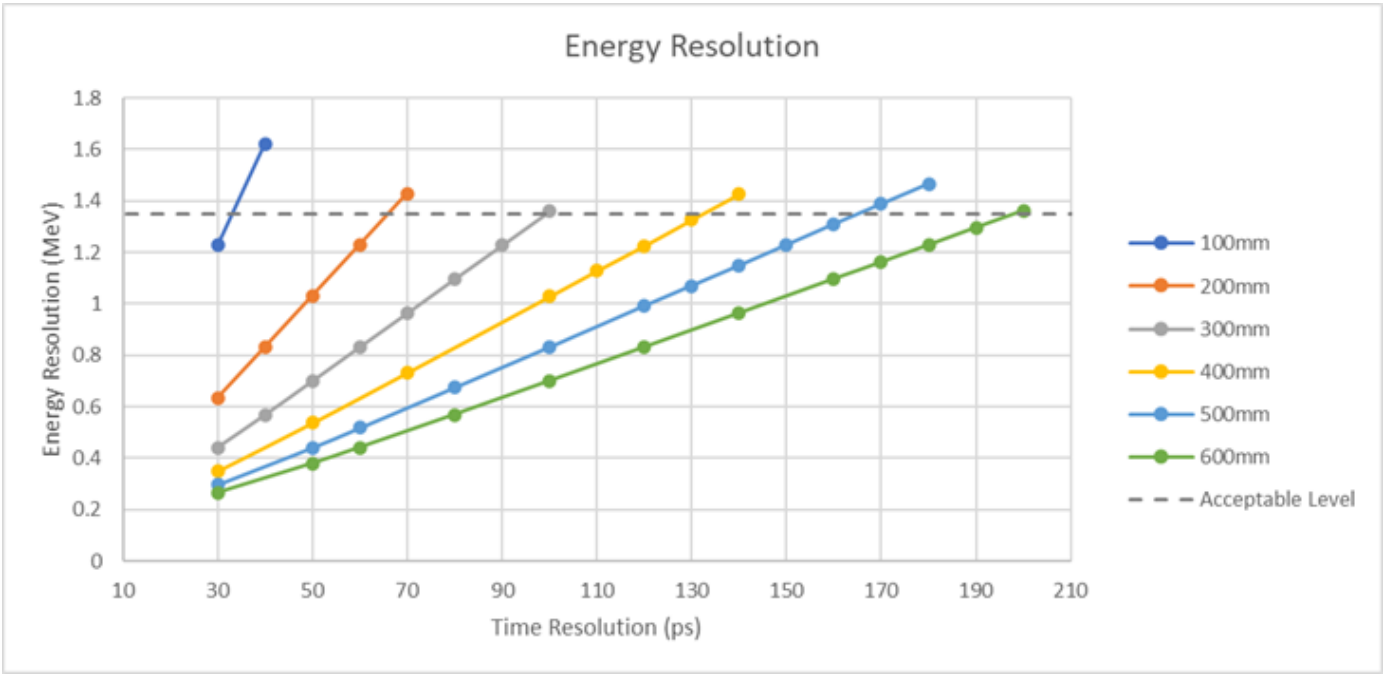


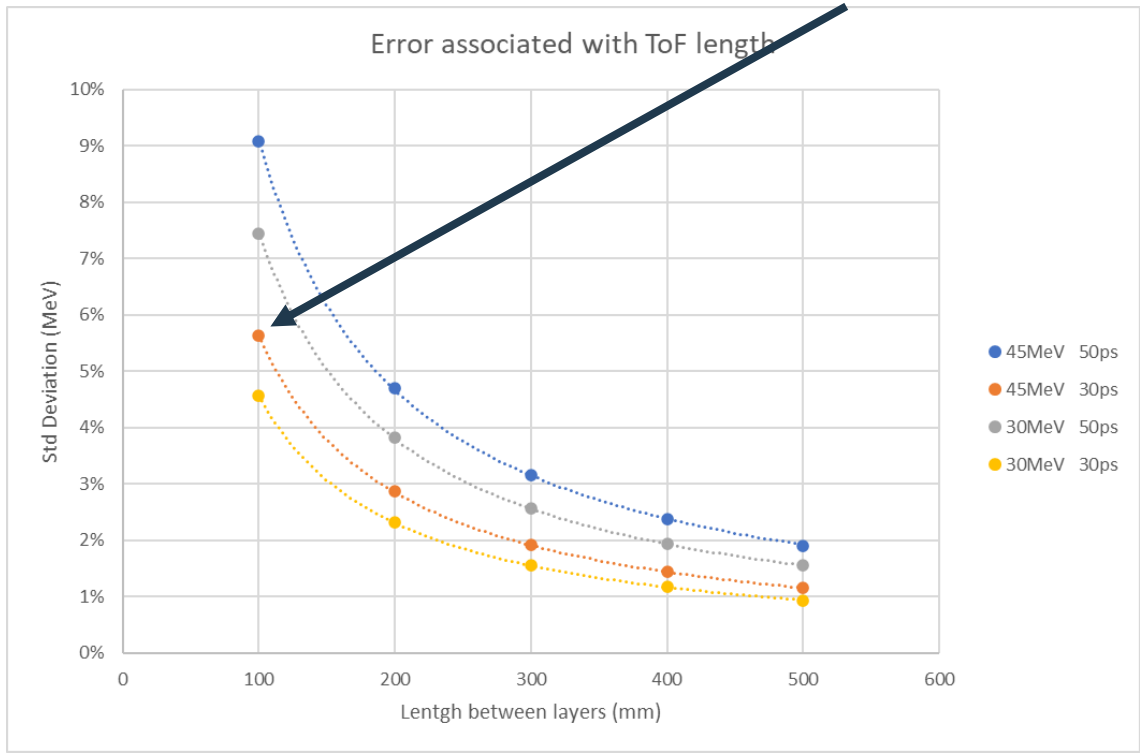
Simulation

Potential LGAD time resolution 30-50 ps
What length chamber makes this suitable for this experiment?



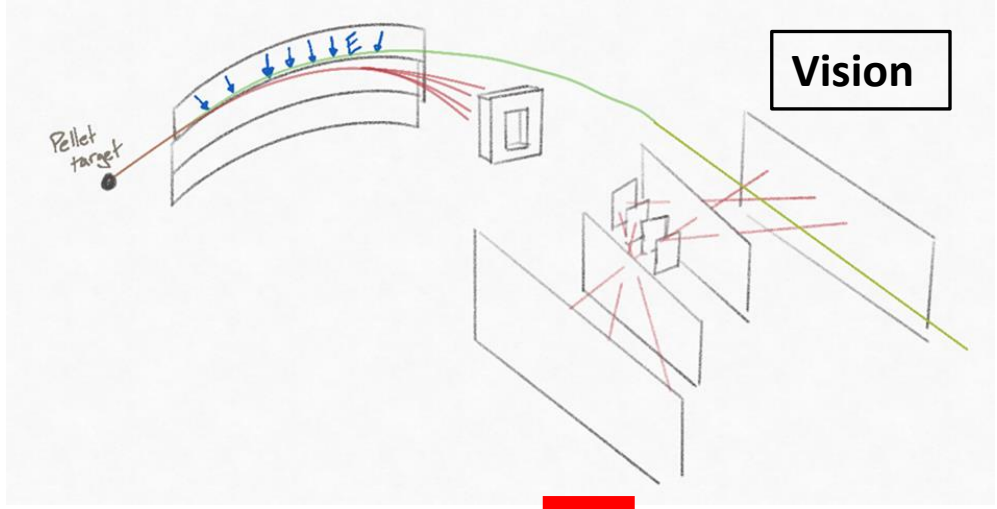






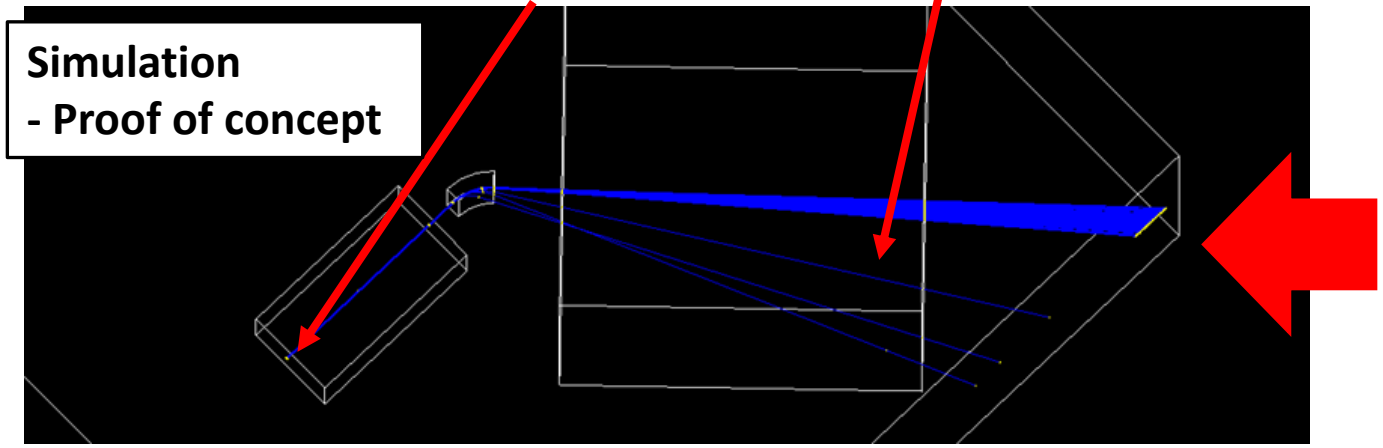
Secondary beam polarimeter via pellet target

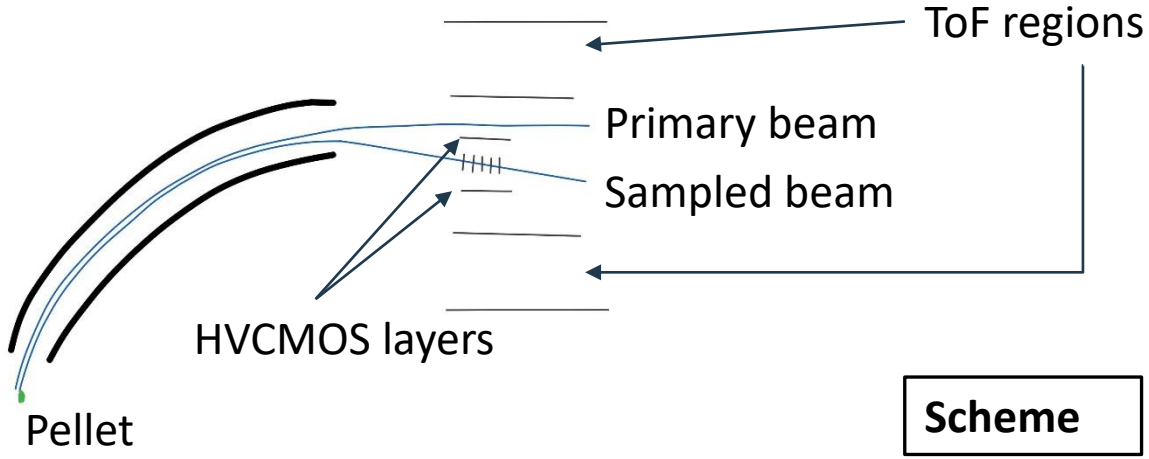
– Influence on primary beam



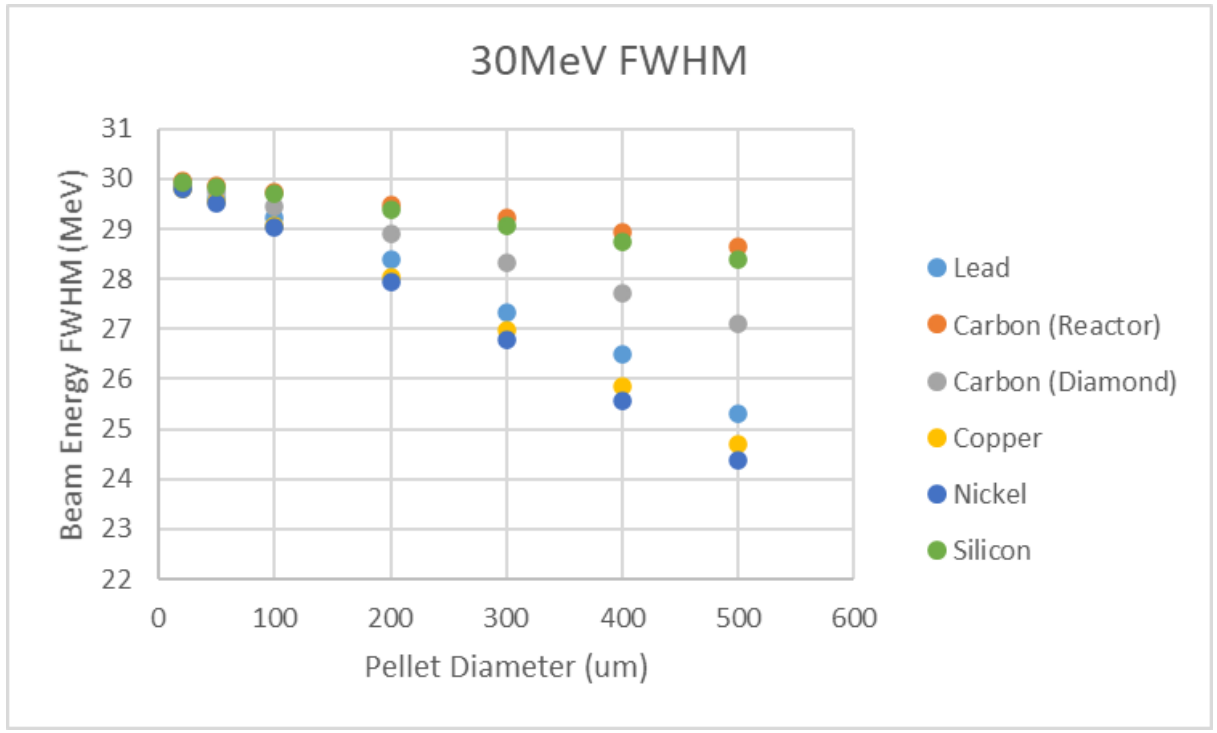
Sampled particles fall slightly out of orbit

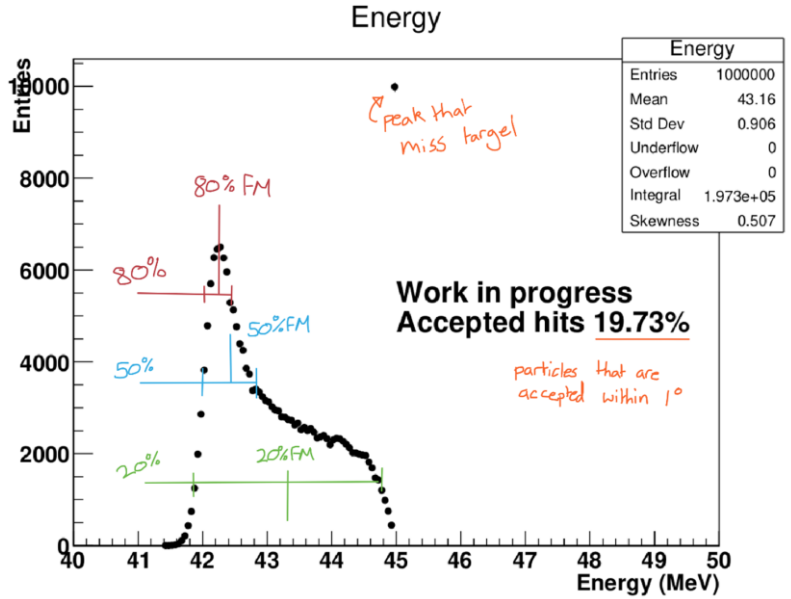
Tiny carbon pellet 20 µm

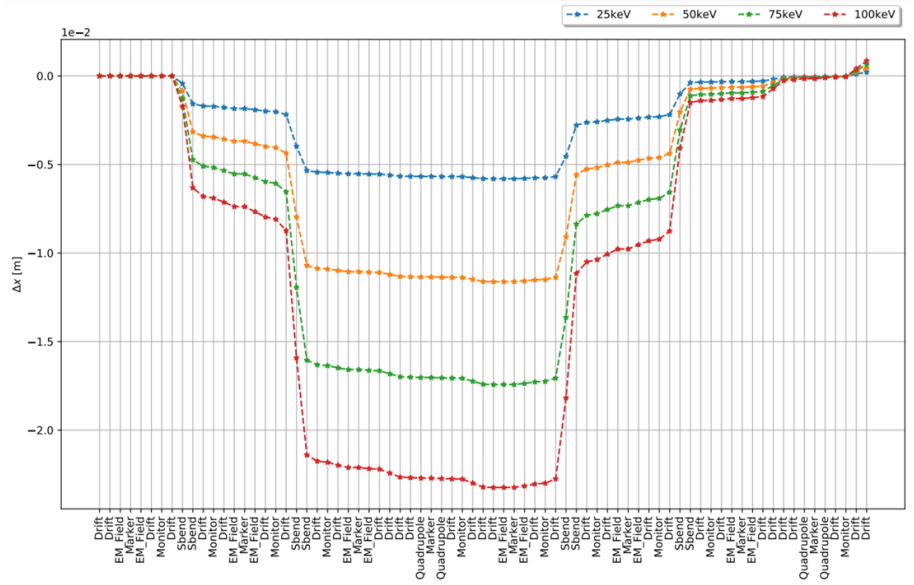




Pellet target feasibility study







Result:

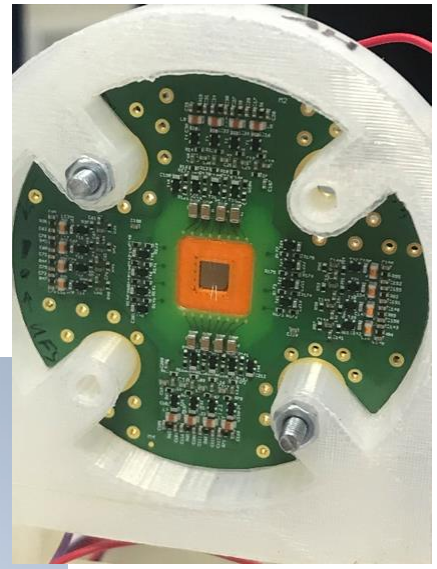
- Pellet target can achieve 2cm offset from main beam whilst retaining stable circulation (100 keV loss in target)

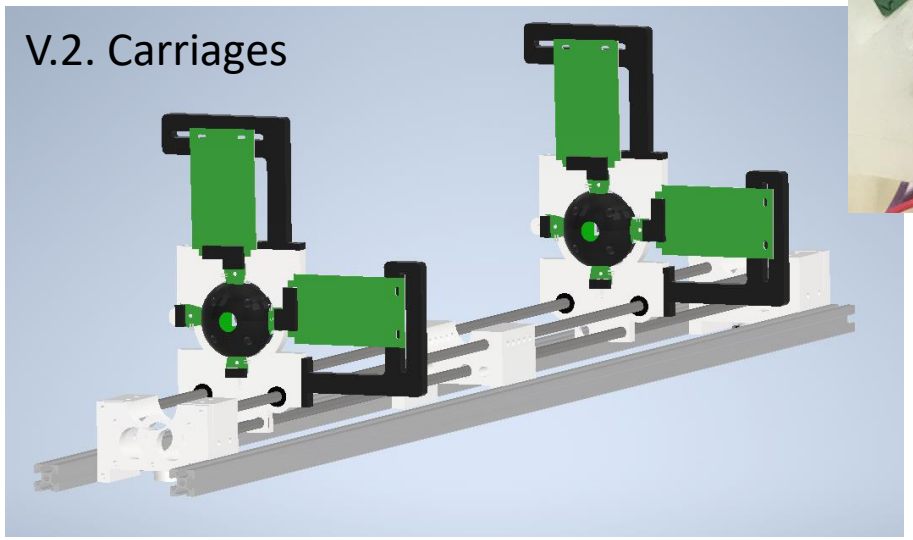
Simulations by Maximilian Vitz

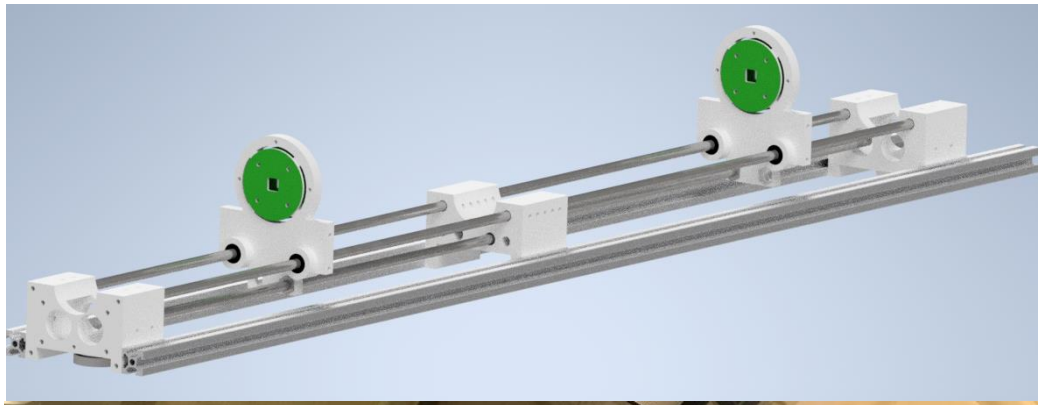
LGAD Time of Flight telescope

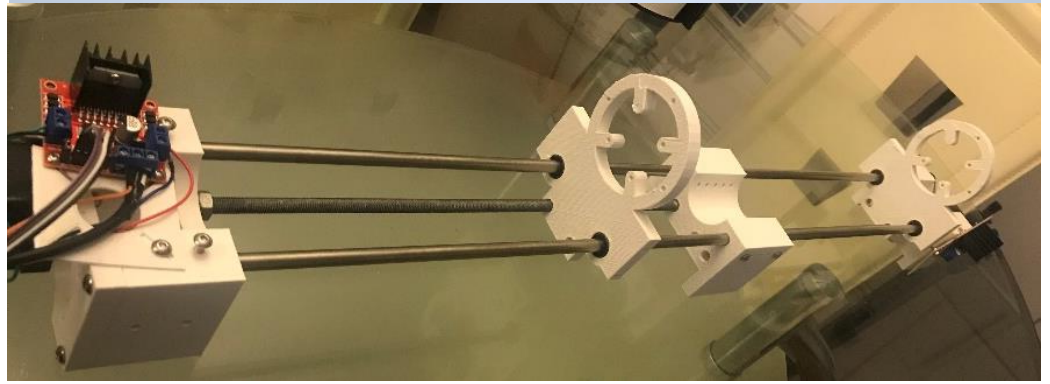
- Remote adjustability to below 100µm accuracy
- Beamline planned with medical proton therapy facility
- ToF distance range 100-900 mm

- Mechanical structure completed
- Awaiting readout systems and PCB manufacture
- Motor control
- GUI?
- Final assembly and wiring
- Test beam
- Data analysis and results

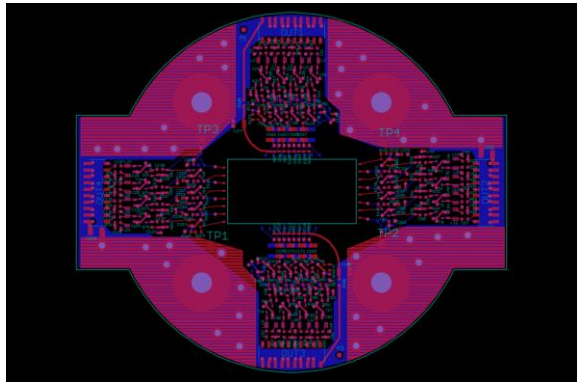




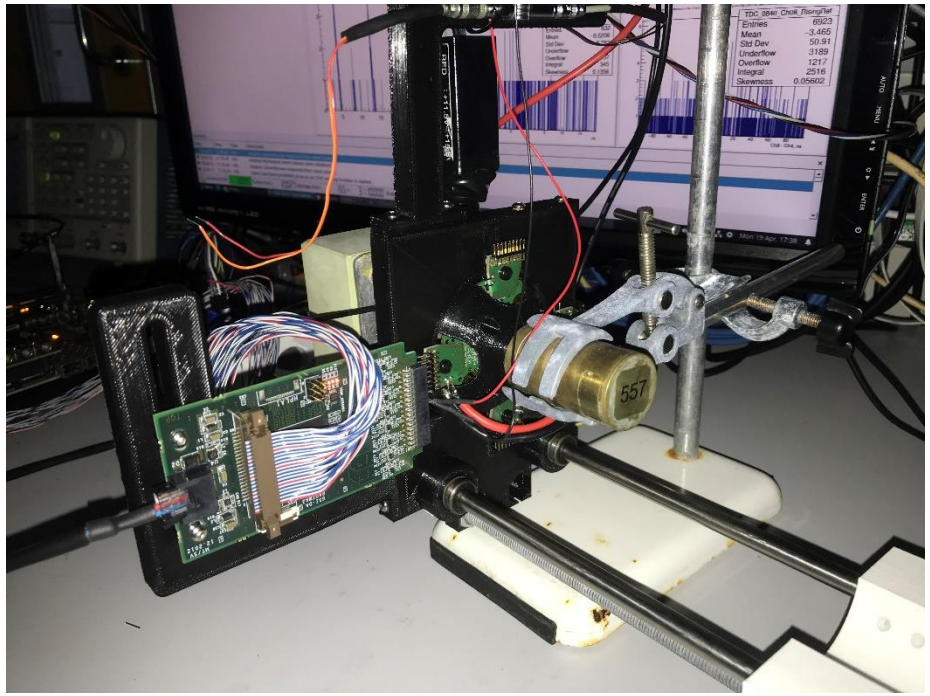


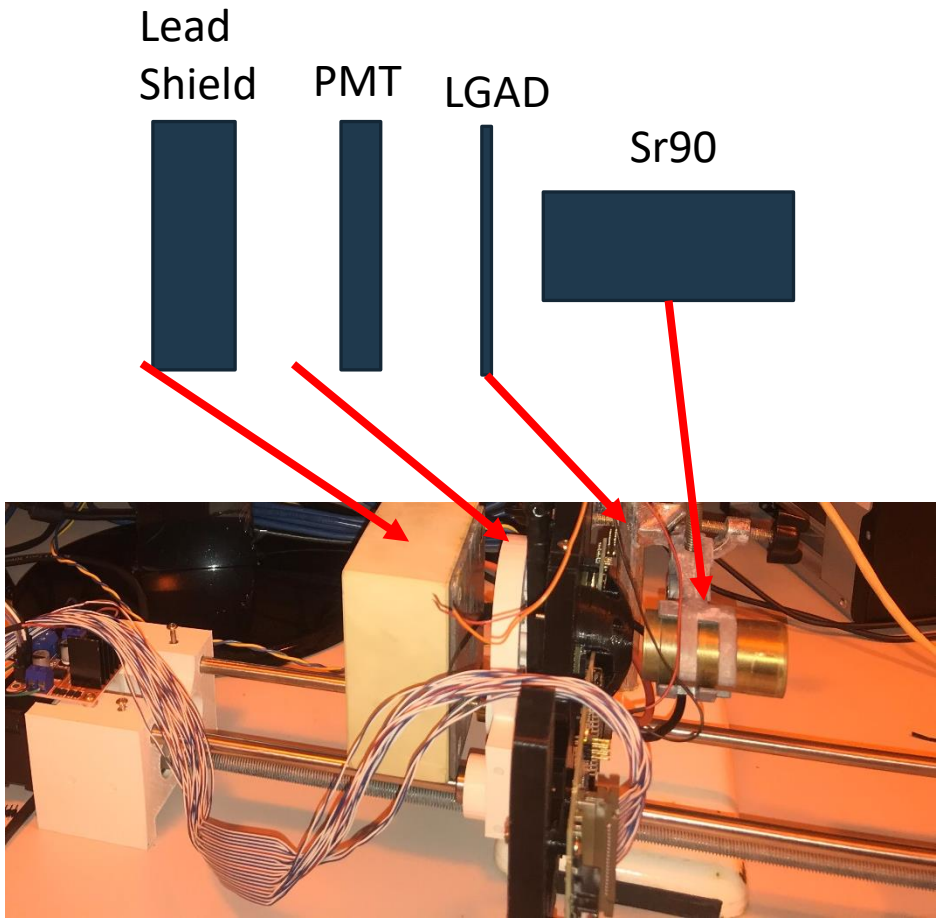


LGAD Time of Flight telescope

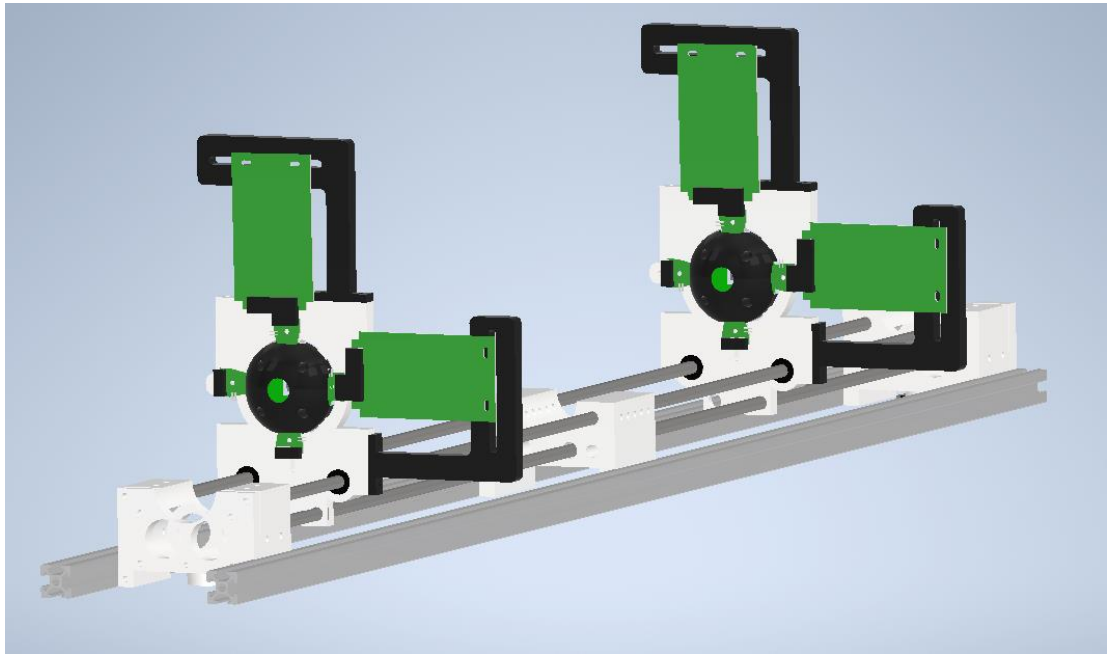


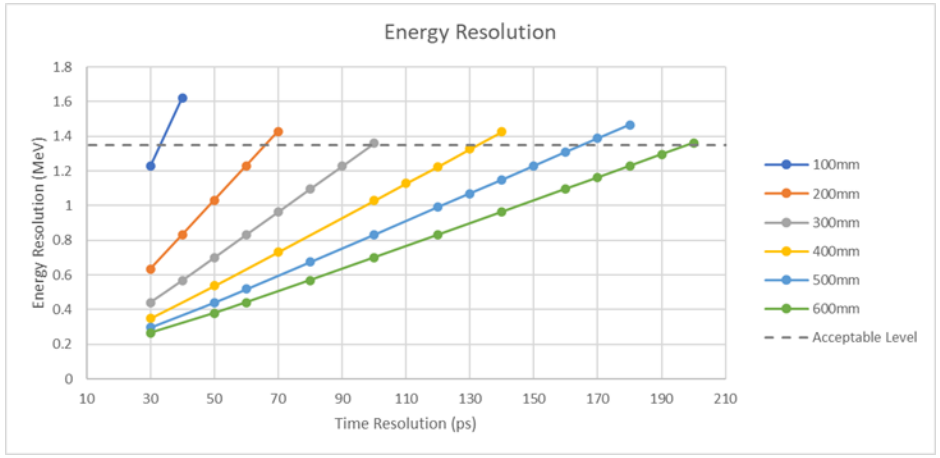
PCB's on order!
PMT used as stand-in

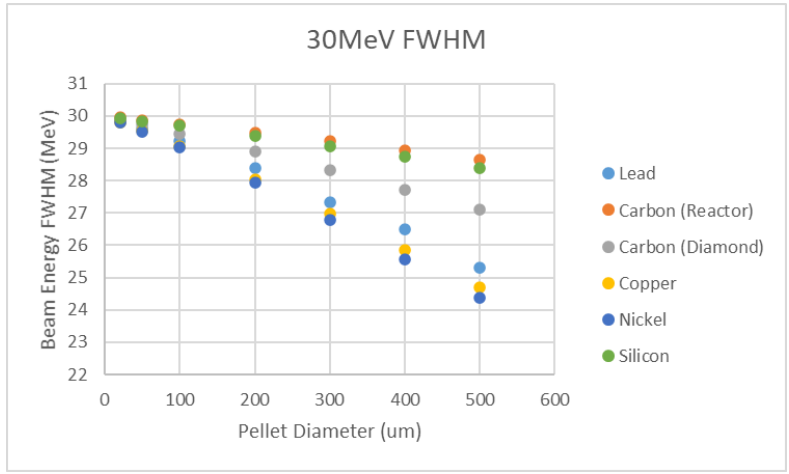


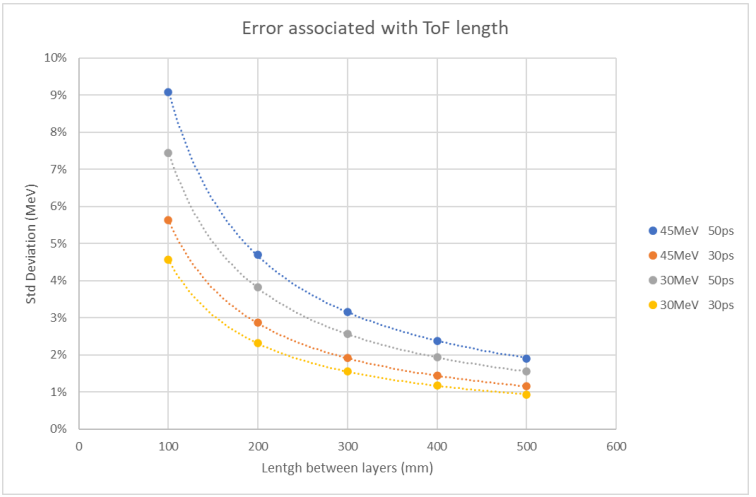


Thank you for listening!
Any Questions?



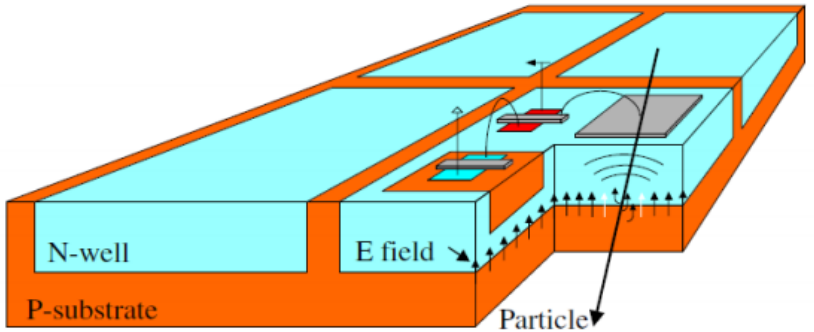






Backup Slides

HVCMOS - High Voltage CMOS

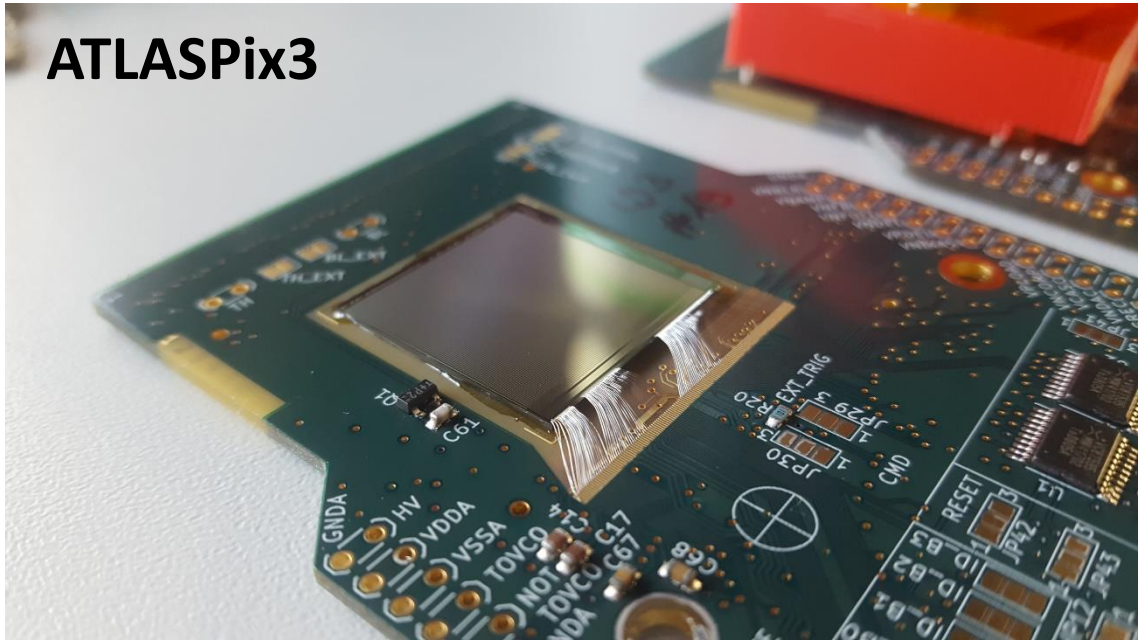


- I. Peric et al (2007)
- MuPix7 simplified cross section

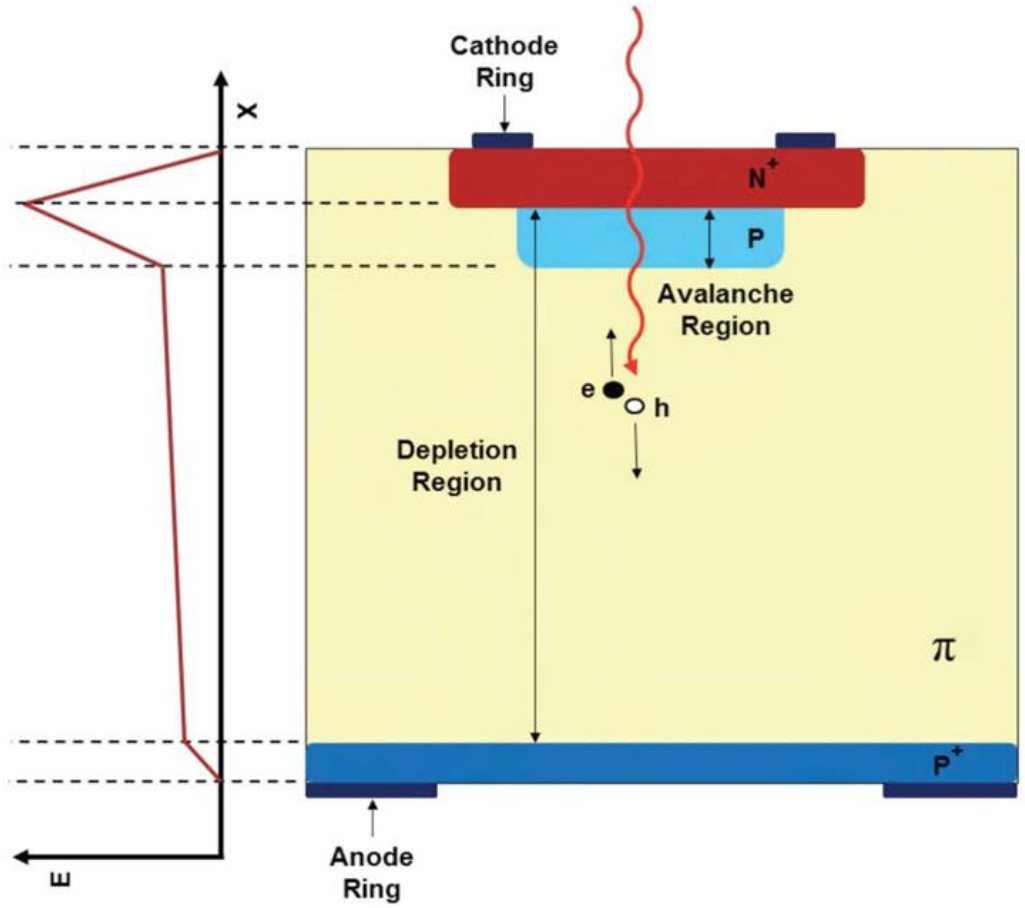
CMOS structure inserted in an isolated deep N-Well.

High resistivity wafers in a standard commercial process allow large depletion to be easily achieved at a low cost compared to other detector systems such as hybrid silicon.

- Small pixel sizes (50µm×50µm)
- Thin modules (>50µm)
- High radiation tolerance (E15 n_eq/cm^2)
- Time resolution (5ns)
- Power consumption (150 mW/cm^2)



LGAD - Low Gain Avalanche Diodes

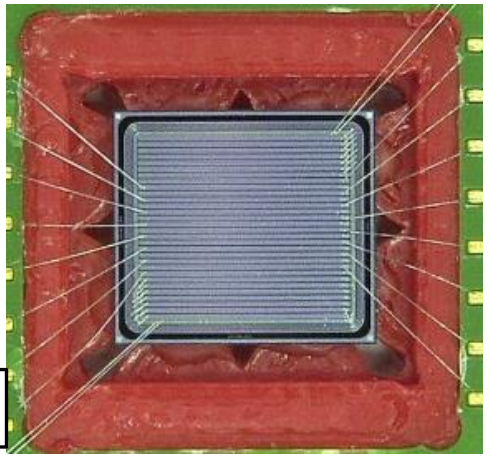


Standard n+ implant is typical for silicon diode detectors.

Heavily doped “P” avalanche/gain region producing a typical range of 10-100.

Very fast hit collection. Resolution in order of tens of ps.

Sensors can be thinned < 300 µm

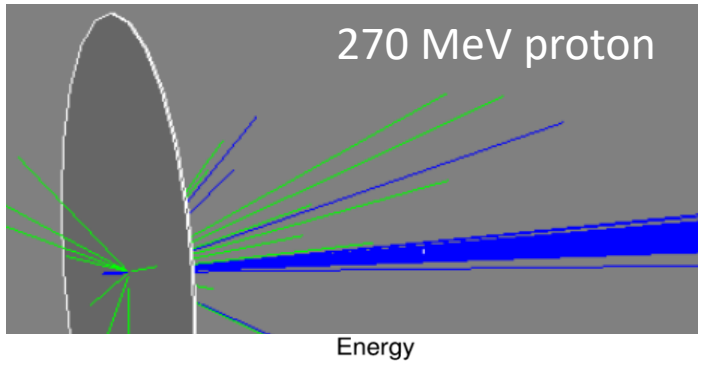


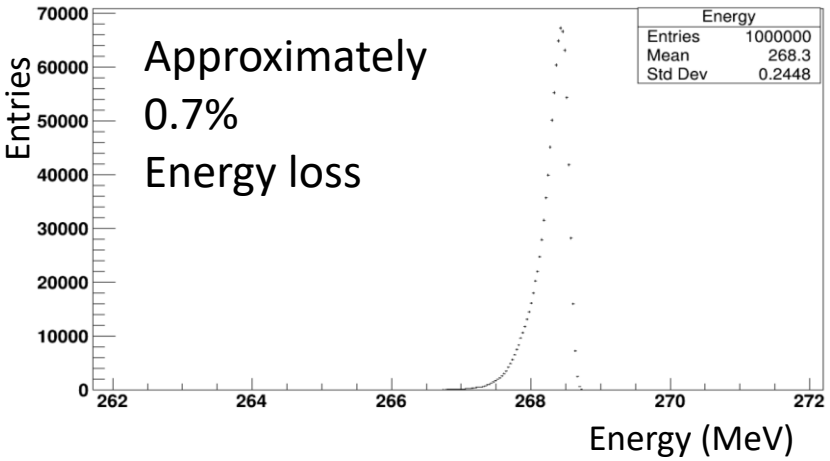
UFSD2 LGAD

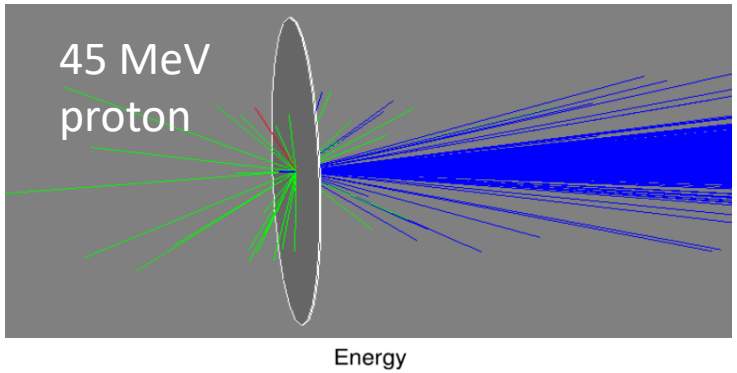
http://scipp.ucsc.edu/~schumm/talks/atlas/LGAD/SCHUMM_CPAD-2018.pptx

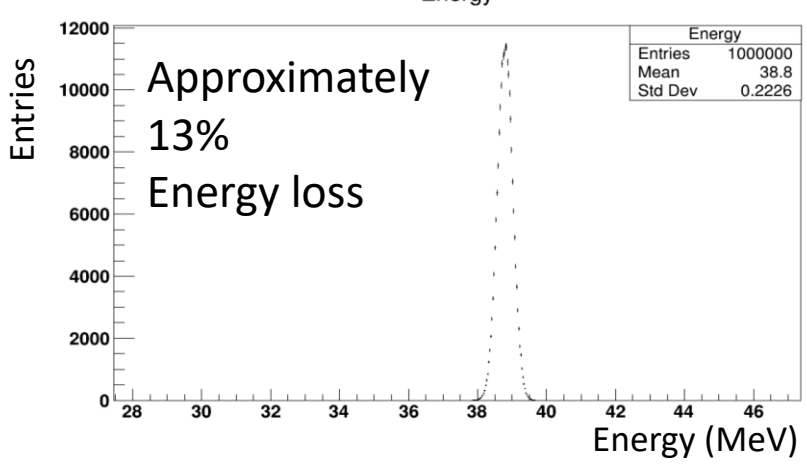
1. The necessity of low material budget

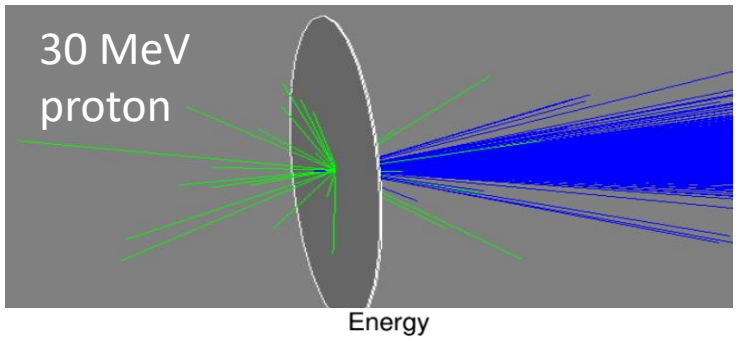
Strong effect from the current 800 um beam window at lower energies.
2cm plastic scintillator also needed for precise position resolution (1mm).
Another approach will be needed for low energy.

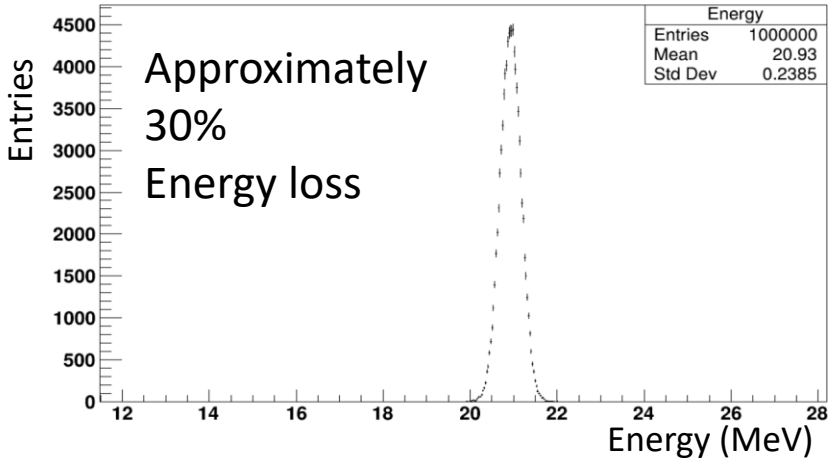




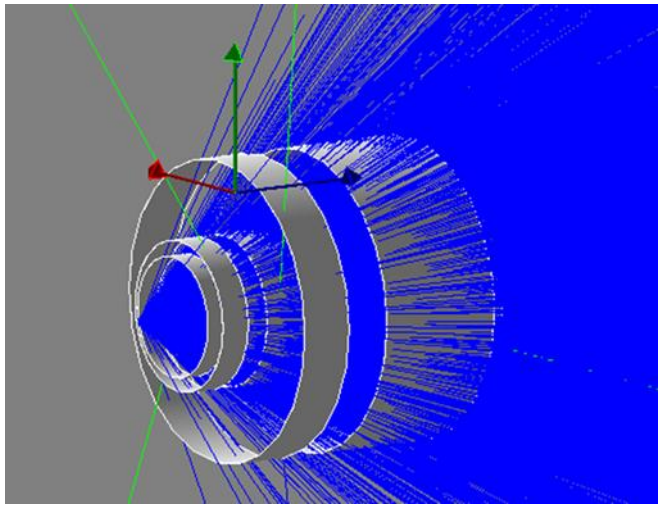








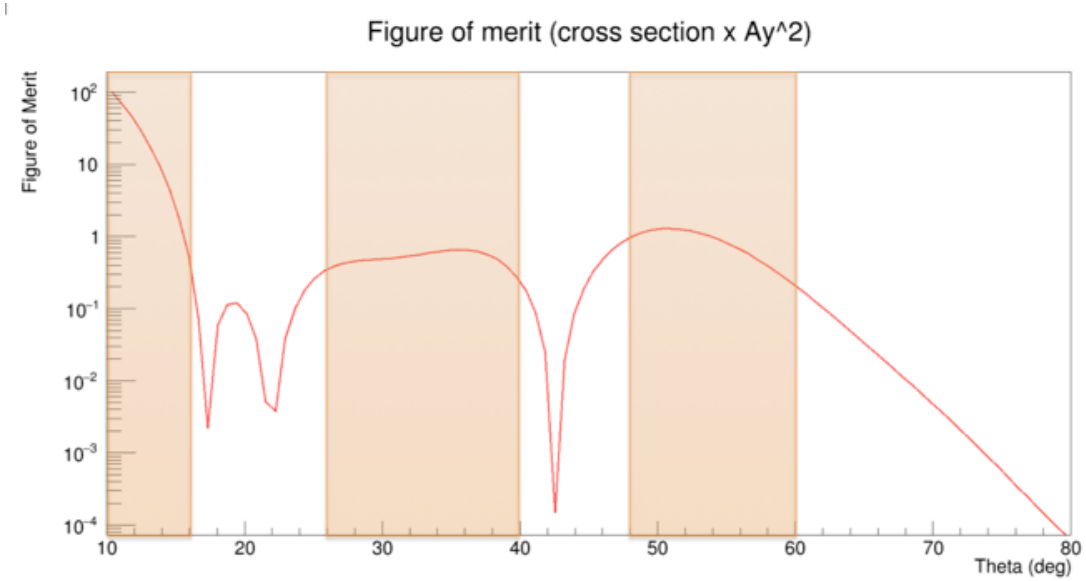
Configuration

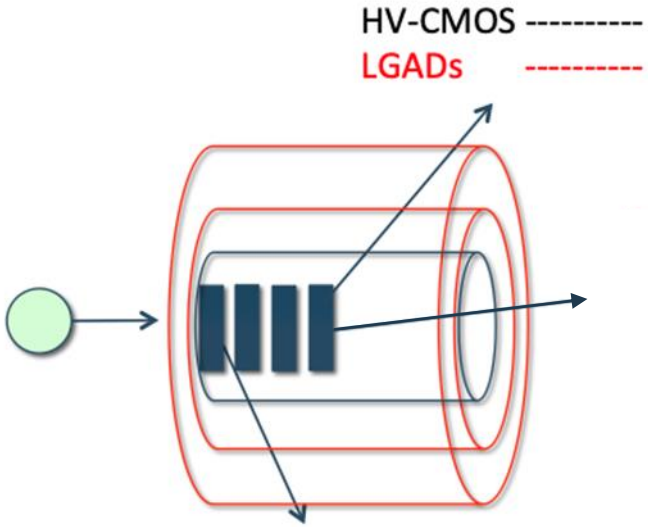


A forward configuration will target only one area of figure of merit

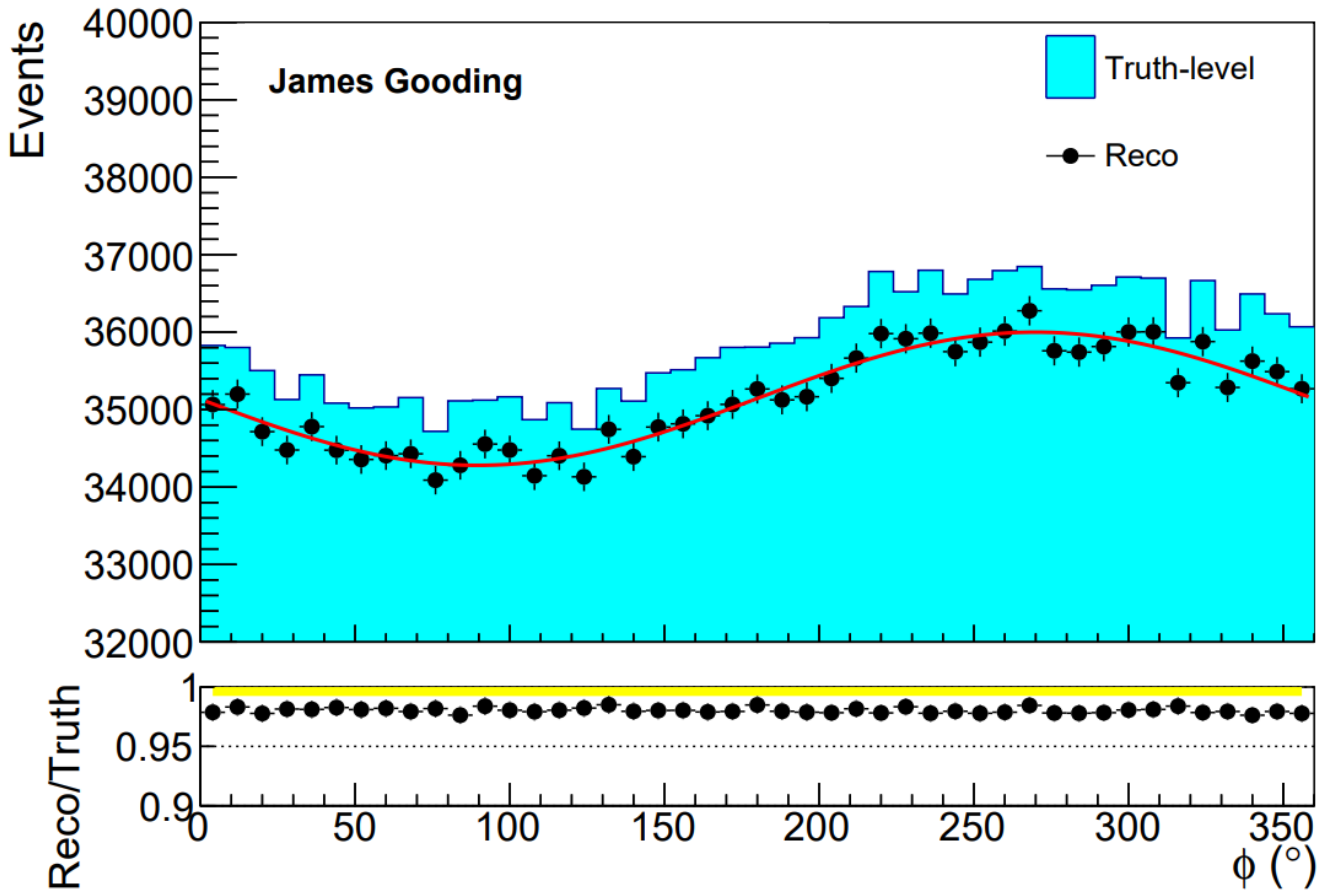
- A cylindrical design surrounding the beamline and target will be effective in two areas of high figure of merit.

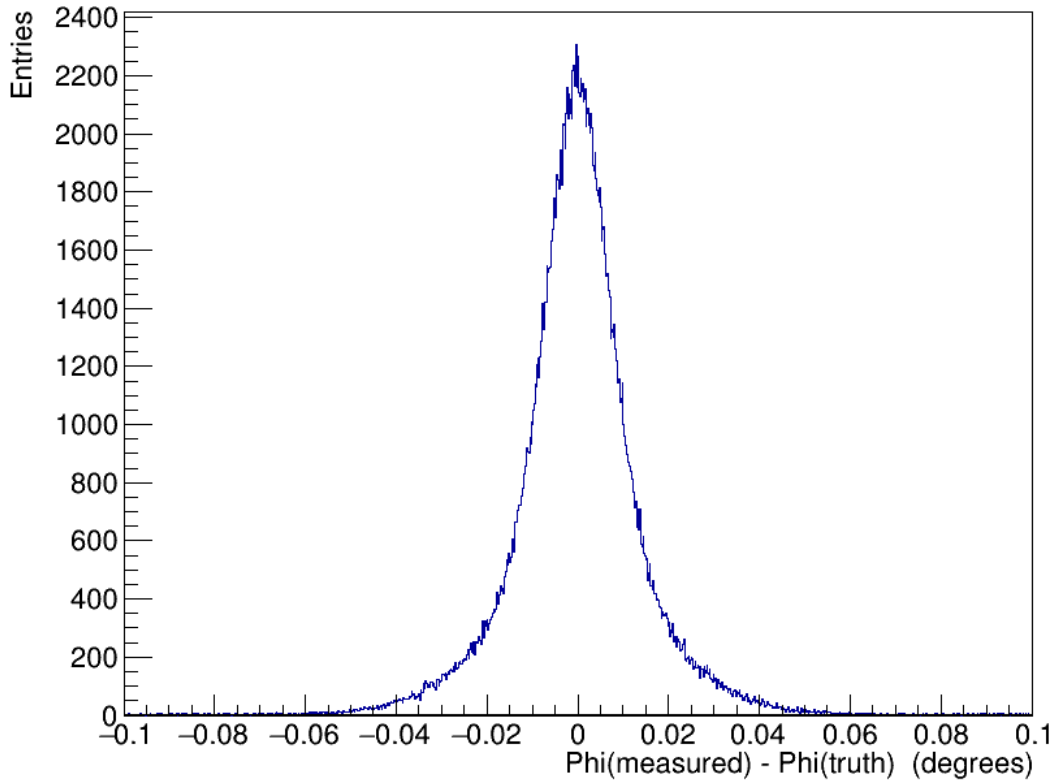
- Forward area figure of merit strongly influenced by rate, not analyzing power.



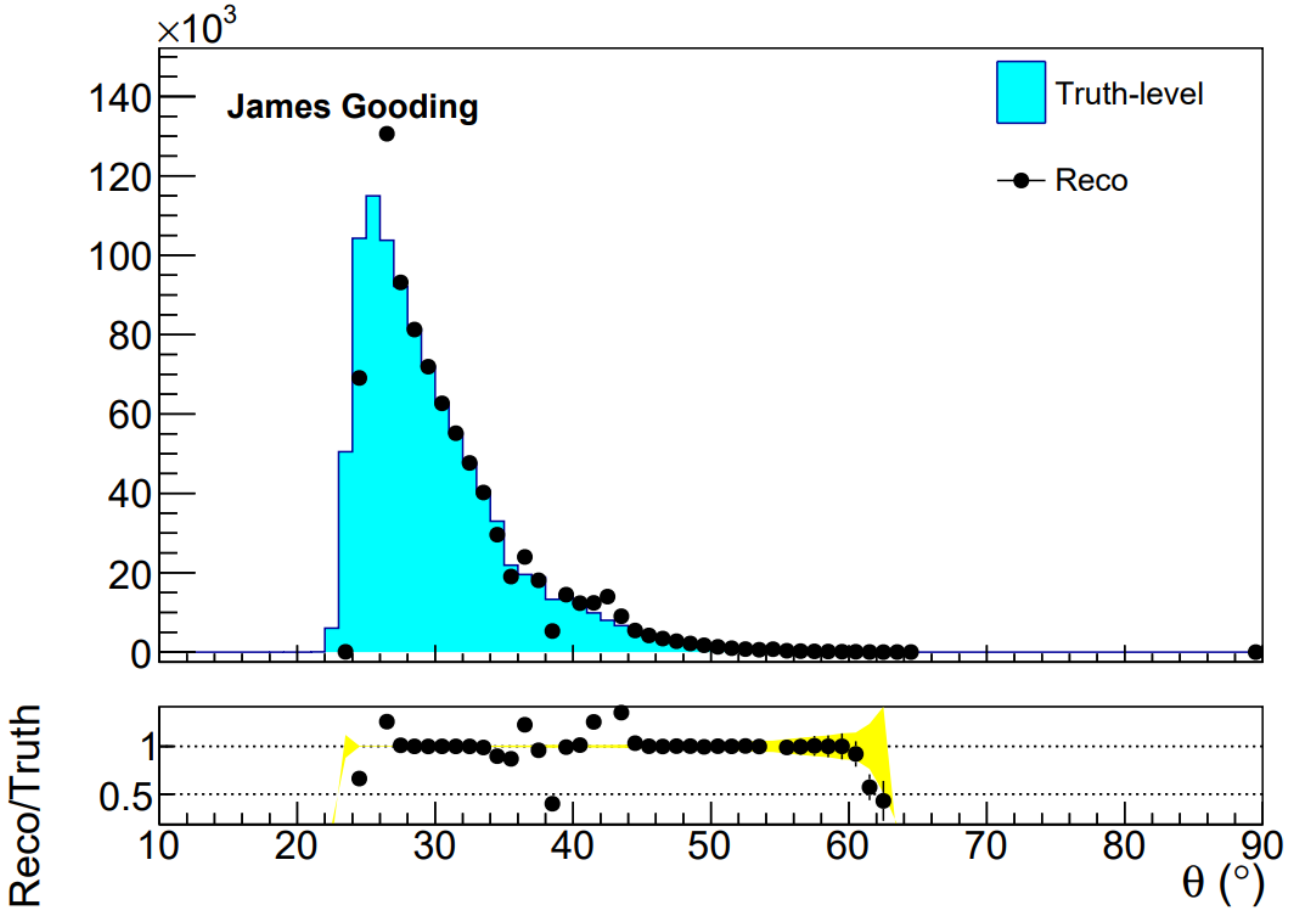


Phi measurement accuracy and efficiency

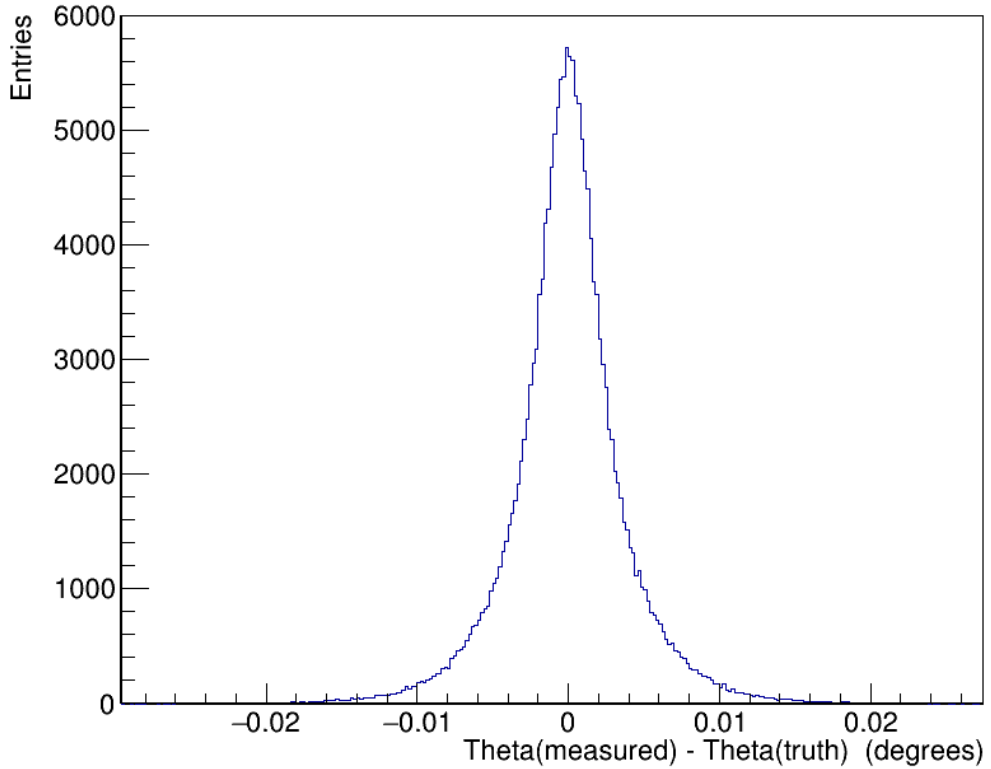


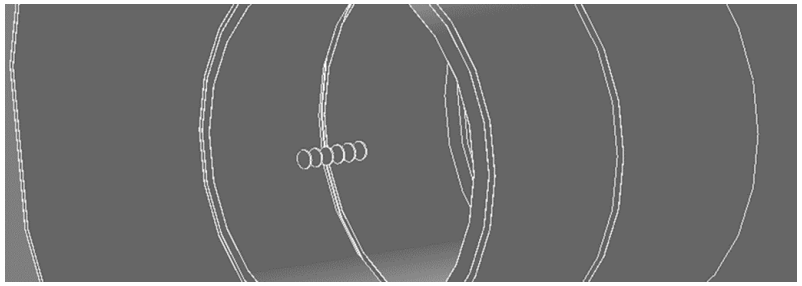


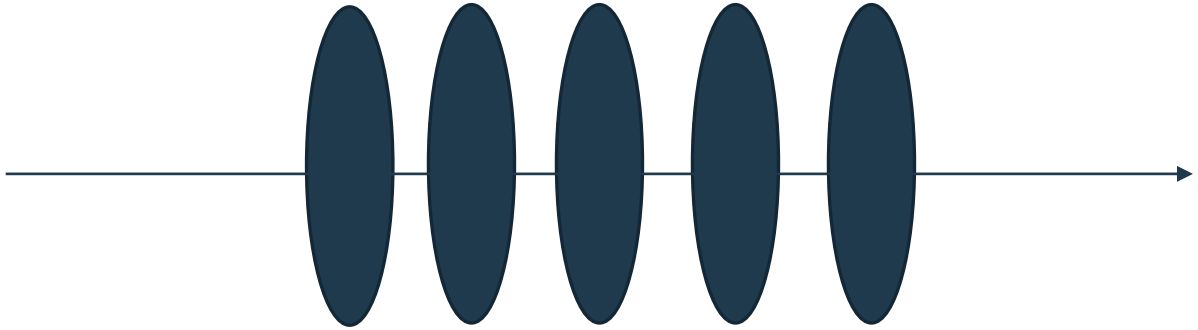
Theta accuracy and efficiency

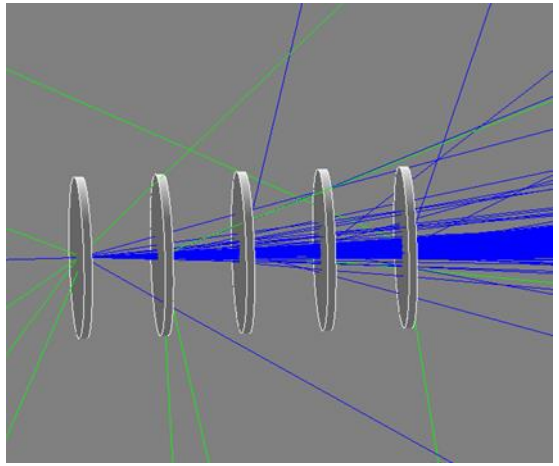


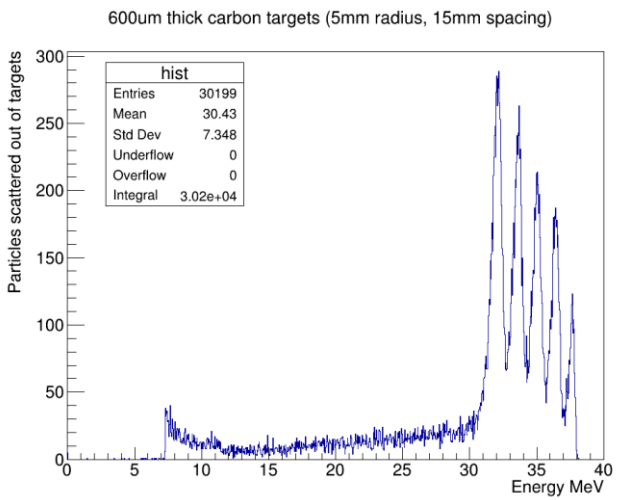
Some theta sections struggle to be reconstructed in sections where there is spacing between cylinders.

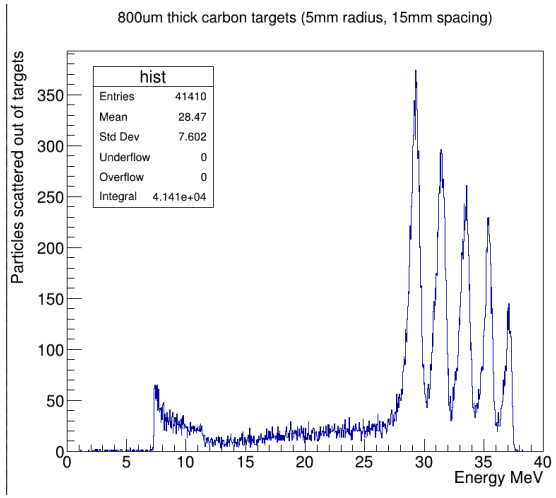


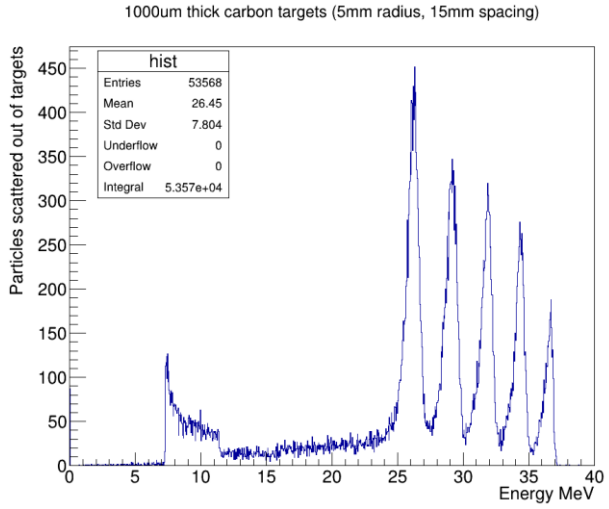


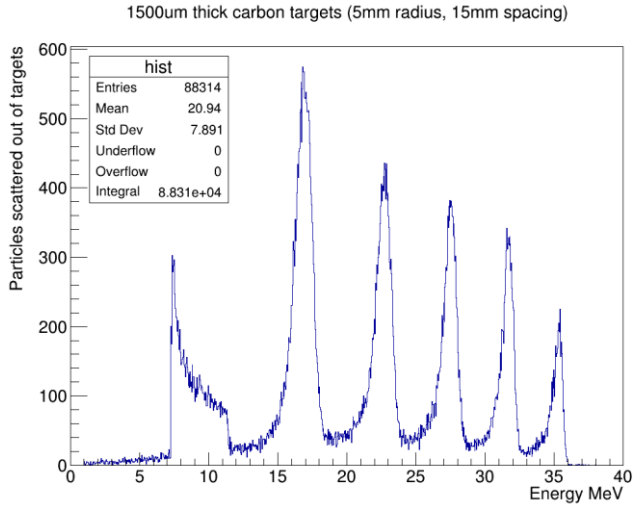




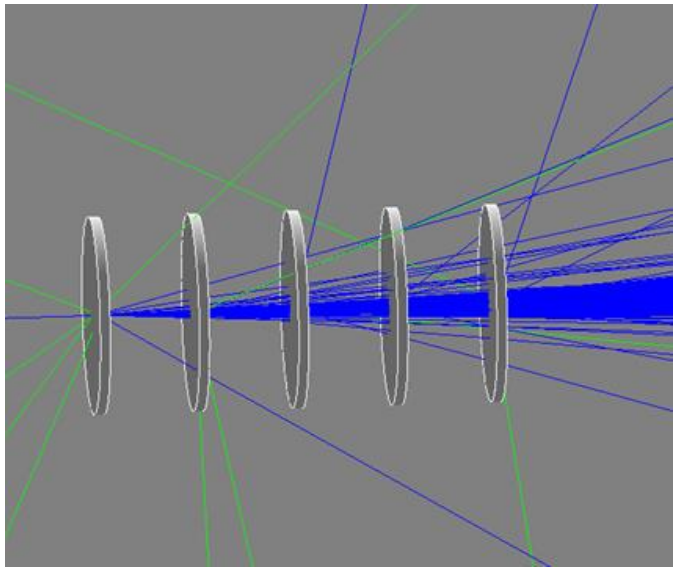

600um thick carbon targets (5mm radius, 15mm spacing)
Particles scattered out of targets
Energy MeV
hist
Entries 30199
Mean 30.43
Std Dev 7.348
Underflow 0
Overflow 0
Integral 3.02e+04

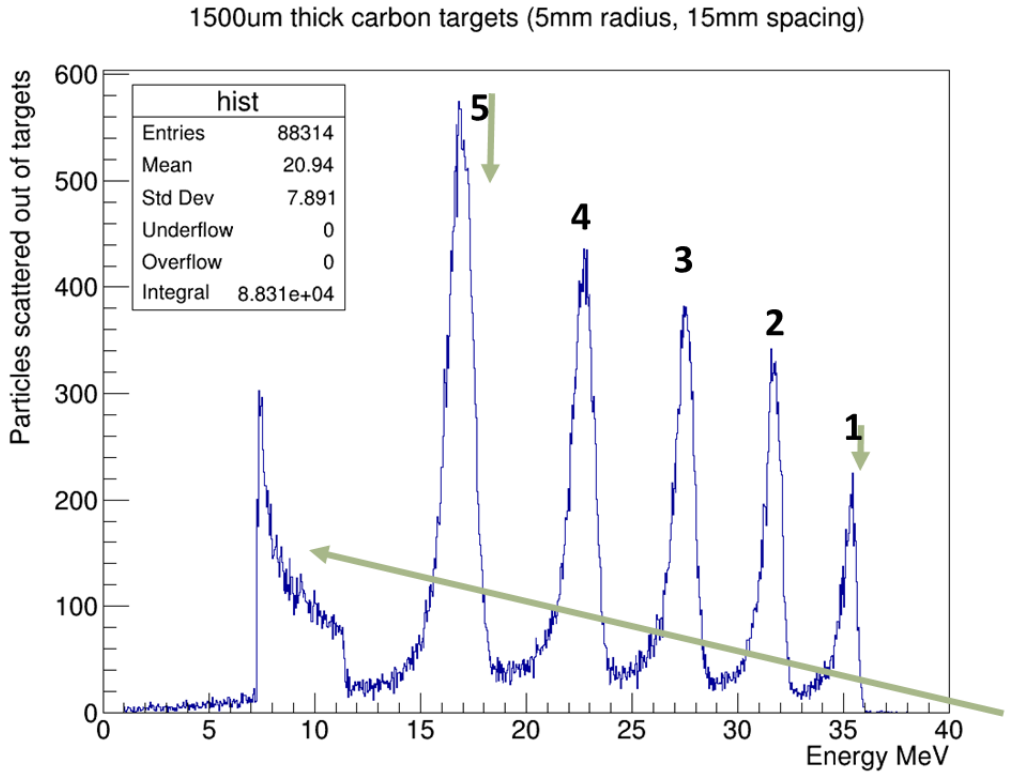

800um thick carbon targets (5mm radius, 15mm spacing)
Particles scattered out of targets
Energy MeV
hist
Entries 41410
Mean 28.47
Std Dev 7.602
Underflow 0
Overflow 0
Integral 4.141e+04


1000um thick carbon targets (5mm radius, 15mm spacing)
Particles scattered out of targets
Energy MeV
hist
Entries 53568
Mean 26.45
Std Dev 7.804
Underflow 0
Overflow 0
Integral 5.357e+04


1500um thick carbon targets (5mm radius, 15mm spacing)
Particles scattered out of targets
Energy MeV
hist
Entries 88314
Mean 20.94
Std Dev 7.891
Underflow 0
Overflow 0
Integral 8.831e+04

Split Target Investigations



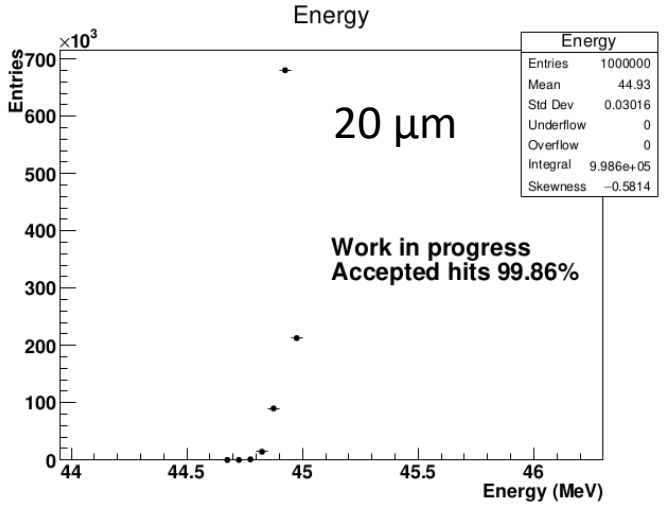


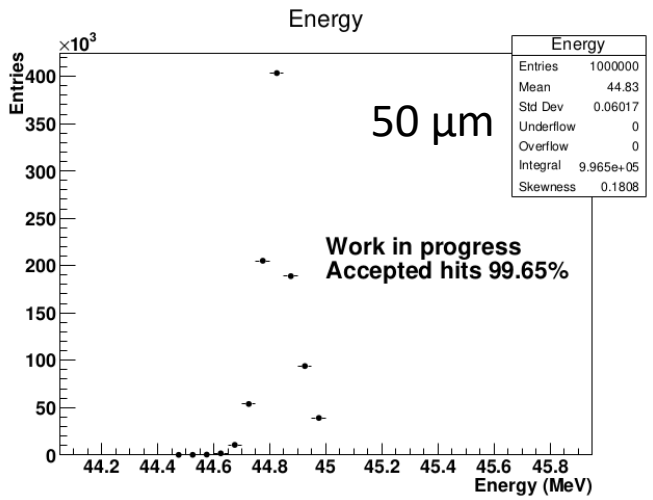
Scatter from last target

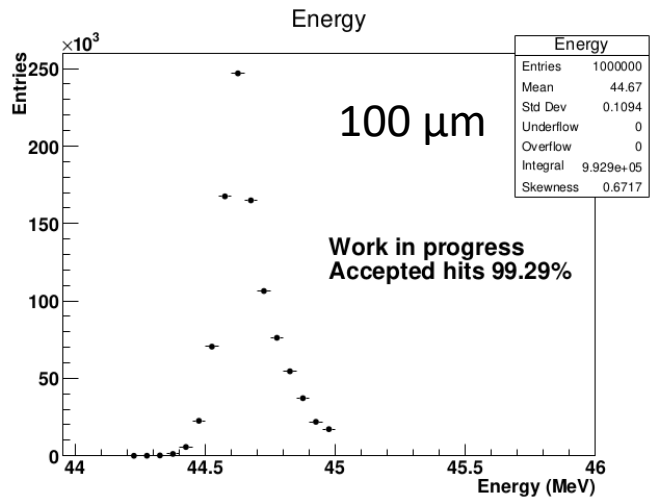
Scatter from first target

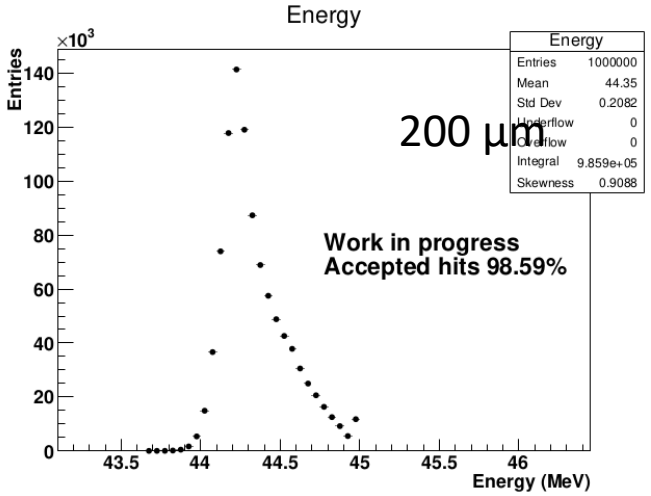
Inelastic landau region
(Proportional to thickness)
(Seems to be radius independent on first testing)

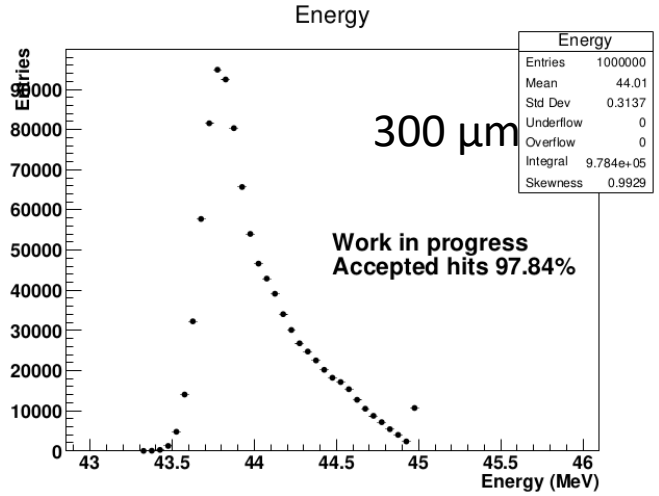
Carbon (Diamond) 45MeV

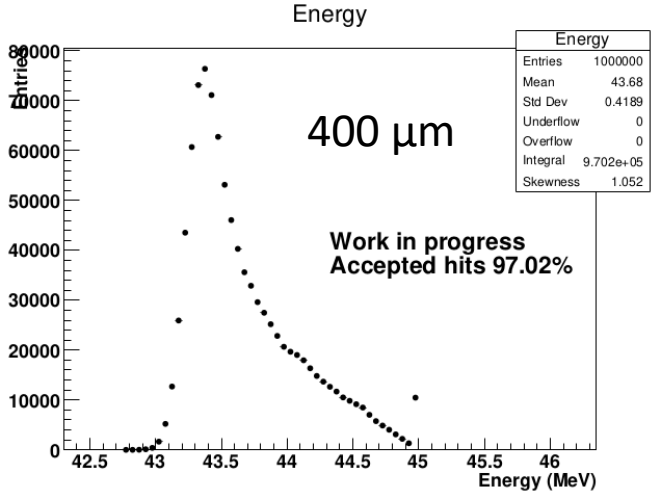






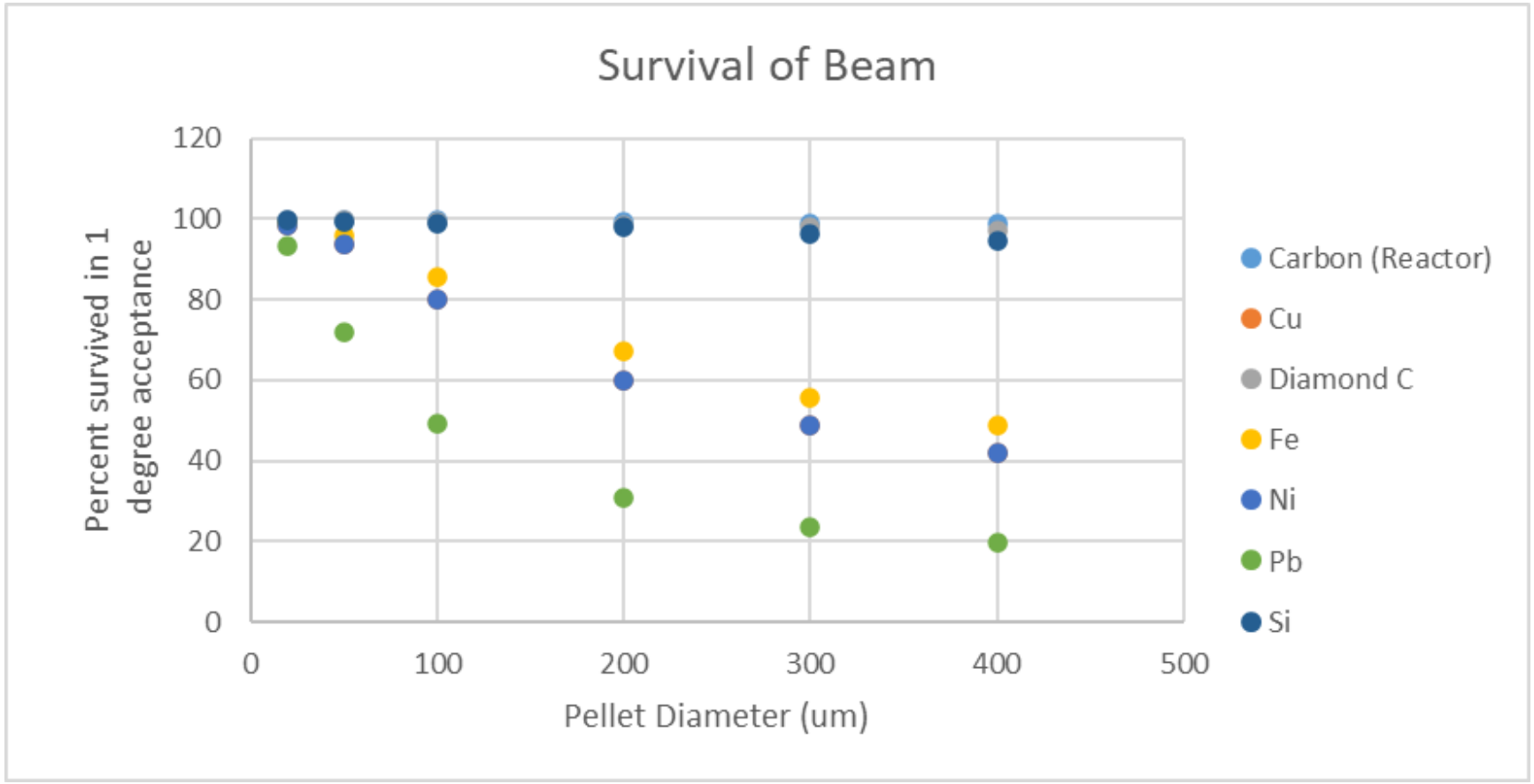






30 MeV

1° acceptance



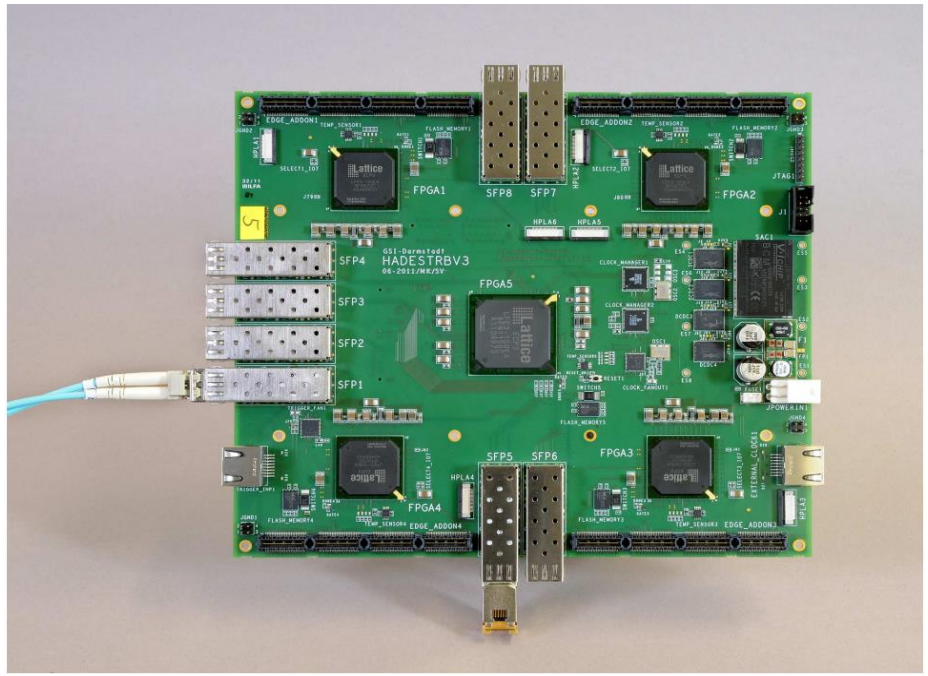
Beam defined as 1% larger diameter then pellet:
- 1.97% by definition passes pellet without interaction

LGAD Time of Flight telescope

- Readout

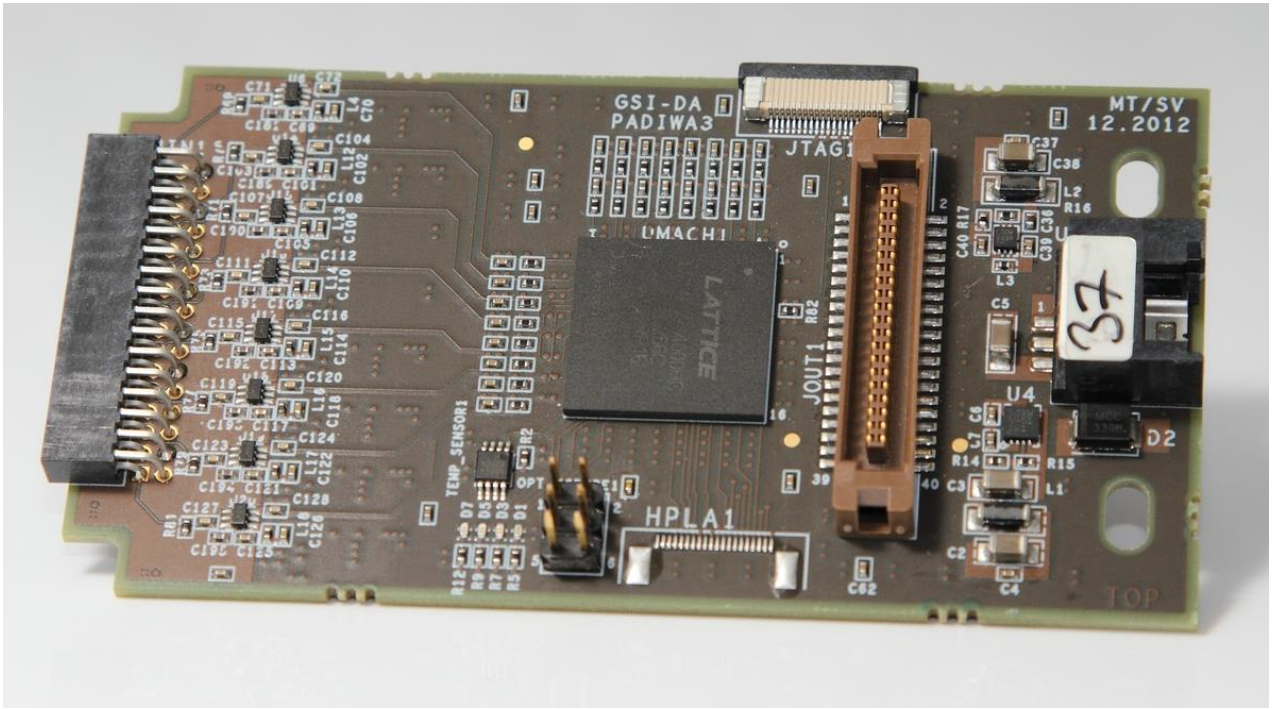
Extra information:
http://jspc29.x-matter.uni-frankfurt.de/trb/publications/201310_NoMeTDC_Ugur.pdf

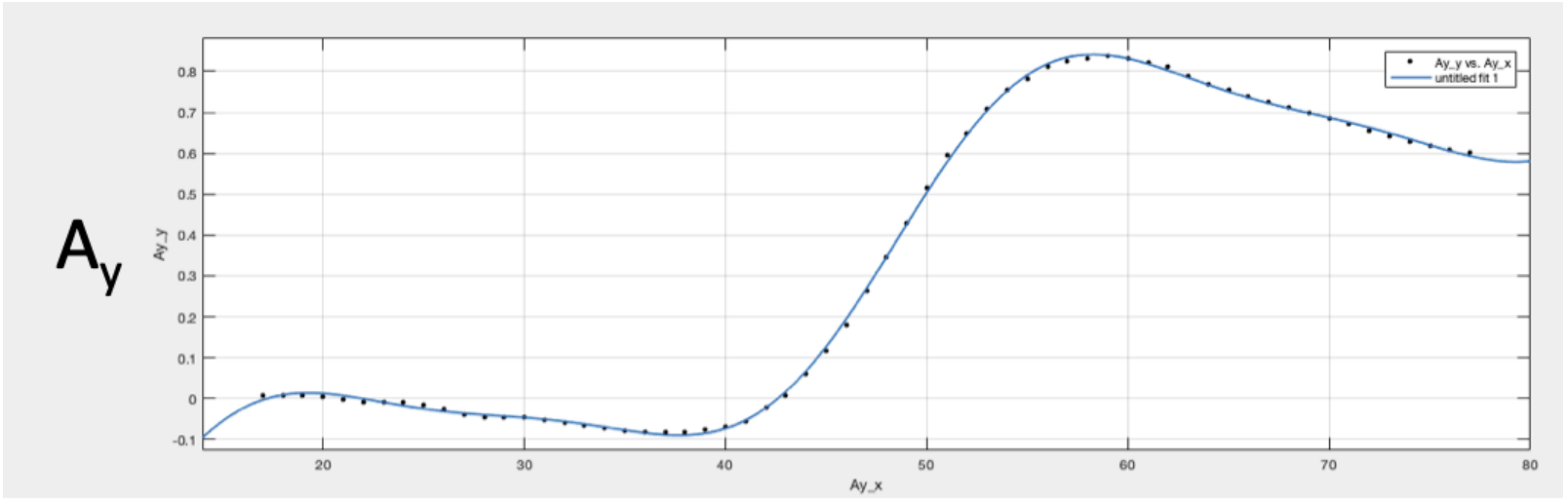
TRB3 & Padiwa boards for TDC and readout

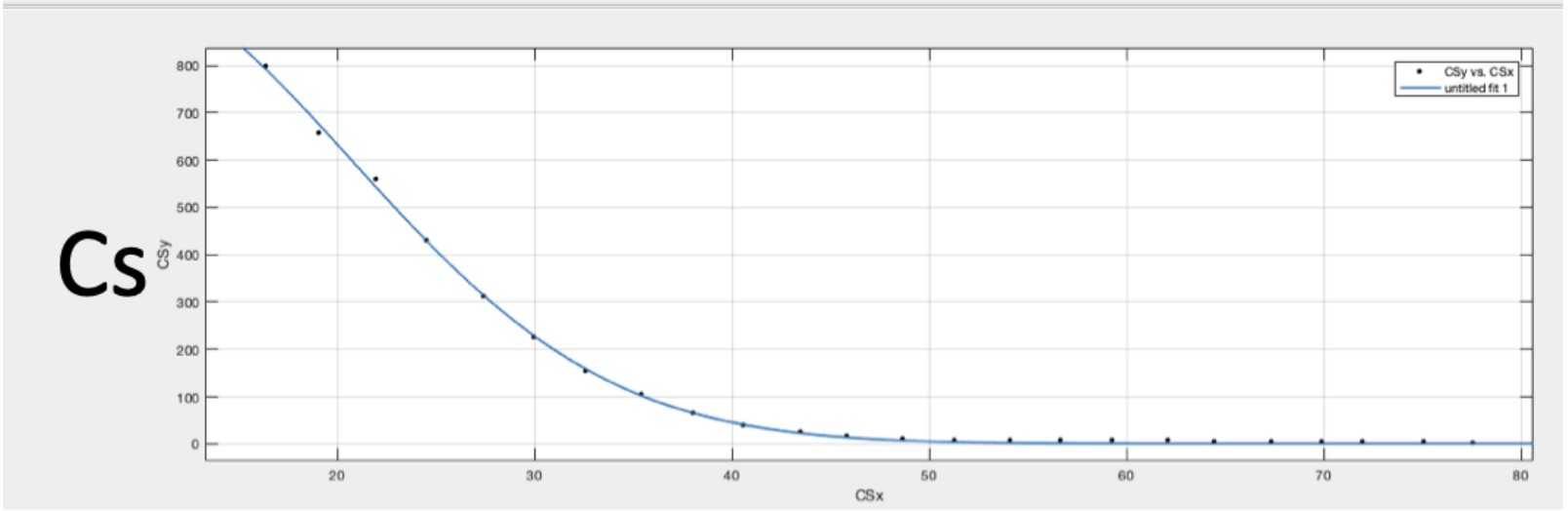


https://iopscience.iop.org/article/10.1088/1748-0221/6/12/C12004/pdf

The third addition to Padiwa-family boards, optimized for direct connection to a MC-PMT - four of these 16 channel boards fit onto the 5x5 cm2 backside of a typical MC-PMT




A_y
Ay_y vs. Ay_x
untitled fit 1
Ay_y
Ay_x
Angle (°)


Cs
CSy vs. CSx
untitled fit 1
CSy
CSx
Angle (°)

39.6 MeV