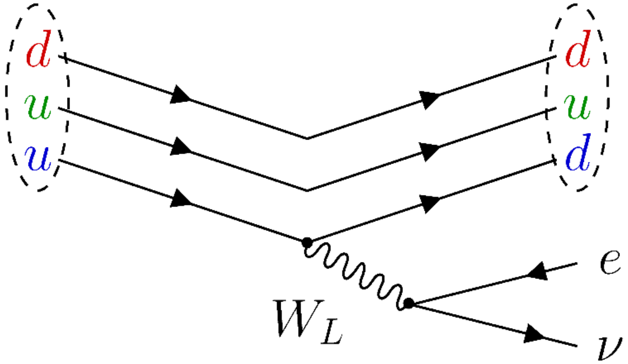
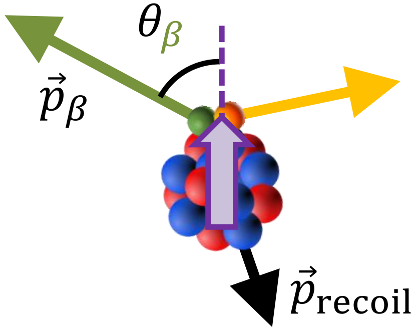
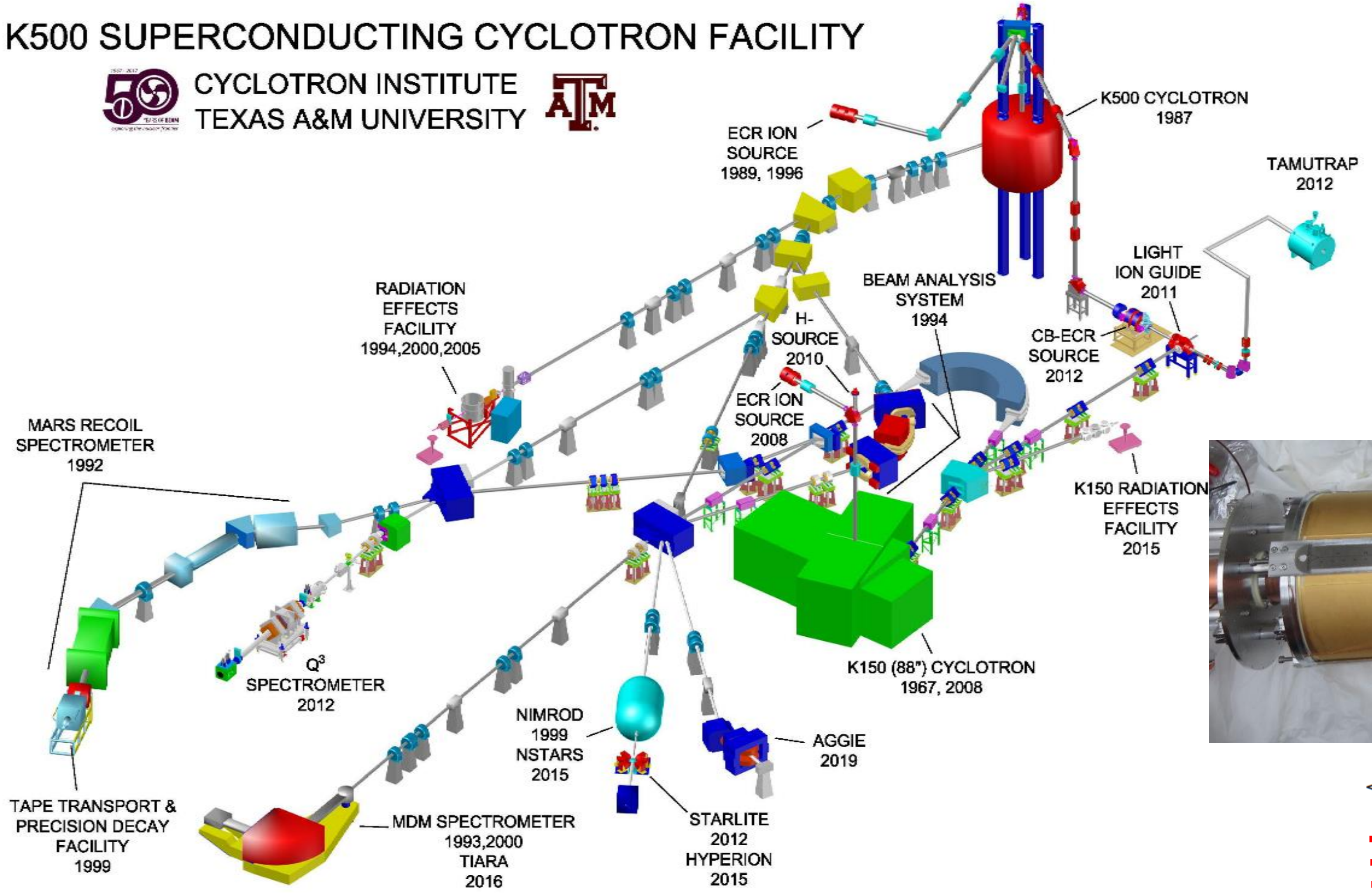
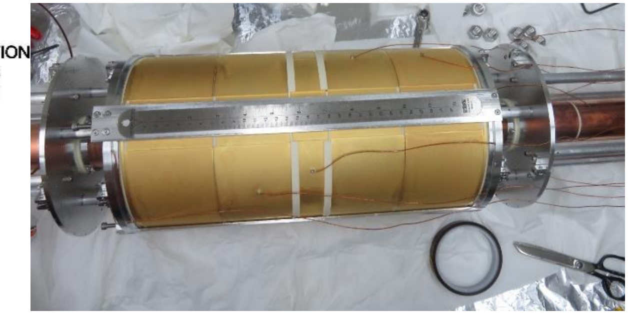
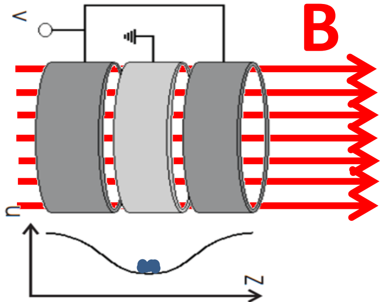
TAMUTRAP plans for and progress towards β-p correlation studies





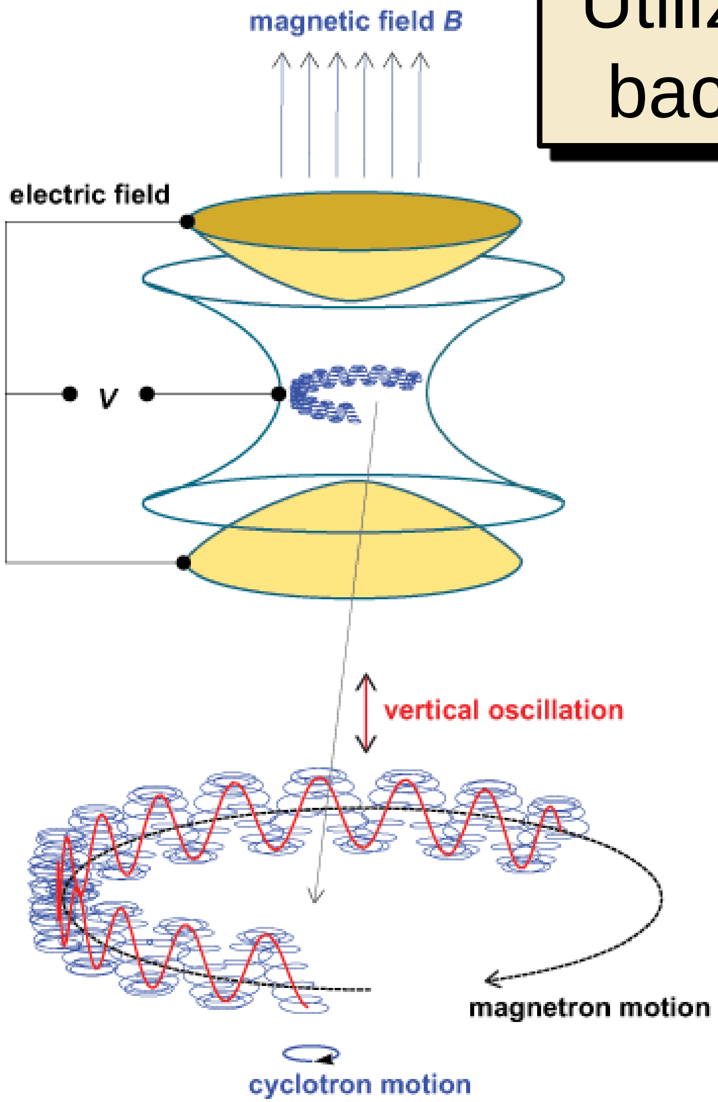




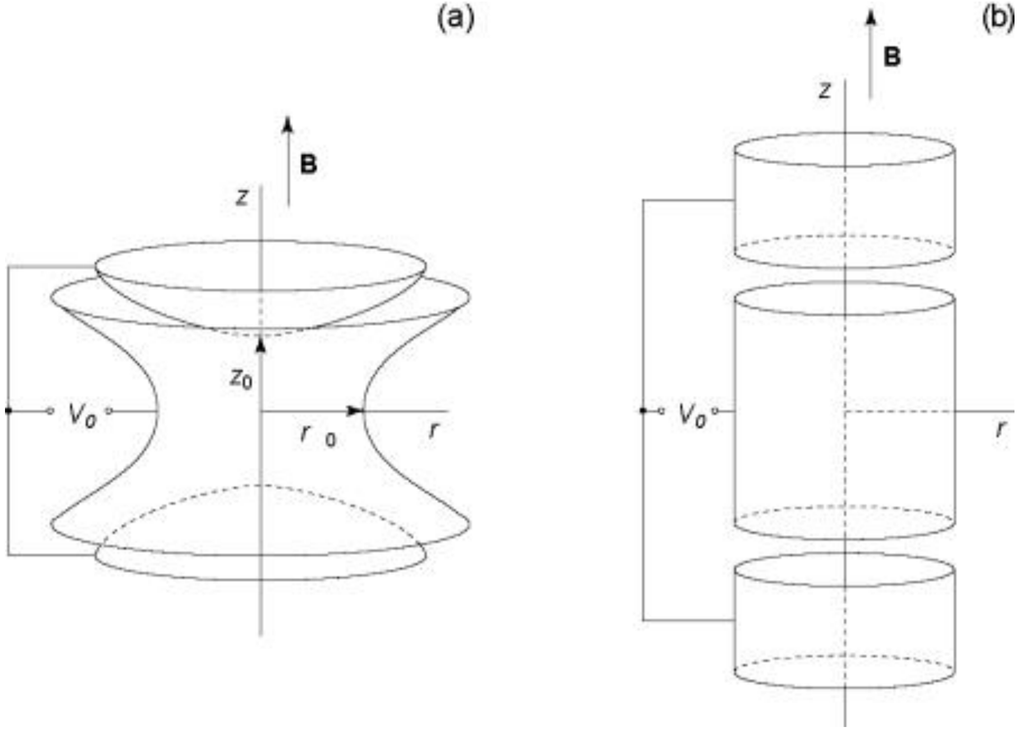


Dan Melconian – WISArD collab 2021

Scattering and energy loss in the foil…



Utilize the technology of Penning traps to provide a backing-free source of localized radioactive ions!!



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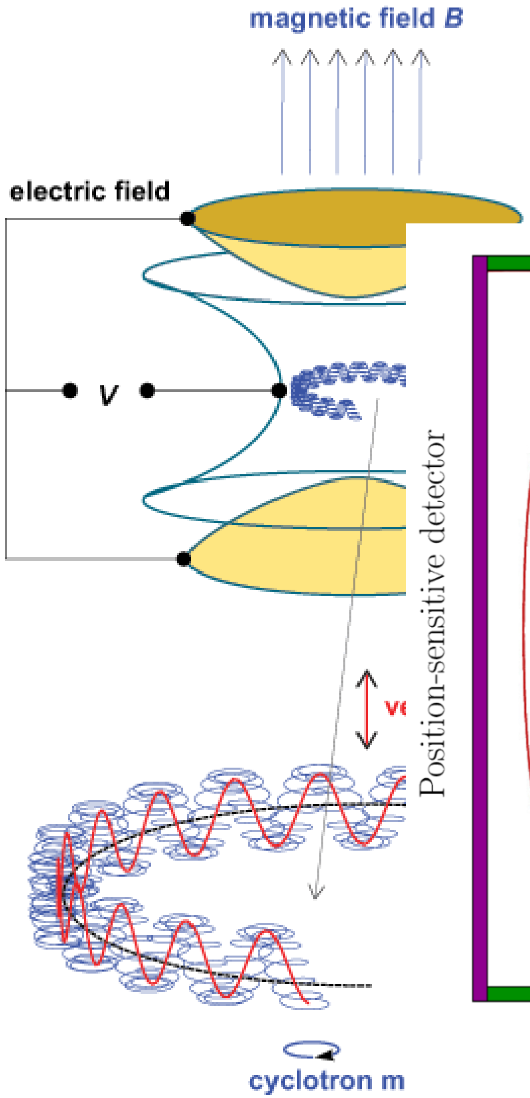
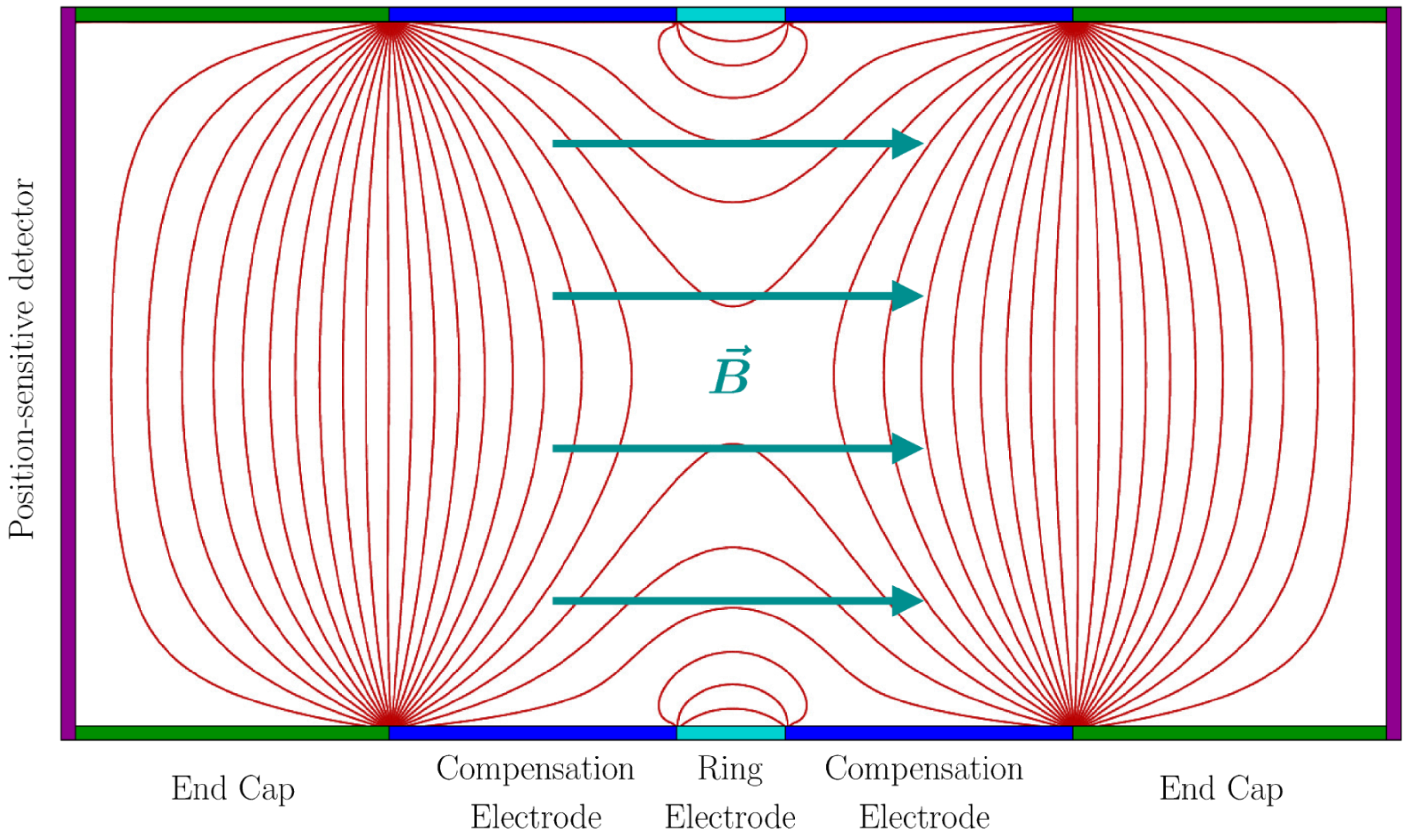
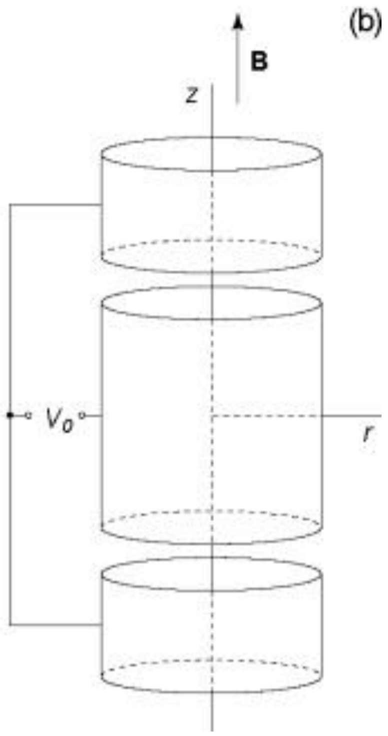
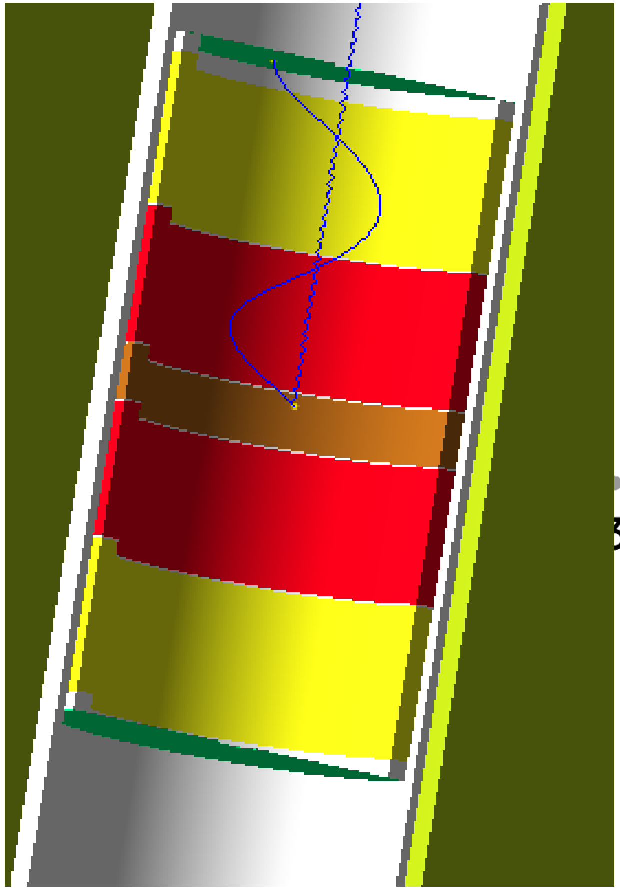
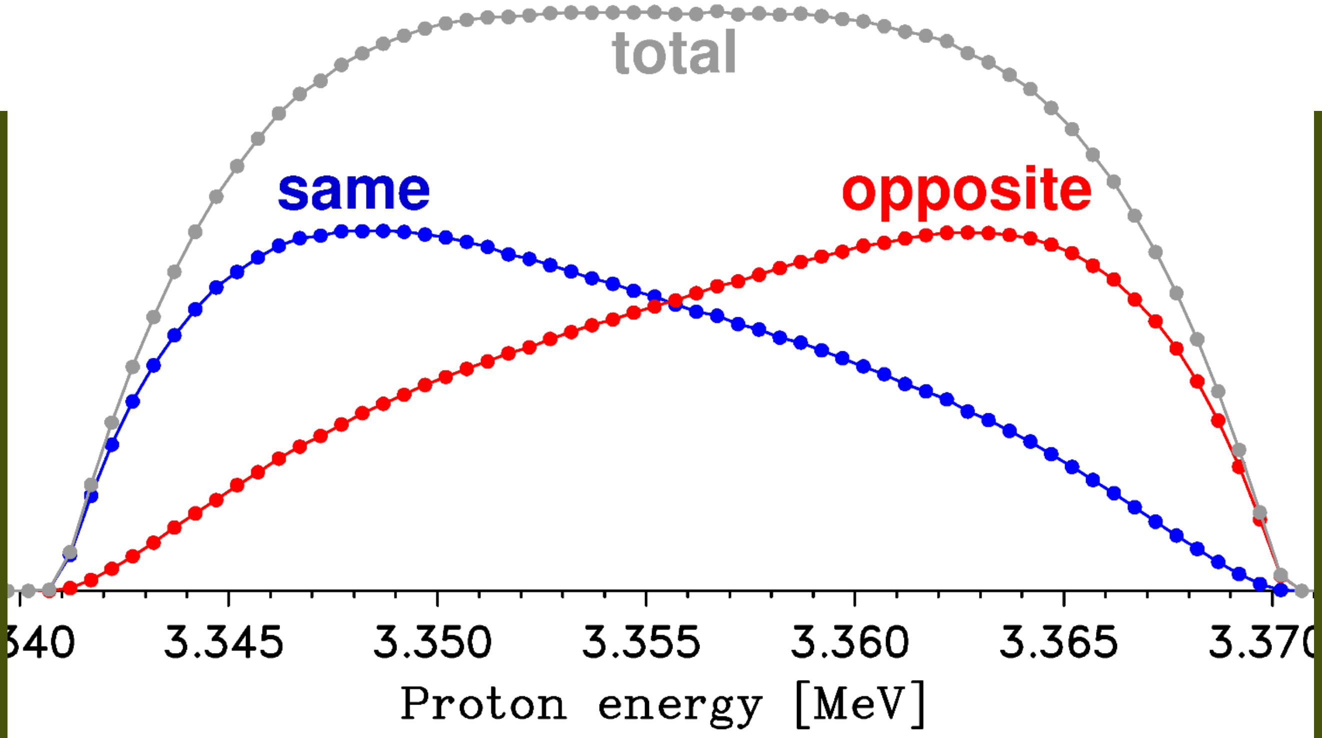


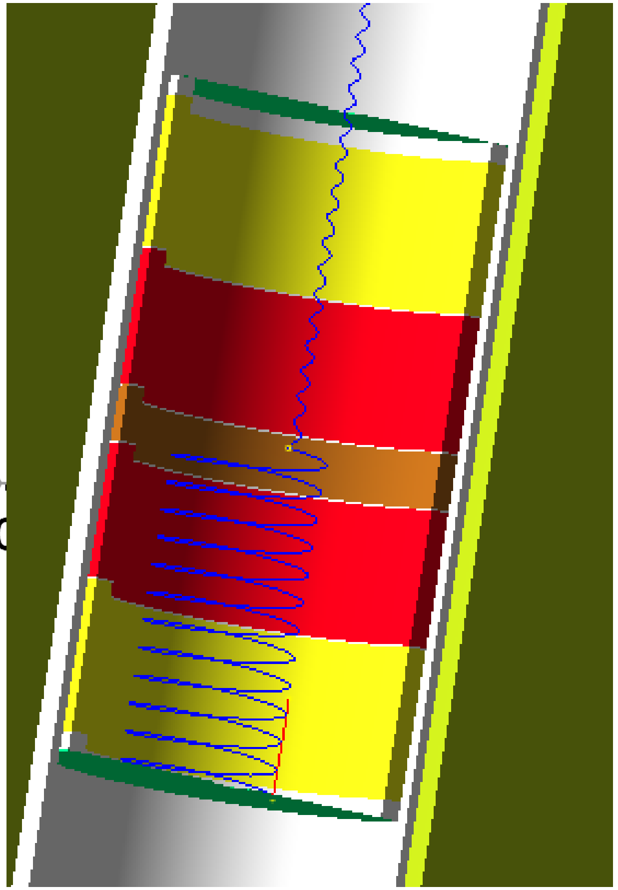


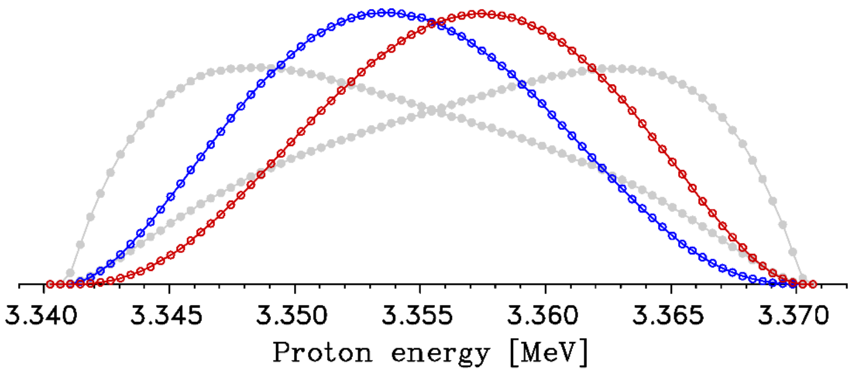


Measure means instead of 2nd moments

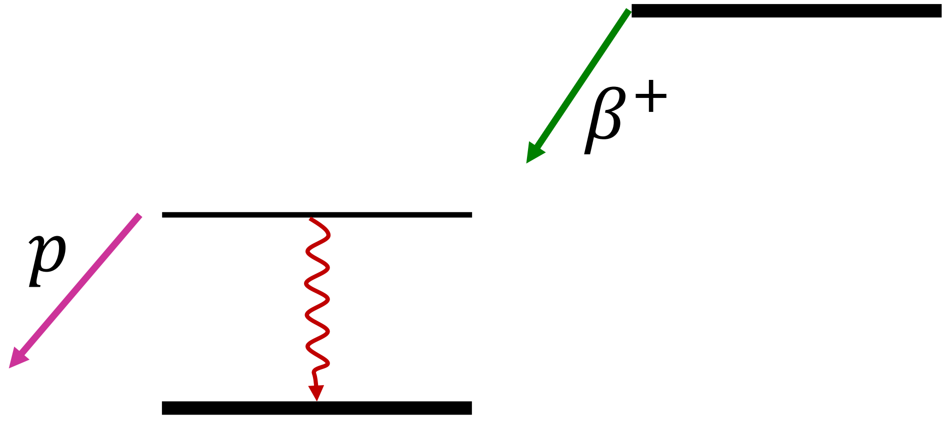


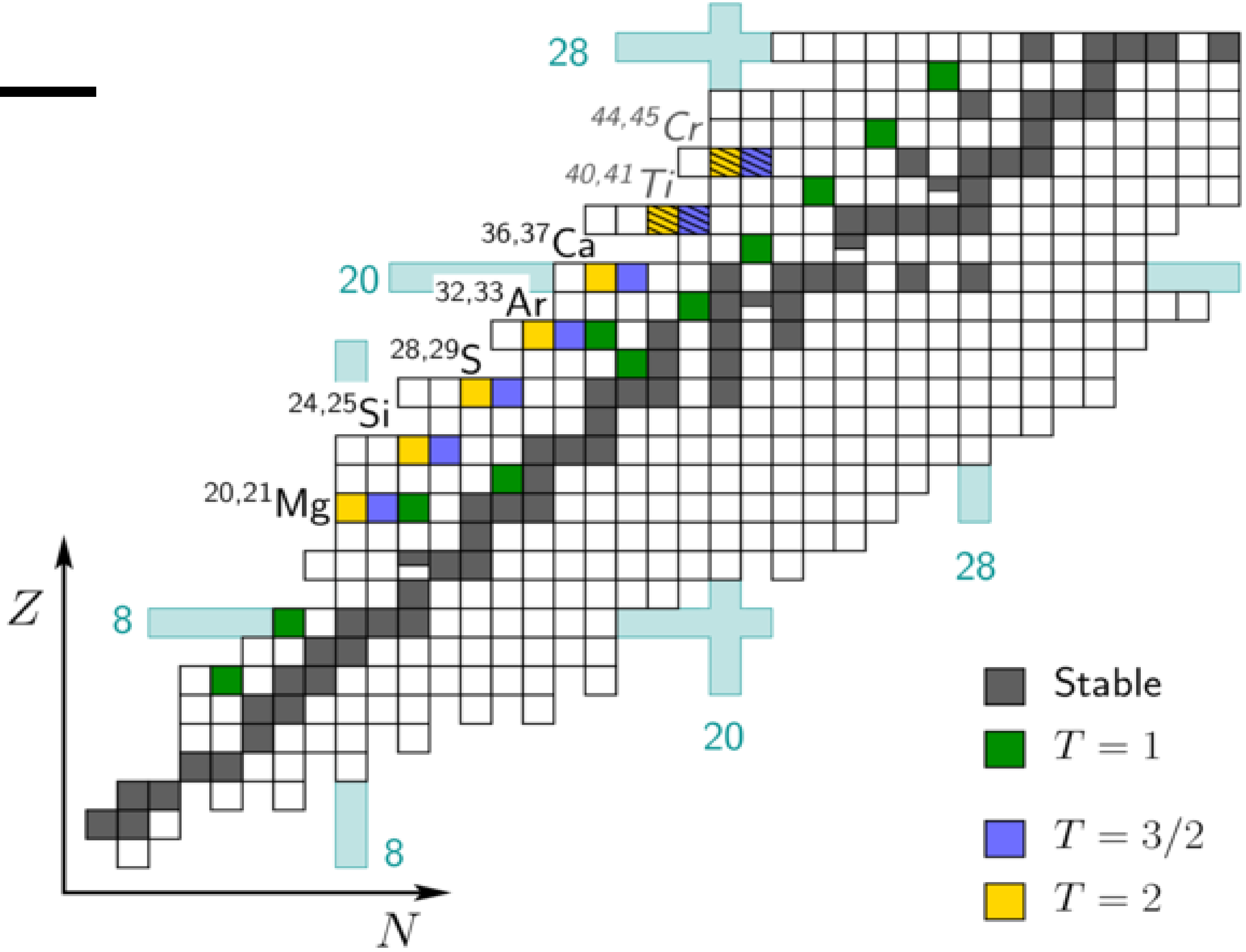




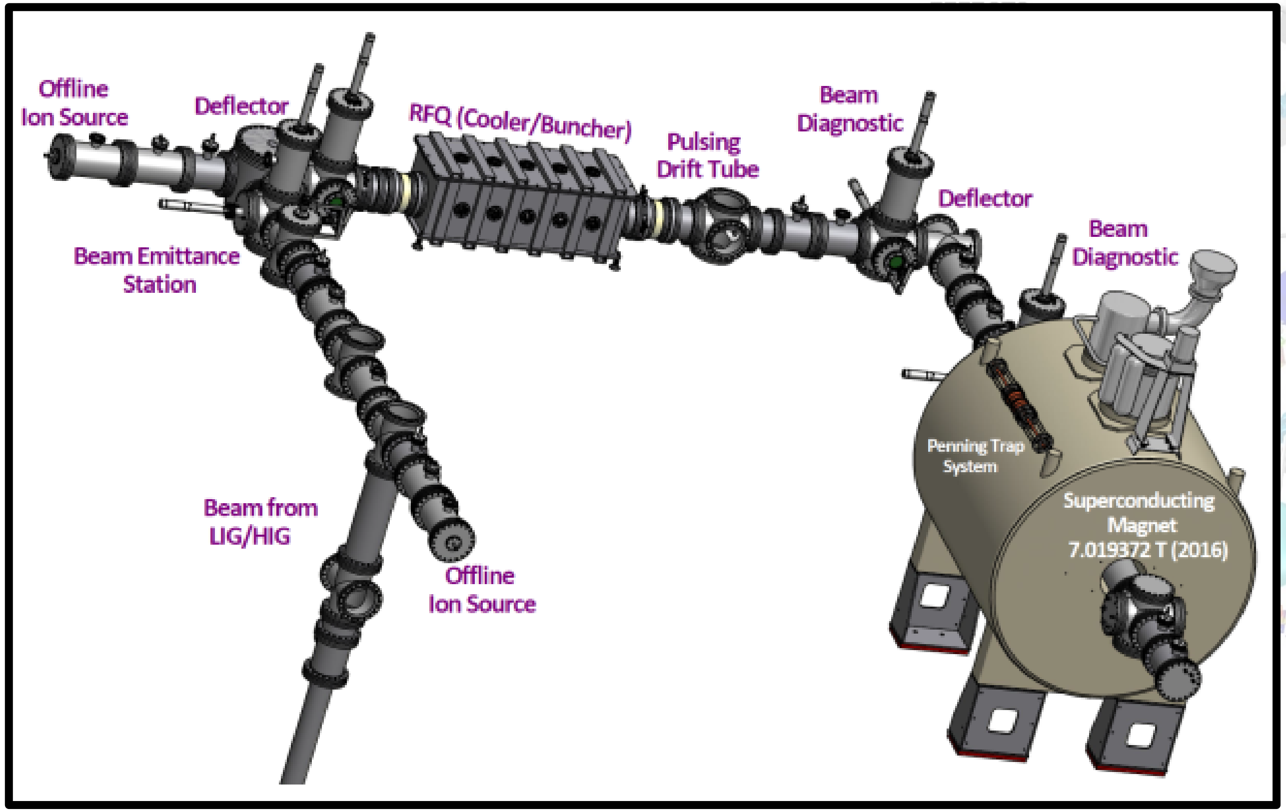


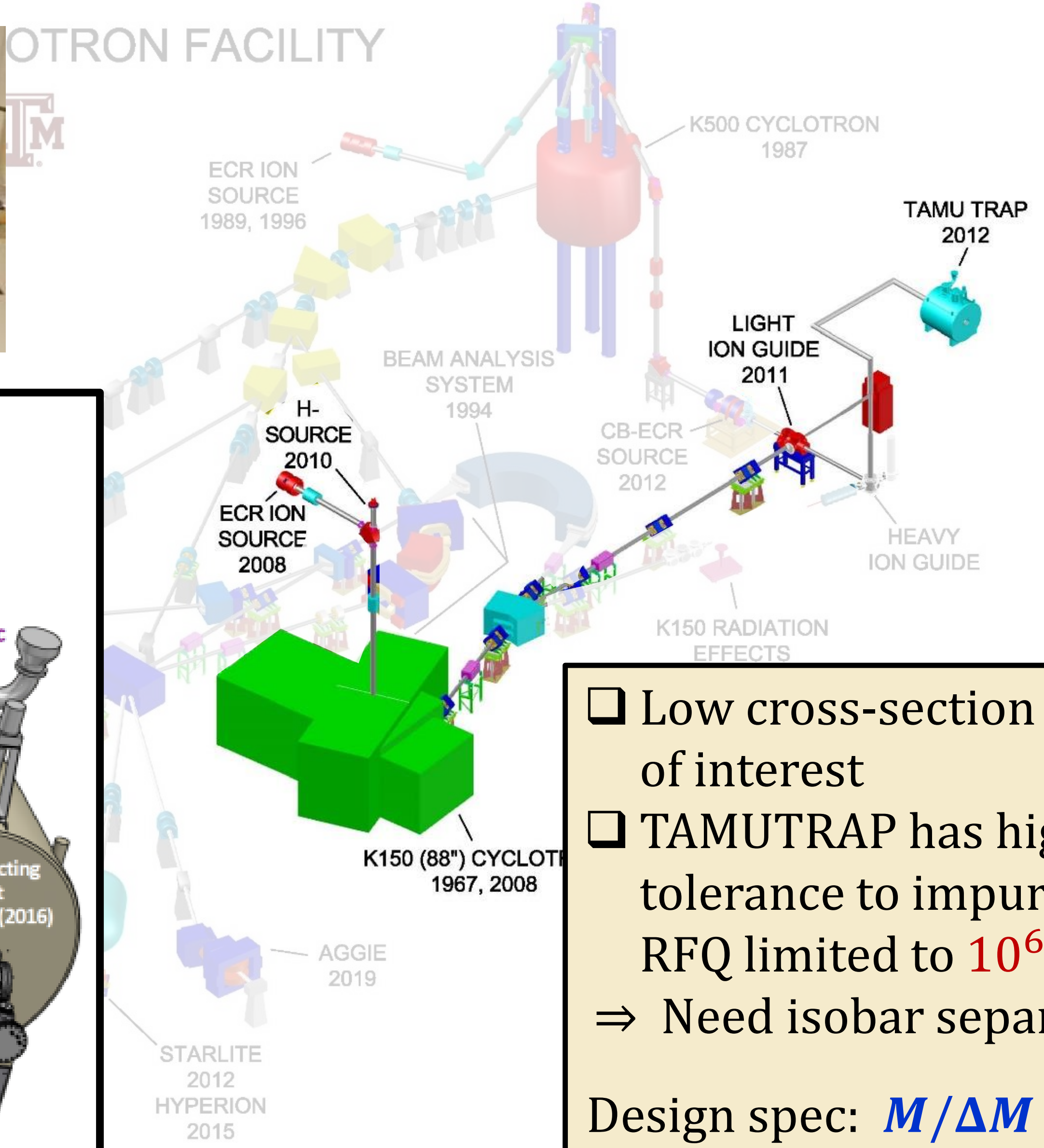
$T = 2, 3/2$ pure Fermi and Gamow-Teller decays





An IGISOL system at the Cyclotron Institute





- ❑ Low cross-section for ions of interest
- ❑ TAMUTRAP has high tolerance to impurities, but RFQ limited to 10^6 ions/sec

$\Rightarrow$ Need isobar separation $\Leftarrow$

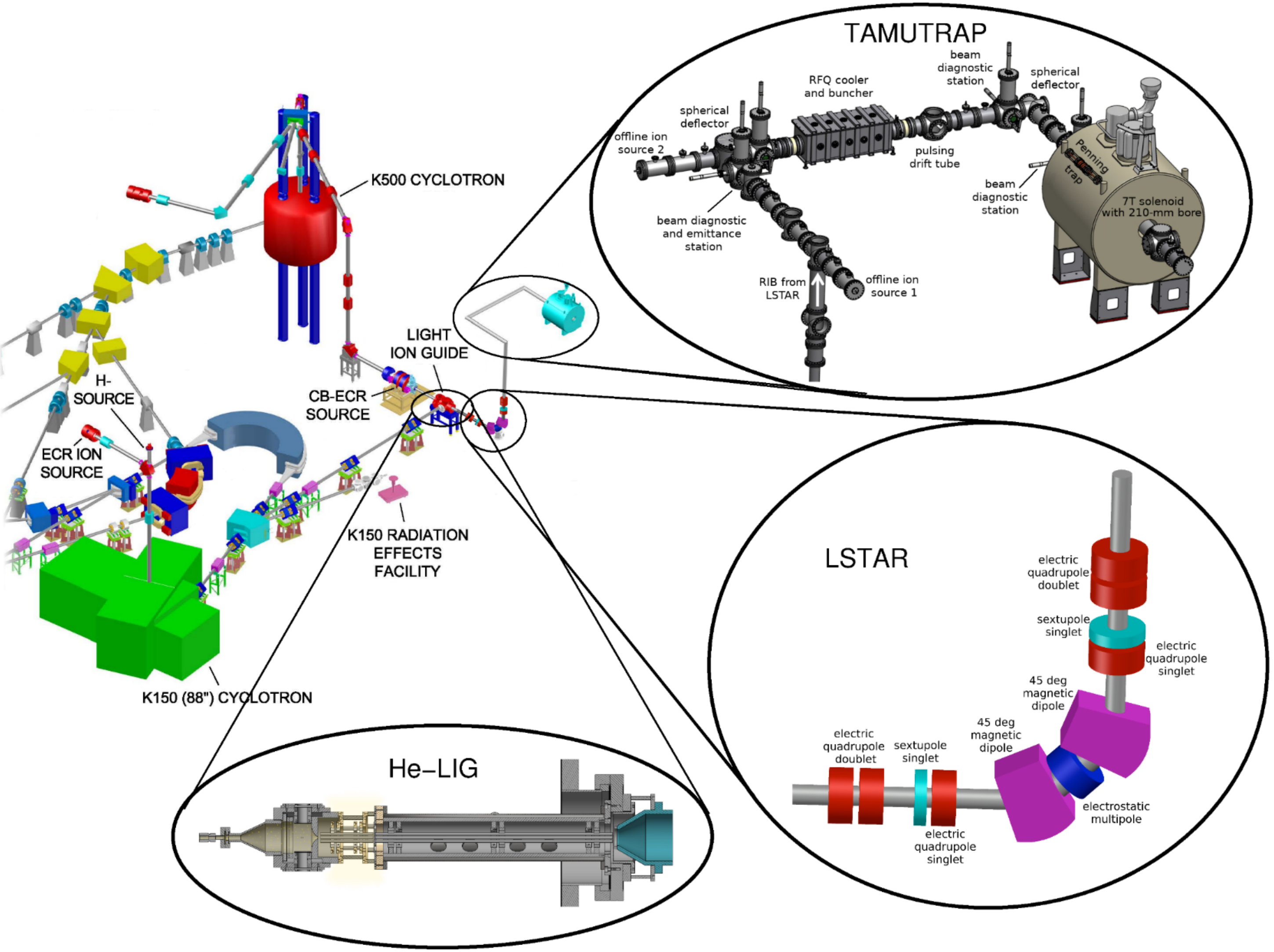
Design spec: $M/\Delta M > 2{,}000$

Developing the RIBs for TAMUTRAP

- Efficiency is absolutely critical
  - IGISOL at Jyvaskyla quotes 5% efficiency for gas cell
  - Gas cell [5%] → separator [85%] → cooler/buncher [20%] → Penning trap
  - Estimate for rates of proton-rich nuclei in the trap:

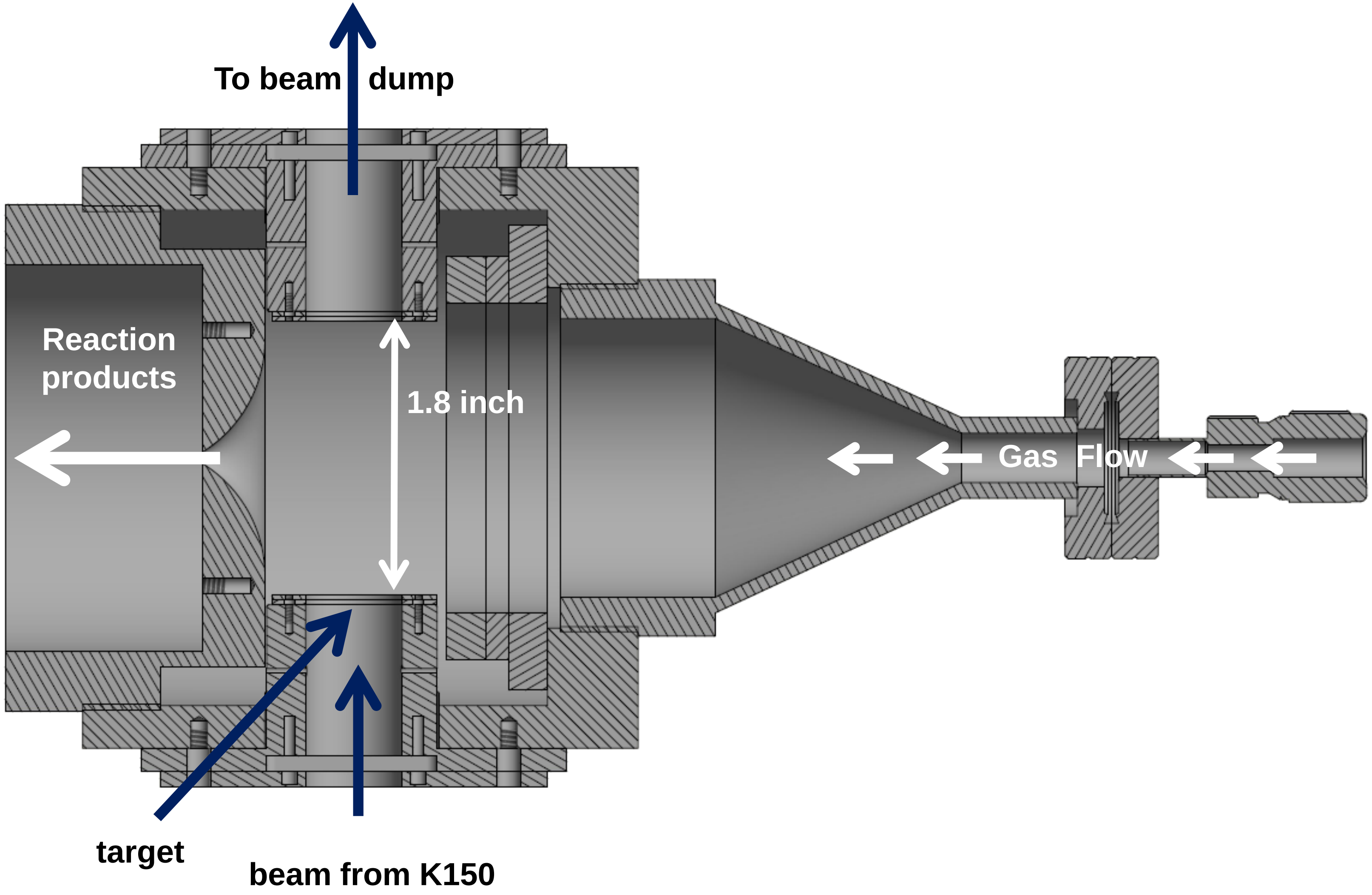
^{21}Mg	2650
^{25}Si	1425
^{29}S	850
^{33}Ar	760
^{37}Ca	190

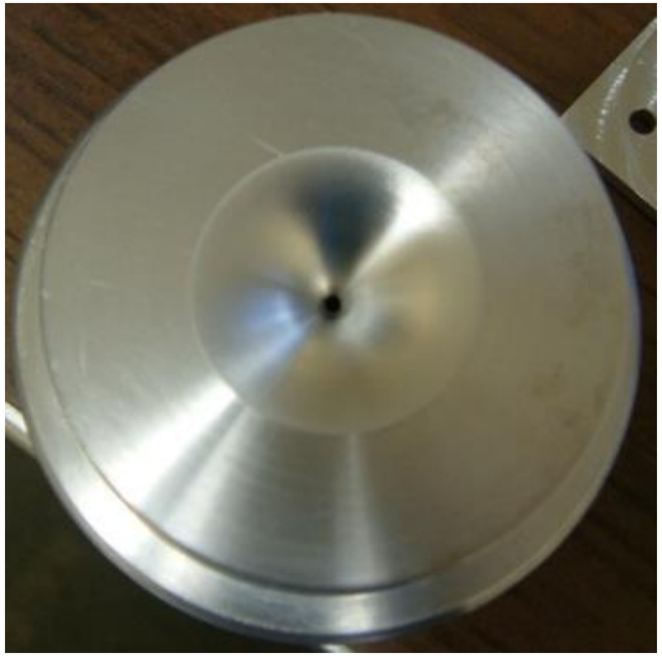
^{20}Mg	40
^{24}Si	30
^{28}S	25
^{32}Ar	10
^{36}Ca	2



We have been developing a new gas cell

- Need highest efficiency possible, and to build a new beamline to get the RIB to TAMUTRAP





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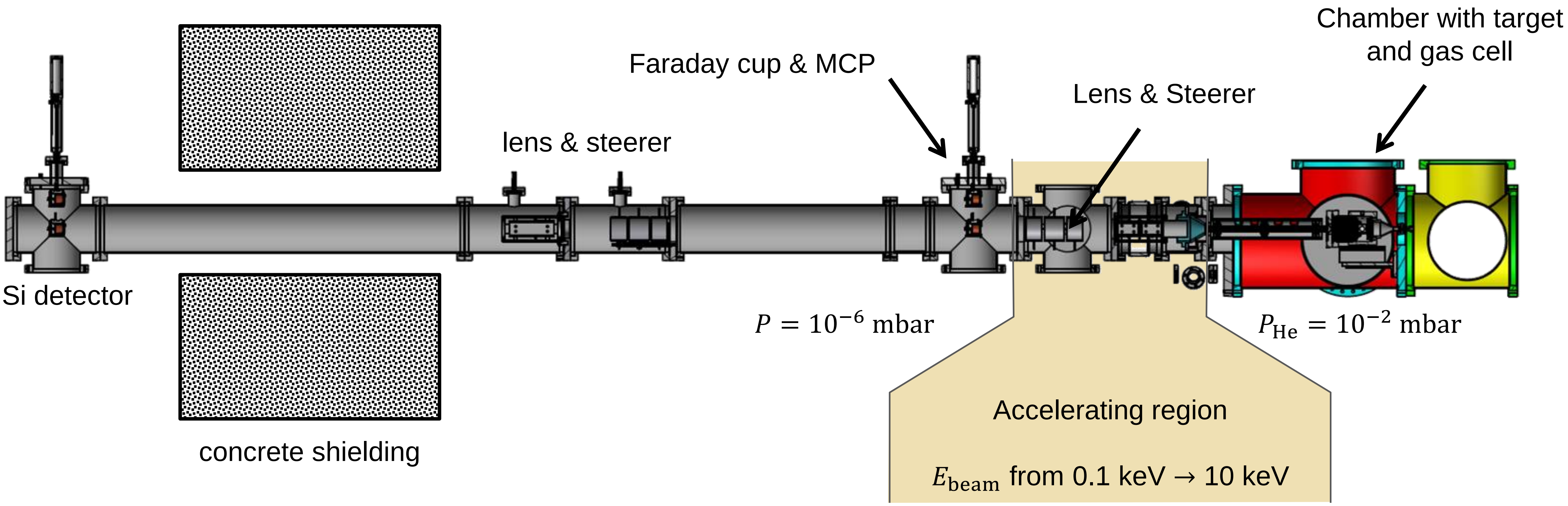
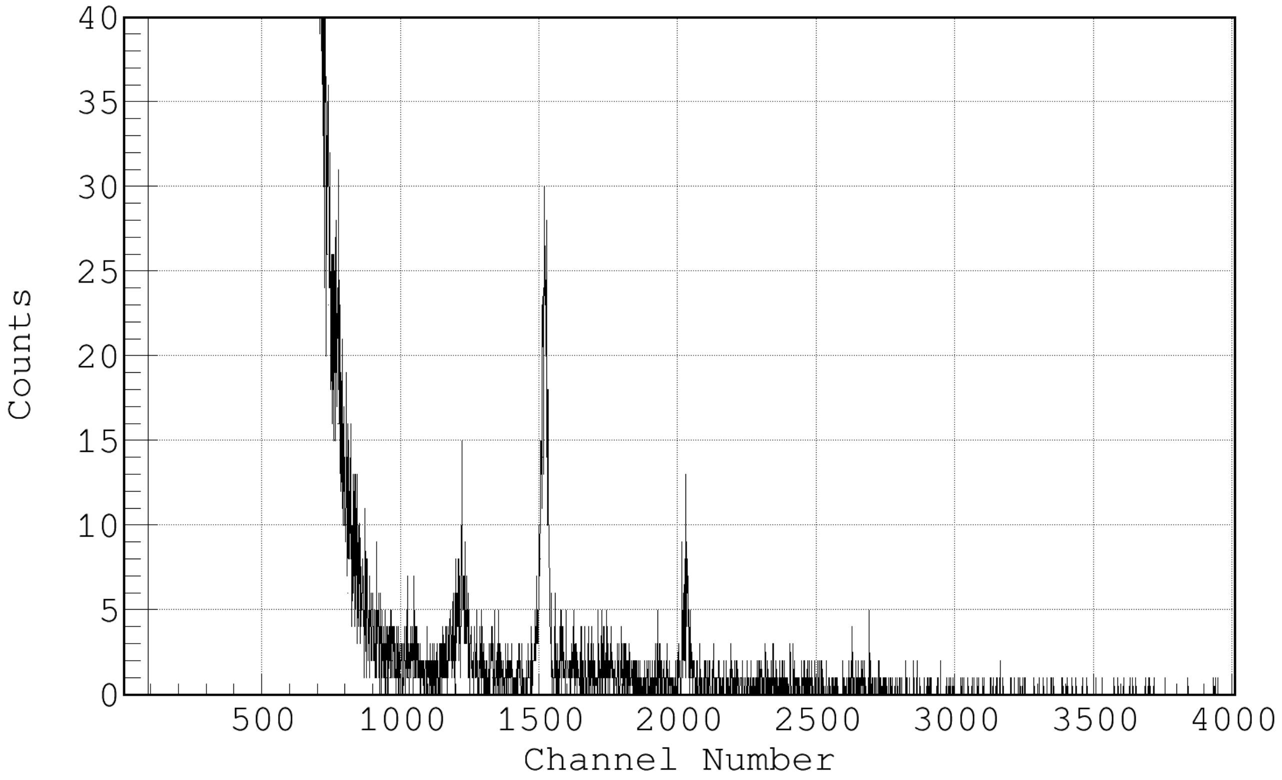


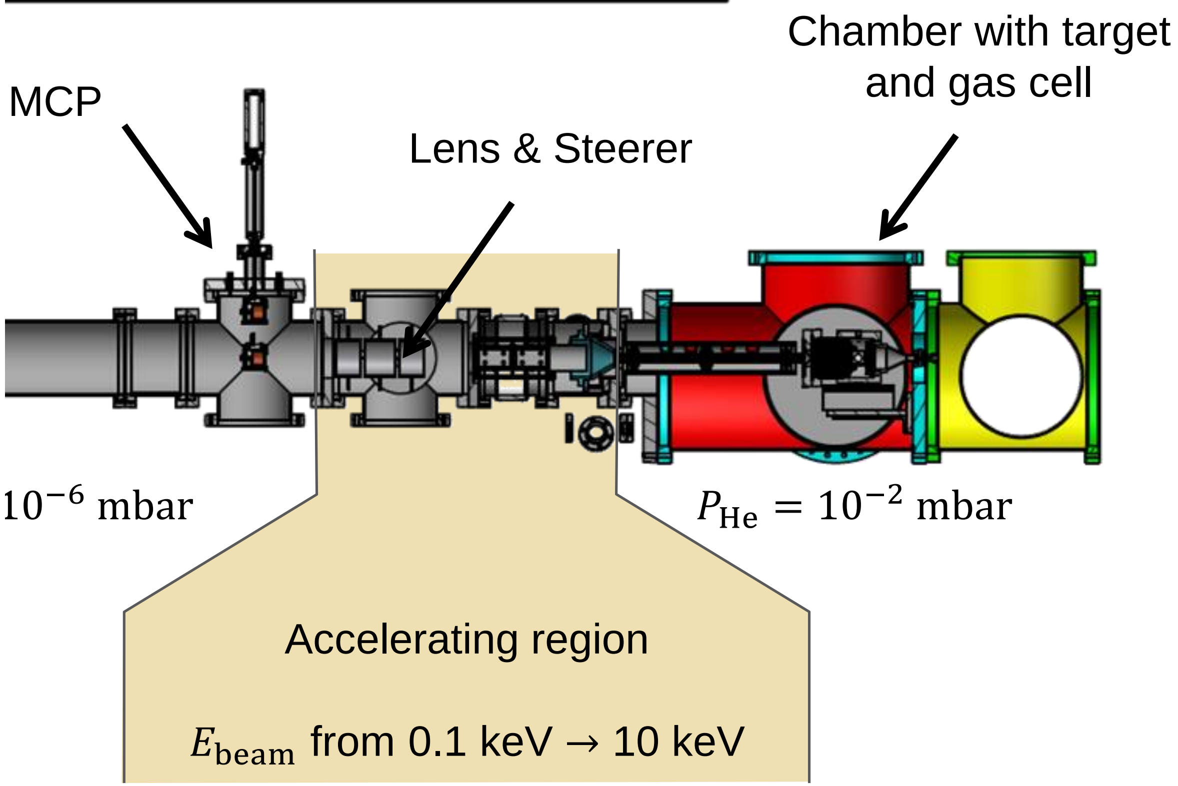
We have been developing a new gas cell

- Need highest efficiency possible, and to build a new beamline to get the RIB to TAMUTRAP

Efficiency of ^{25}Si production *already* **0.13(2)%**!!

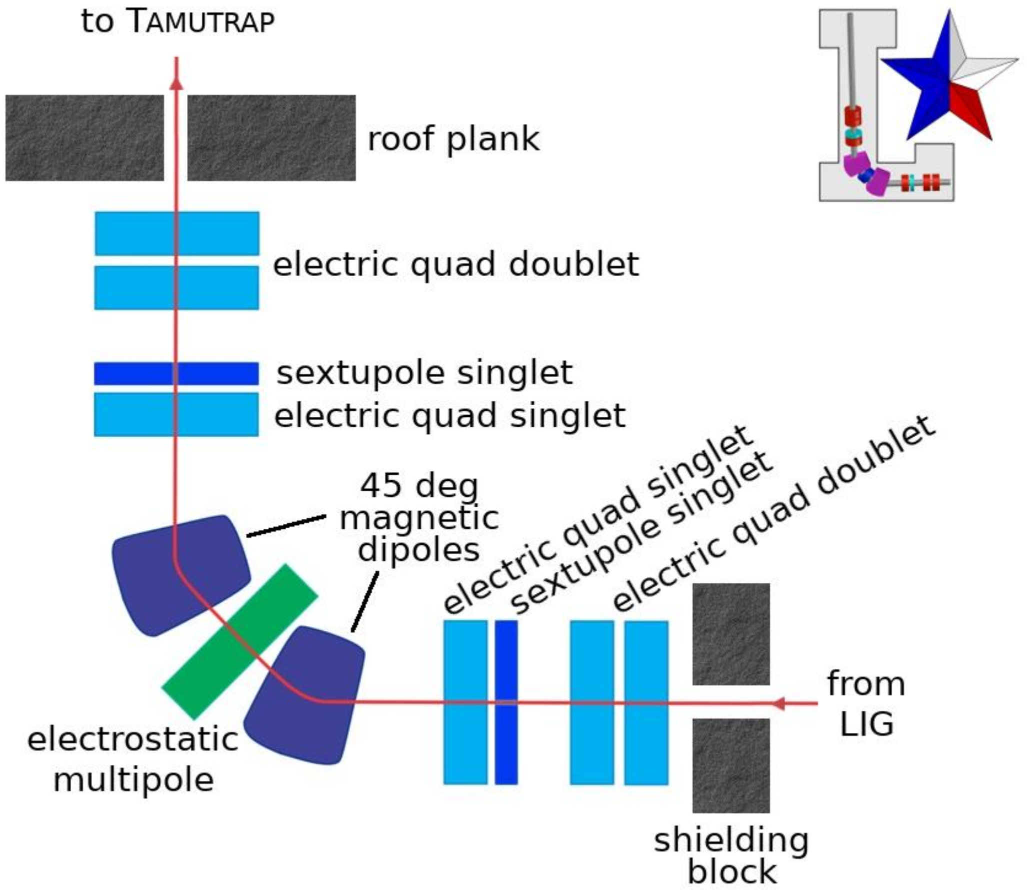
1–2% no problem; 5% is achievable

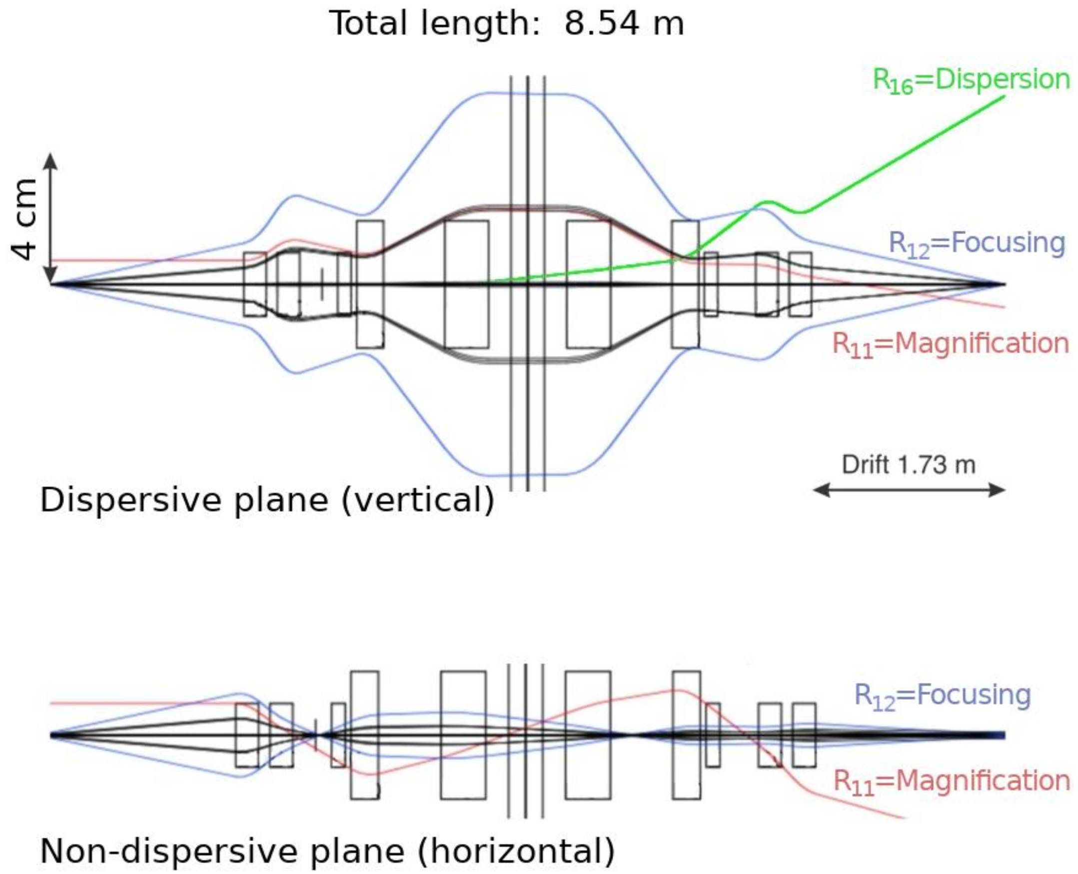




But 120° doesn't fit our existing equipment…

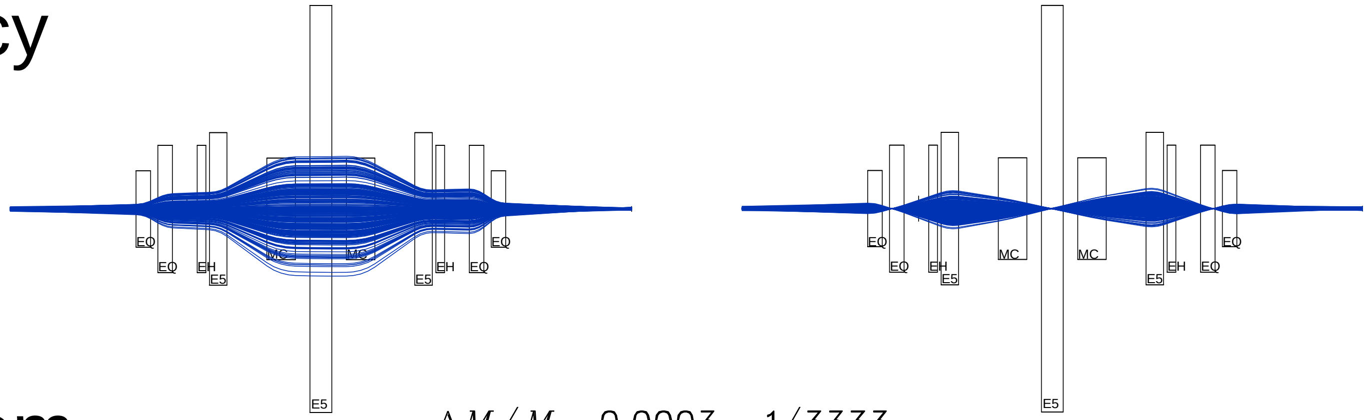
- To bend up, need 45° + 45° instead
- Collaborate with G. Berg, M. Couder and M. Brodeur (ND) to build the Light-ion guide Separator for TAMU's K150 RIBs

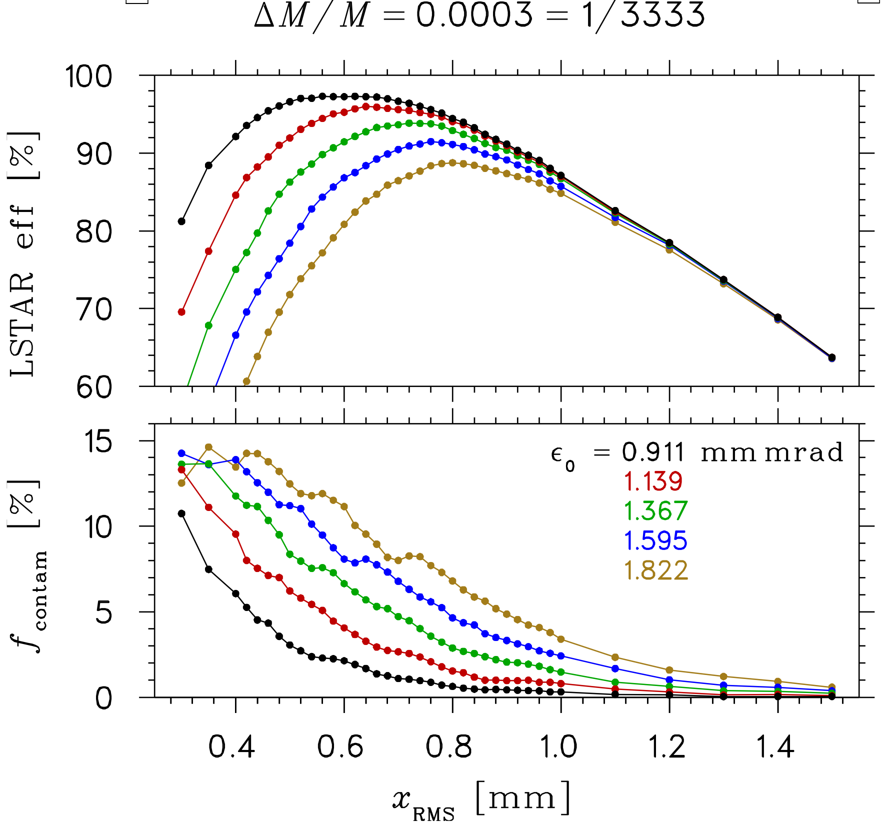




LSTAR performance specs and status

- Using COSY to optimize efficiency versus resolution
- Higher-order abberations corrected (G. Berg, M. Couder)
- SimION to estimate emittance from gas cell & SPIG
  - RFQ comparison ⇒ off by 2 ×?
- DOE funded \$0.78M
  - Start construction soon! (this spring)

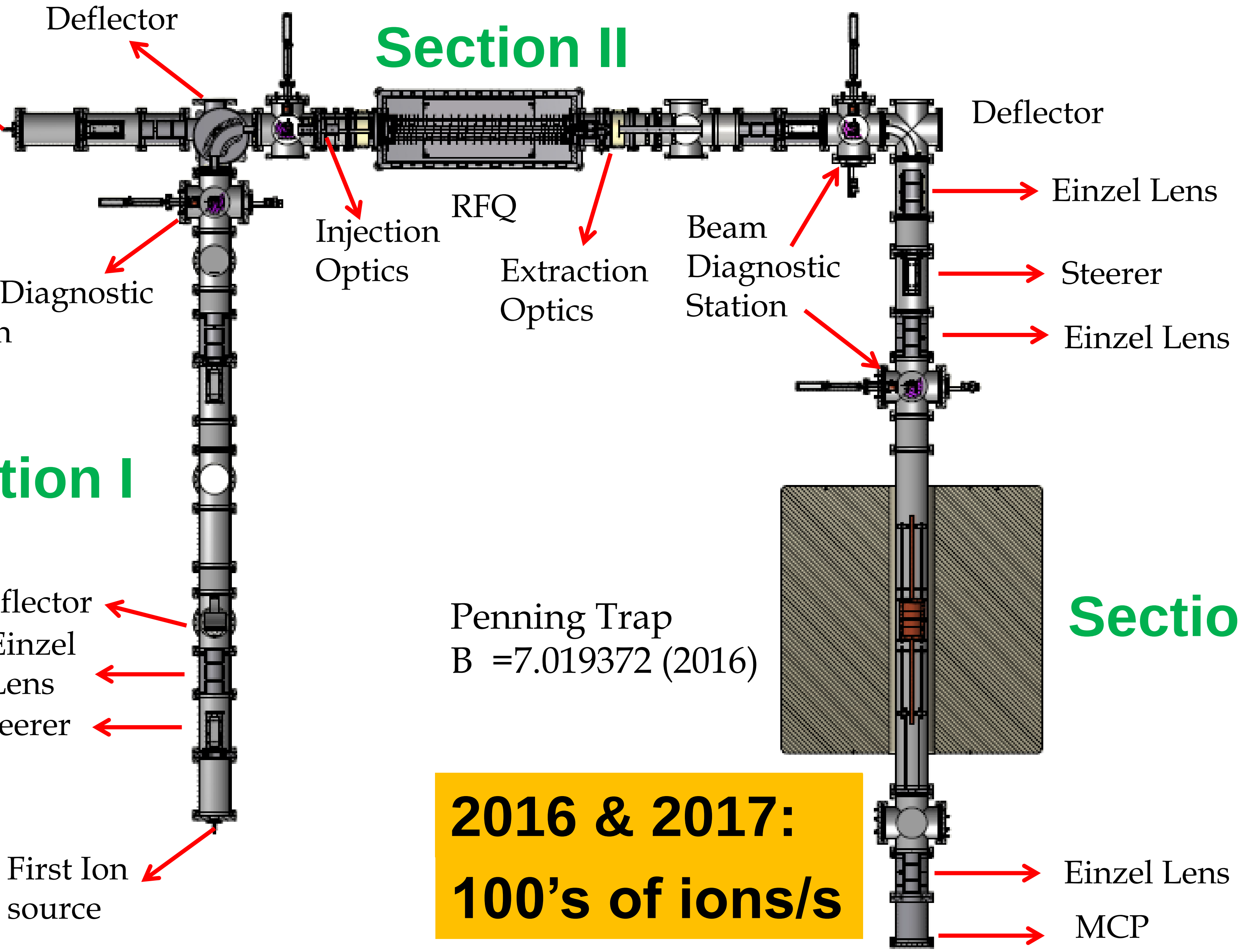




The TAMUTRAP facility at the Cyclotron Institute

2016: 120 pA

2017: <1 pA

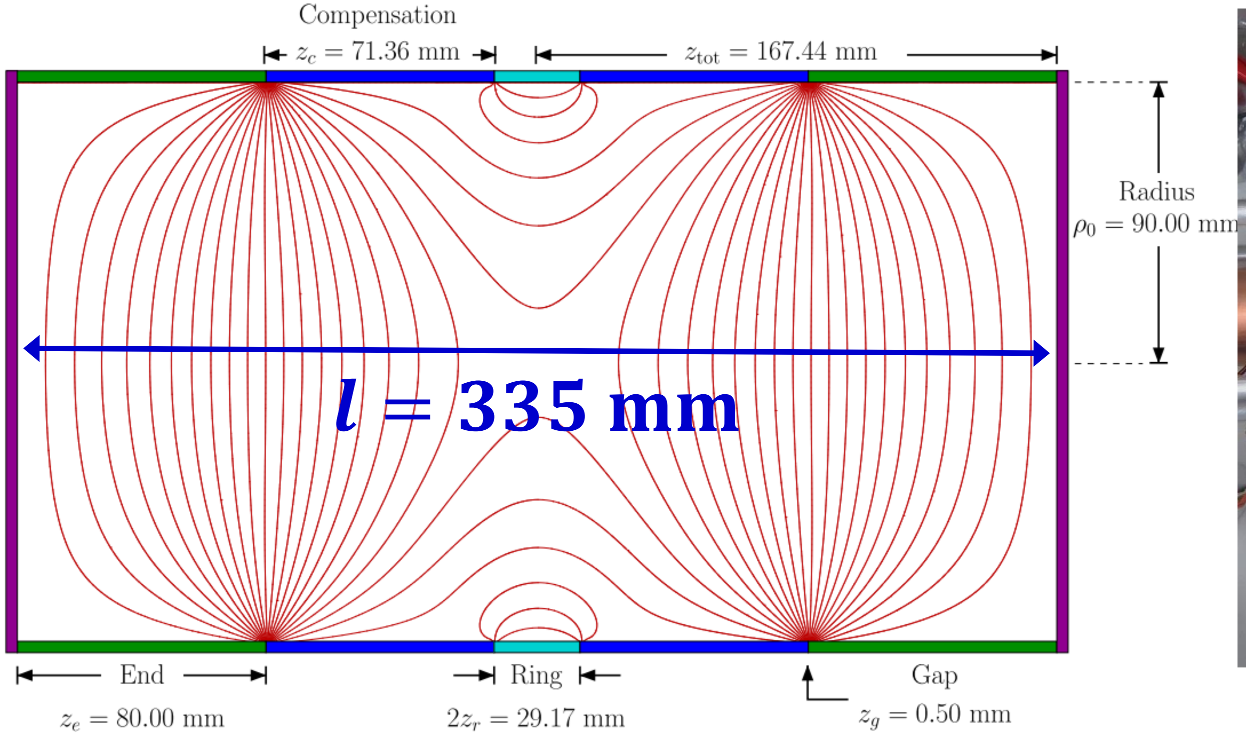


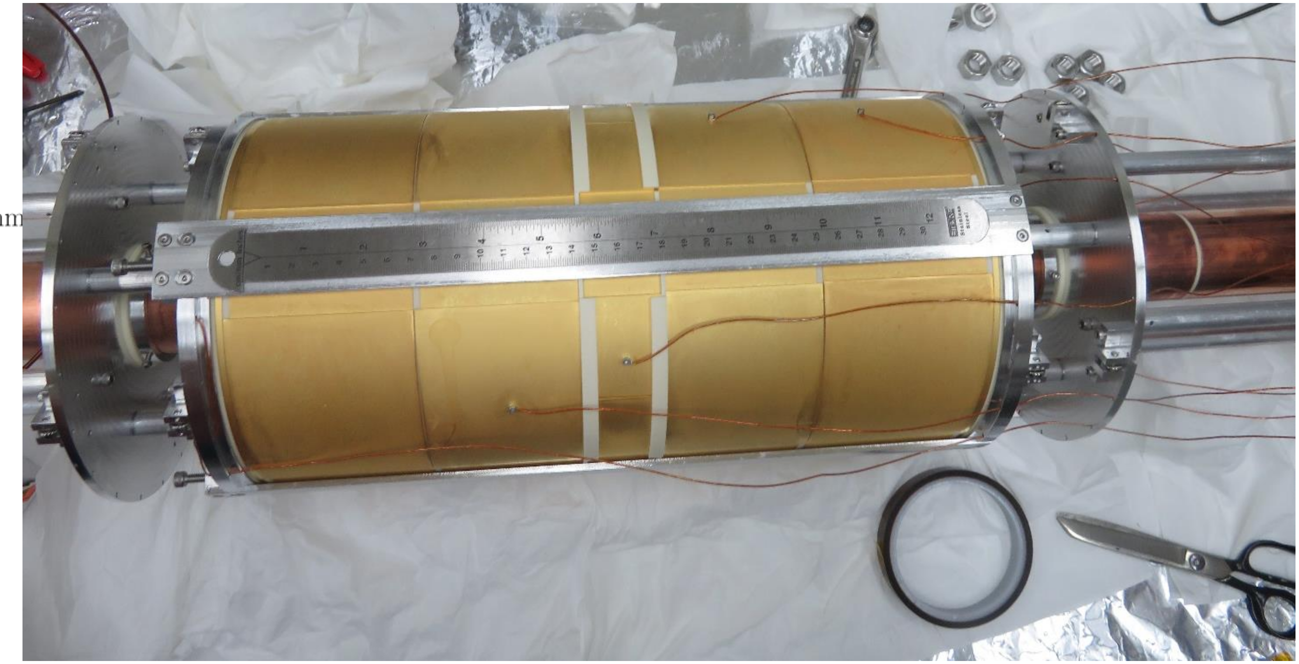
2016 & 2017:

100’s of ions/s

World's largest Penning trap commissioned

- Most cylindrical Penning traps have a length-to-radius ratio of $l/r = 11.75$
- To confine the protons from $T = 2$ decays, need $r = 90\ \mathrm{mm}$
  - Needed a new design to make it fit in the 7T magnet





$l/r = 3.72$

M.Mehlman *et al.*, NIMA **712**, 9 (2013)
P.Shidling *et al.*, Hyperfine Interact **240**, 40 (2019)

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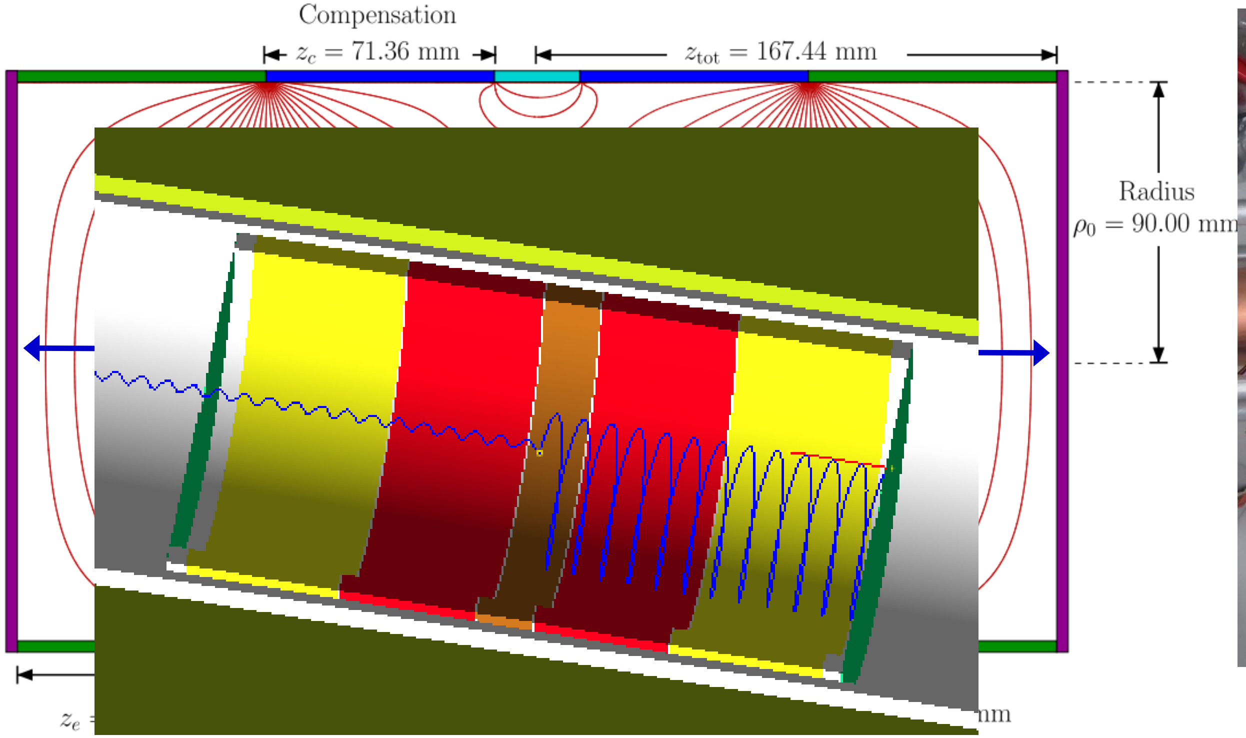
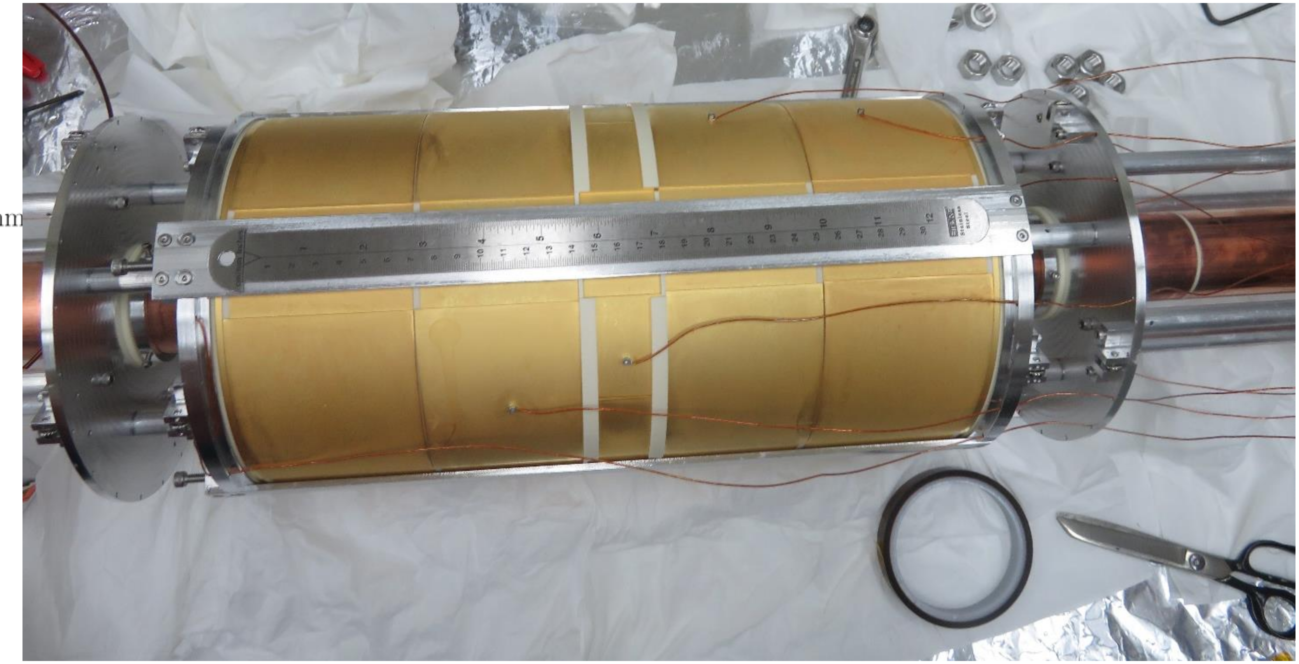




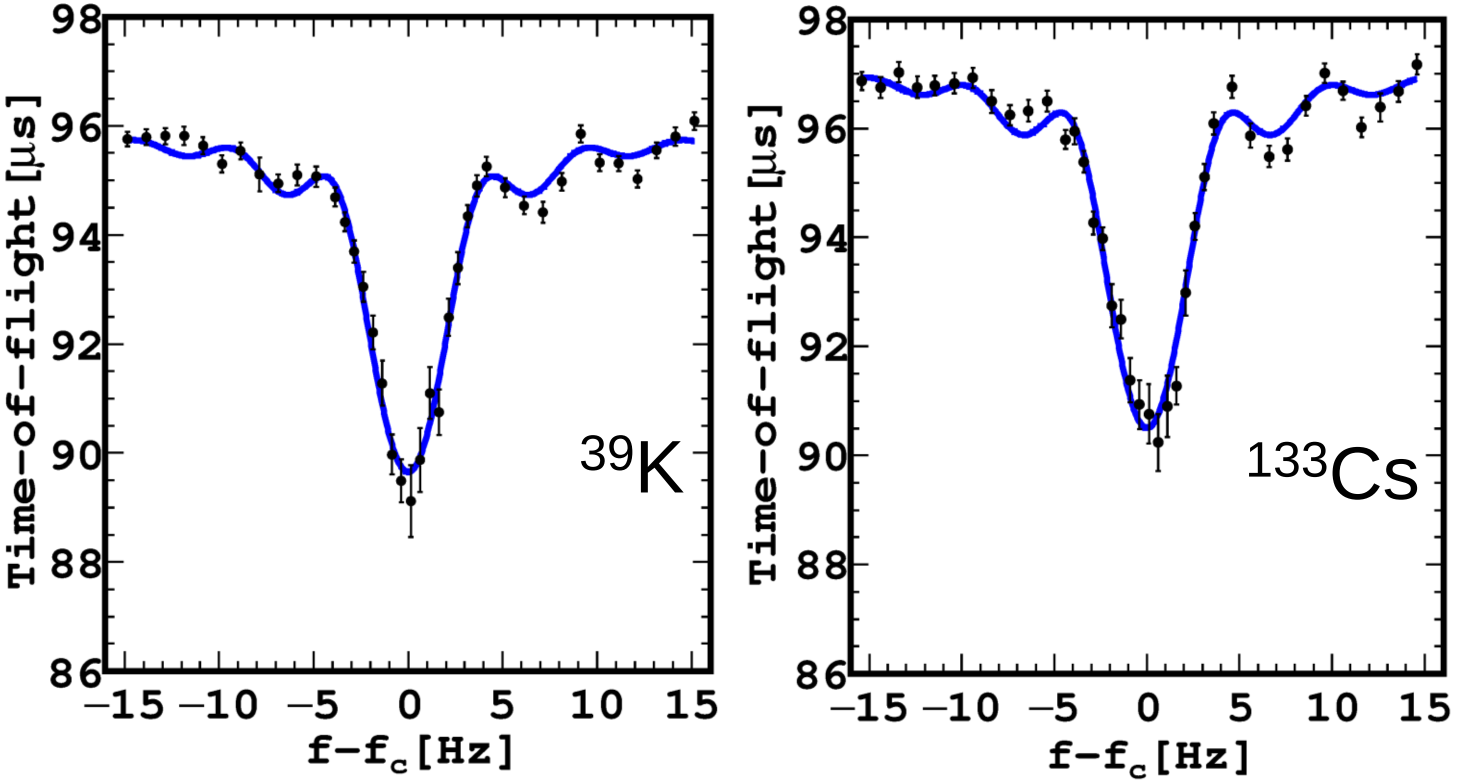
$l/r = 3.72$

M.Mehlman *et al.*, NIMA **712**, 9 (2013)
P.Shidling *et al.*, Hyperfine Interact **240**, 40 (2019)

Mass measurement of stable ions

- Find resonant frequencies for ^{23}Na, ^{85,87}Rb, ^{133}Cs and ^{39}K
- Use AME value for ^{39}K, and calculate other masses
- Good agreement with AME values (within uncertainties)
- Precision
  - ^{23}Na: 240 ppb
  - ^{85}Rb: 5 ppb
  - ^{87}Rb: 6 ppb
  - ^{133}Cs: 7 ppb

200 ms excitation time



P.Shidling *et al.*, in preparation (Int J Mass Spect)

Final thoughts, people involved

- TAMUTRAP: commissioned, just need radioactive ions…
- LSTAR starting to be built; RIB in ~3 yrs?
- PENELOPE simulations are starting
  - Complement G4 for WISArD
  - Flush out the details of the concept for TAMUTRAP's detection
  - Backscattering, backscattering, backscattering…
- Benchmark G4 and PENELOPE using TRINAT's system

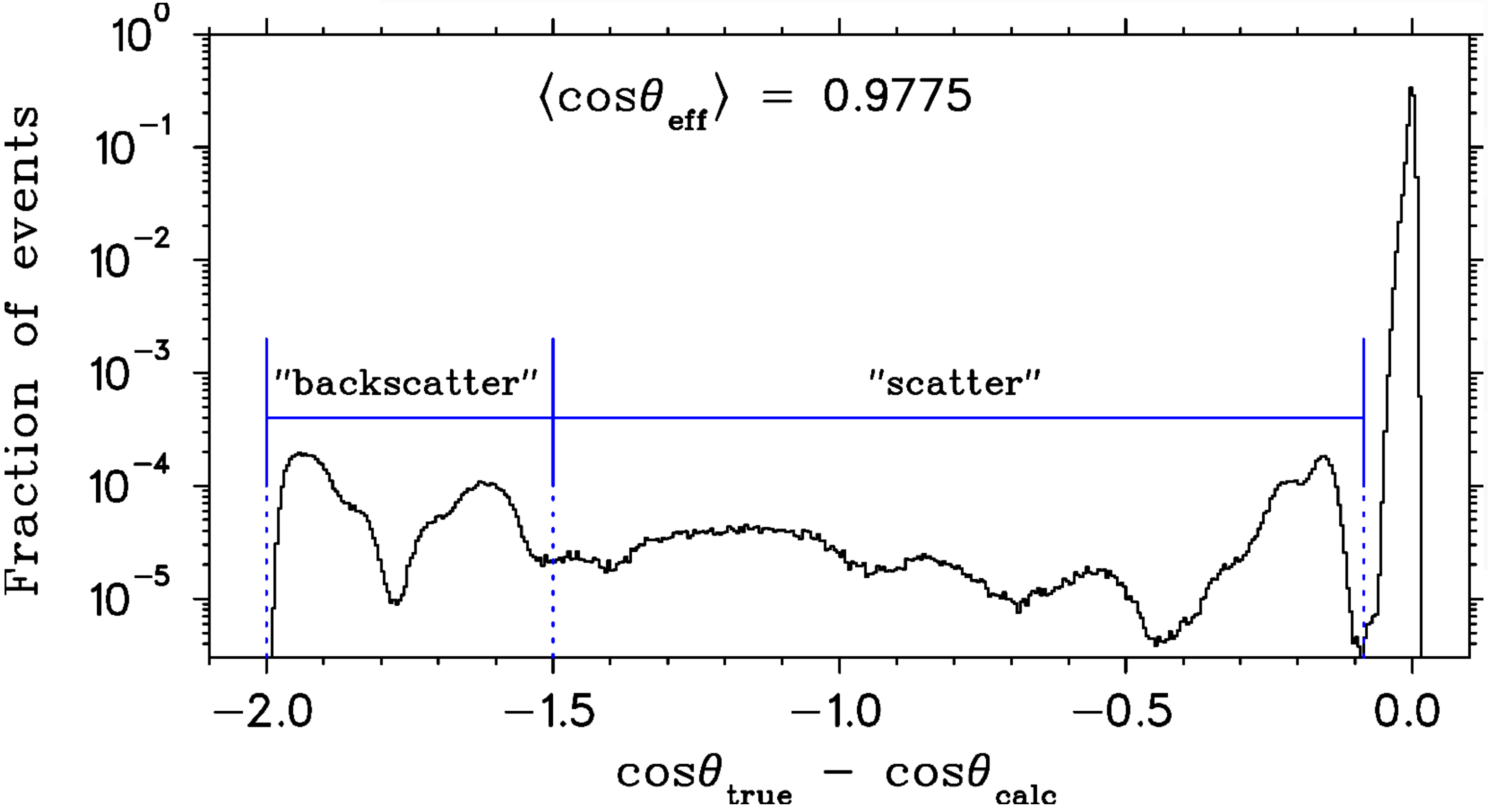
B. Fenker
S. Behling
M. Mehlman
D. Melconian
P.D. Shidling
G. Chubaryan

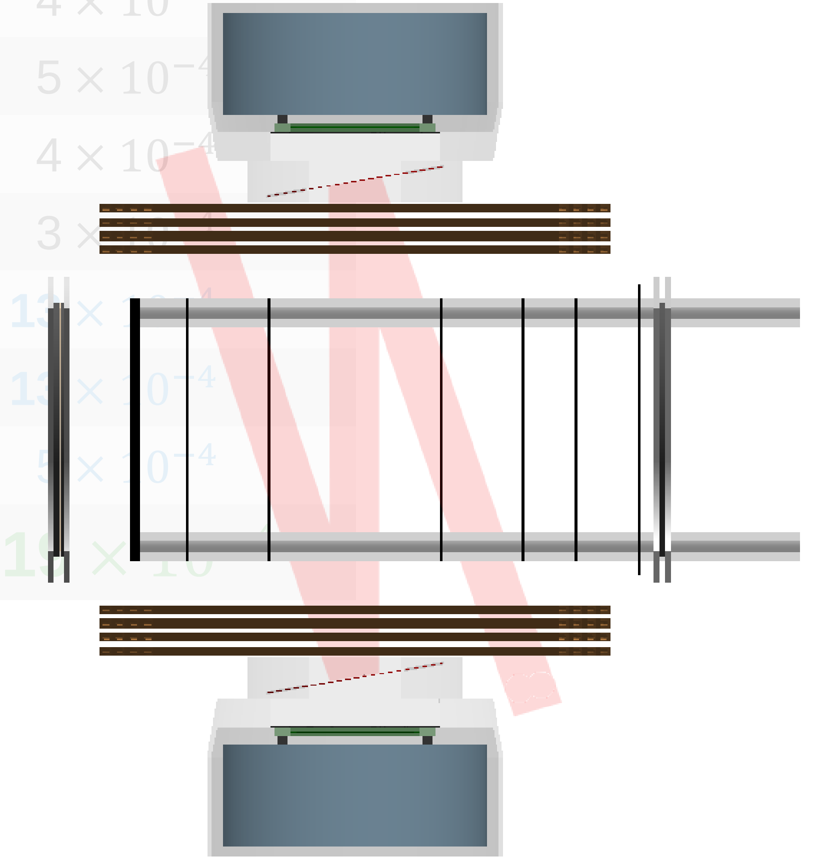
B. Schroeder
N. Morgan
A. Ozmetin
D. McClain
V. Kolhinen
V. Iacob

M. Soulard (2015)
F. Bidault (2016)
E. Gilg (2017)

TRINAT backscattering from A_β measurement

Source	Correction	Uncertainty, ΔA_β
Systematics		
Background	1.0014	8×10^{-4}
β scattering	**1.0230**	**7×10^{-4}**





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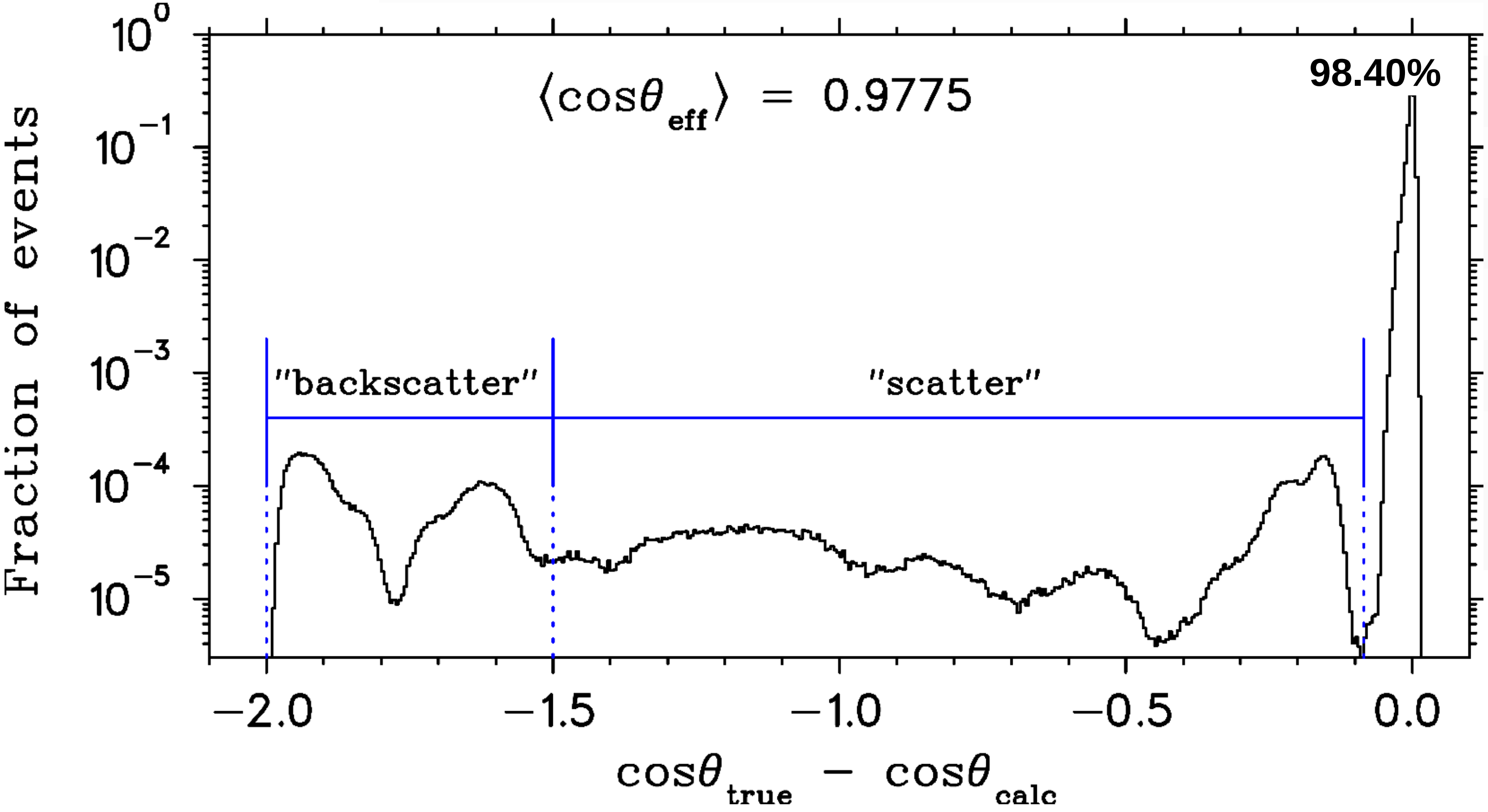

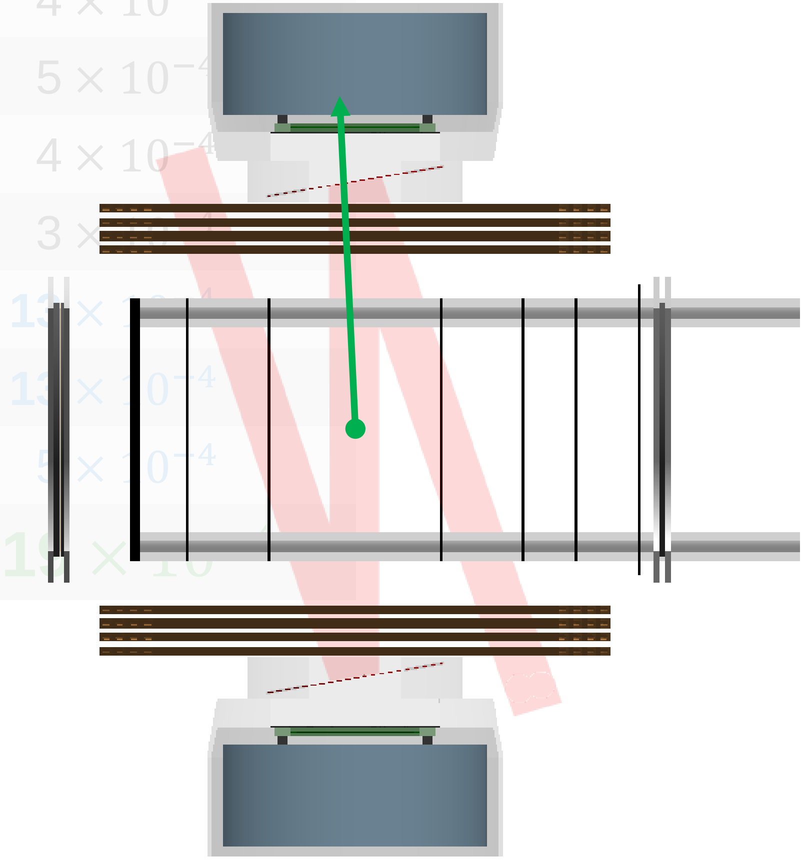

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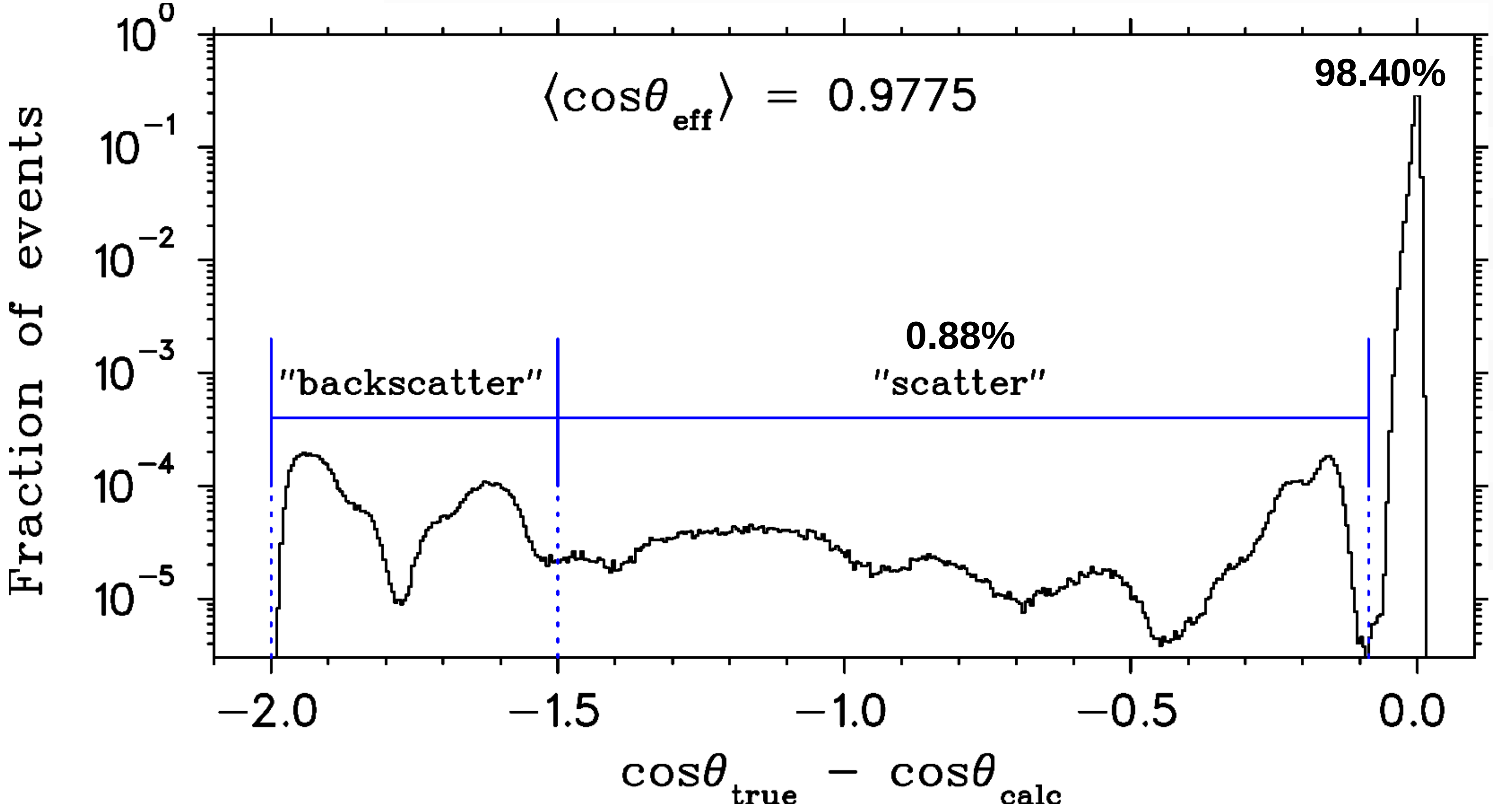

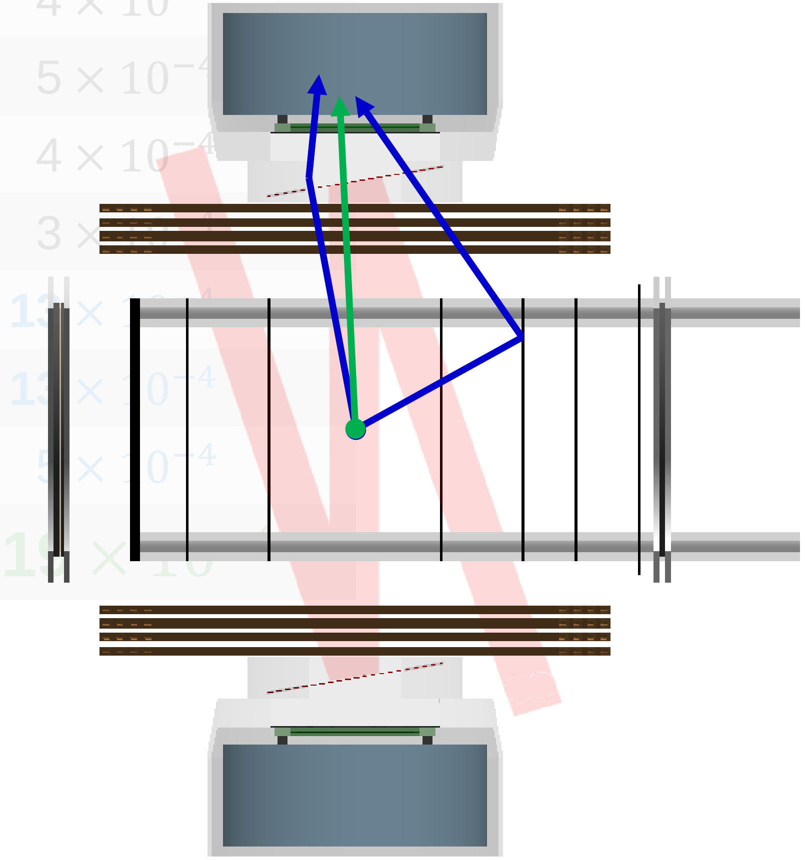

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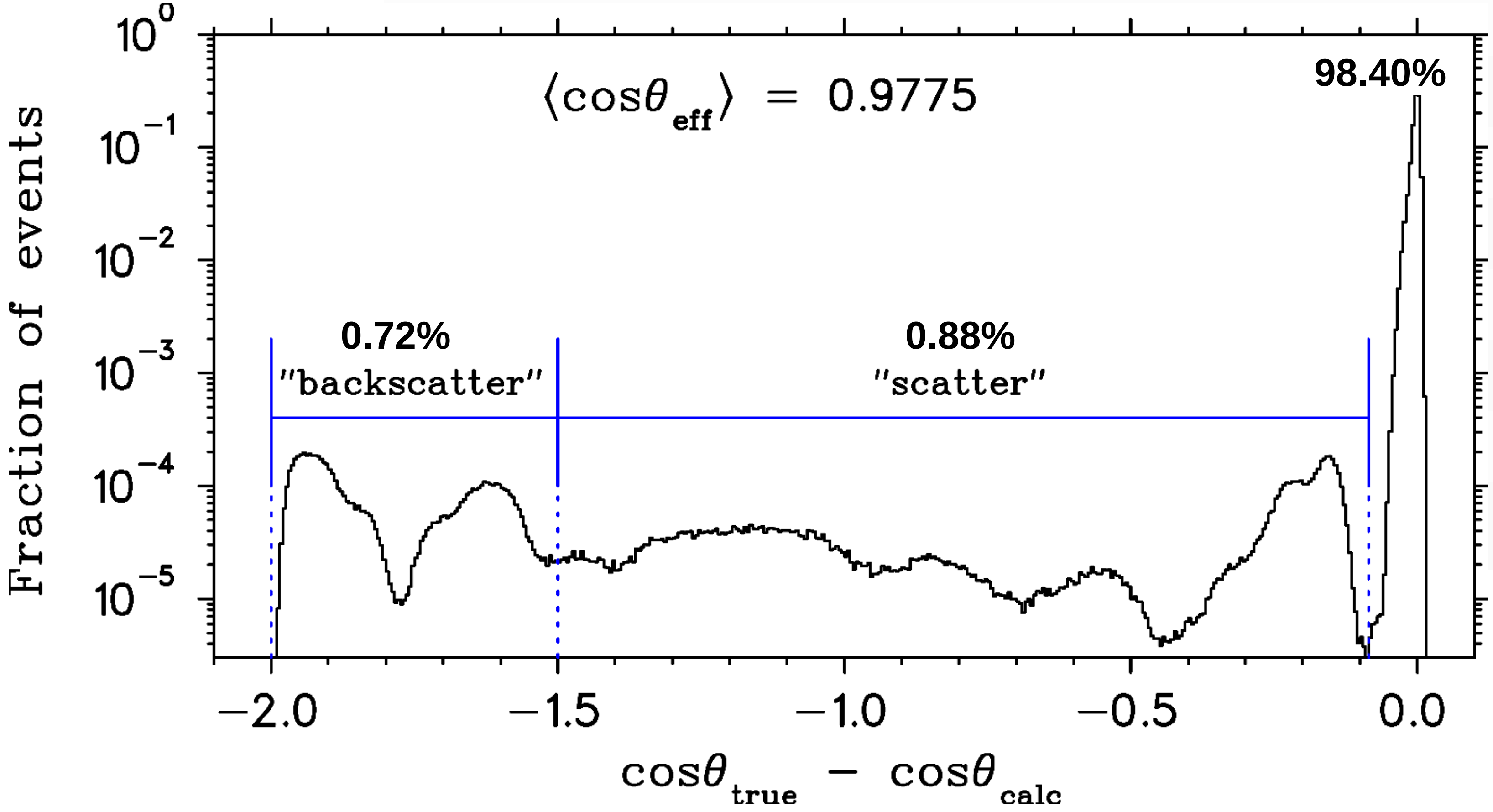

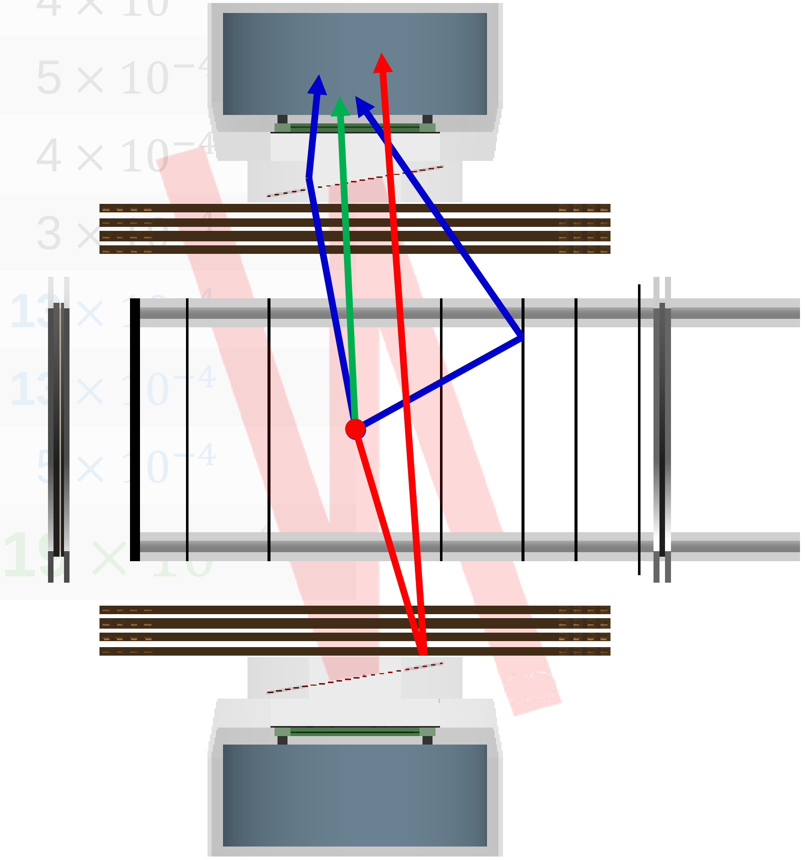

TRINAT backscattering from A_β measurement

How well can we trust GEANT4 to simulated β scattering?

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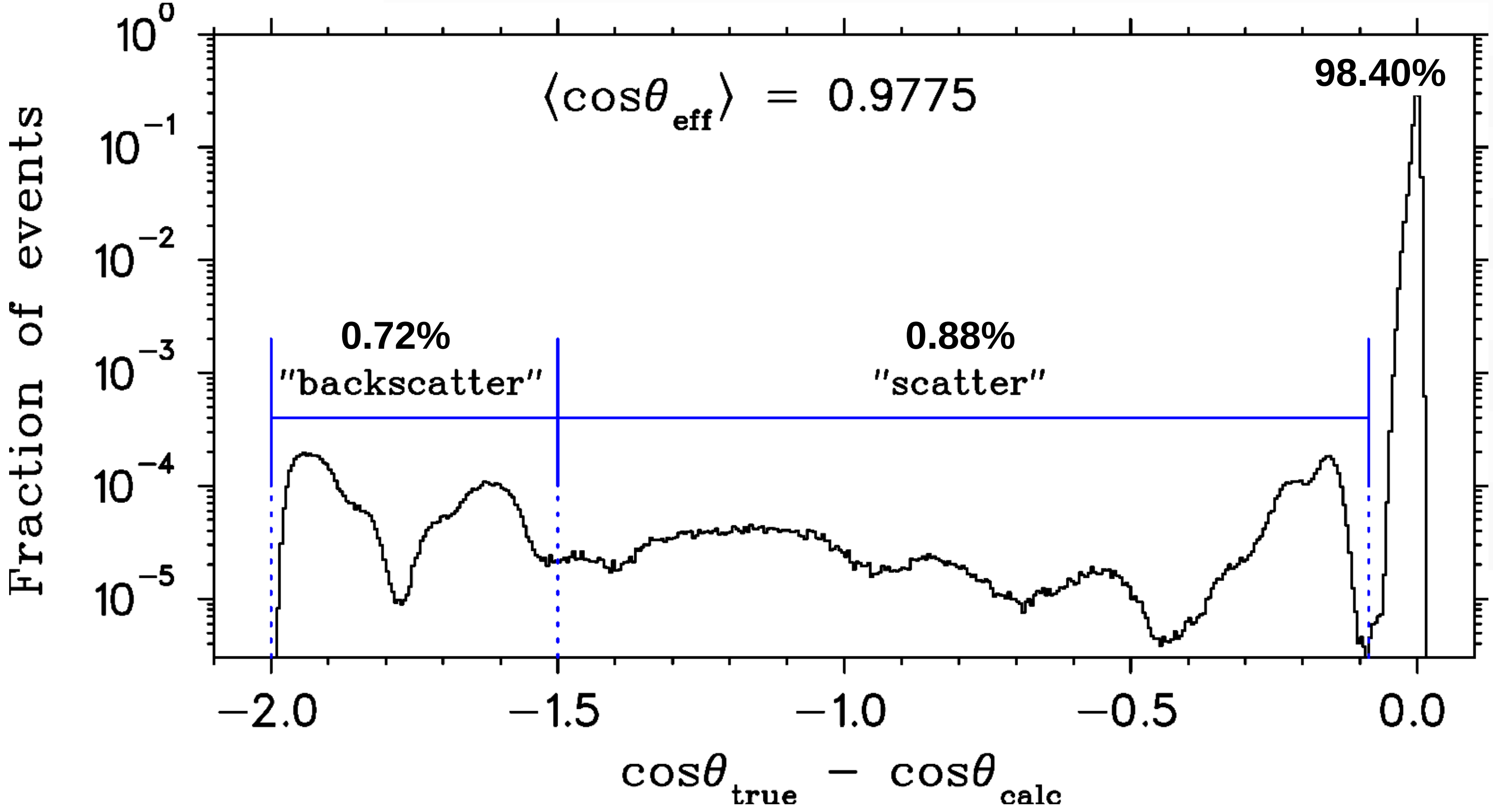
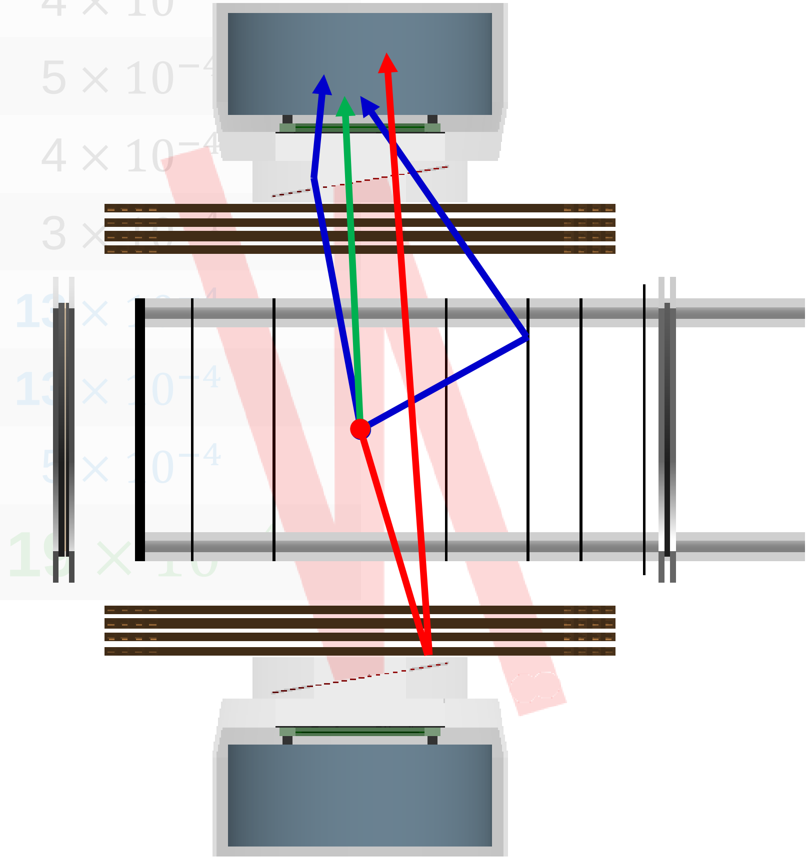
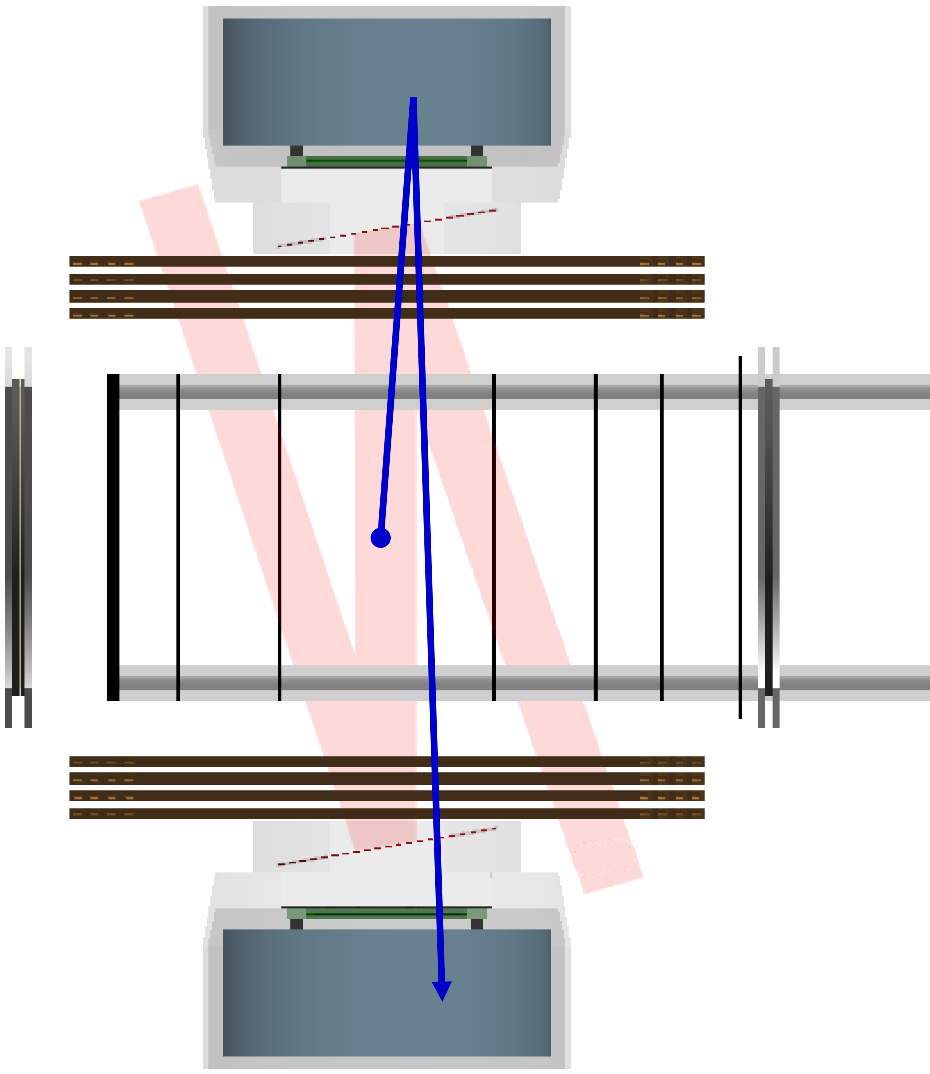




Measurement of β scattering

- TRINAT geometry allows us to measure backscattering of βs and compare to GEANT4 simulations
- Obvious, very clean check: both telescopes register a β event
- Due to small solid angle to go from one to the other ($\sim 0.25\%$), not enough statistics with current data set ($\sim 10^{-4}$ of non-scattered)



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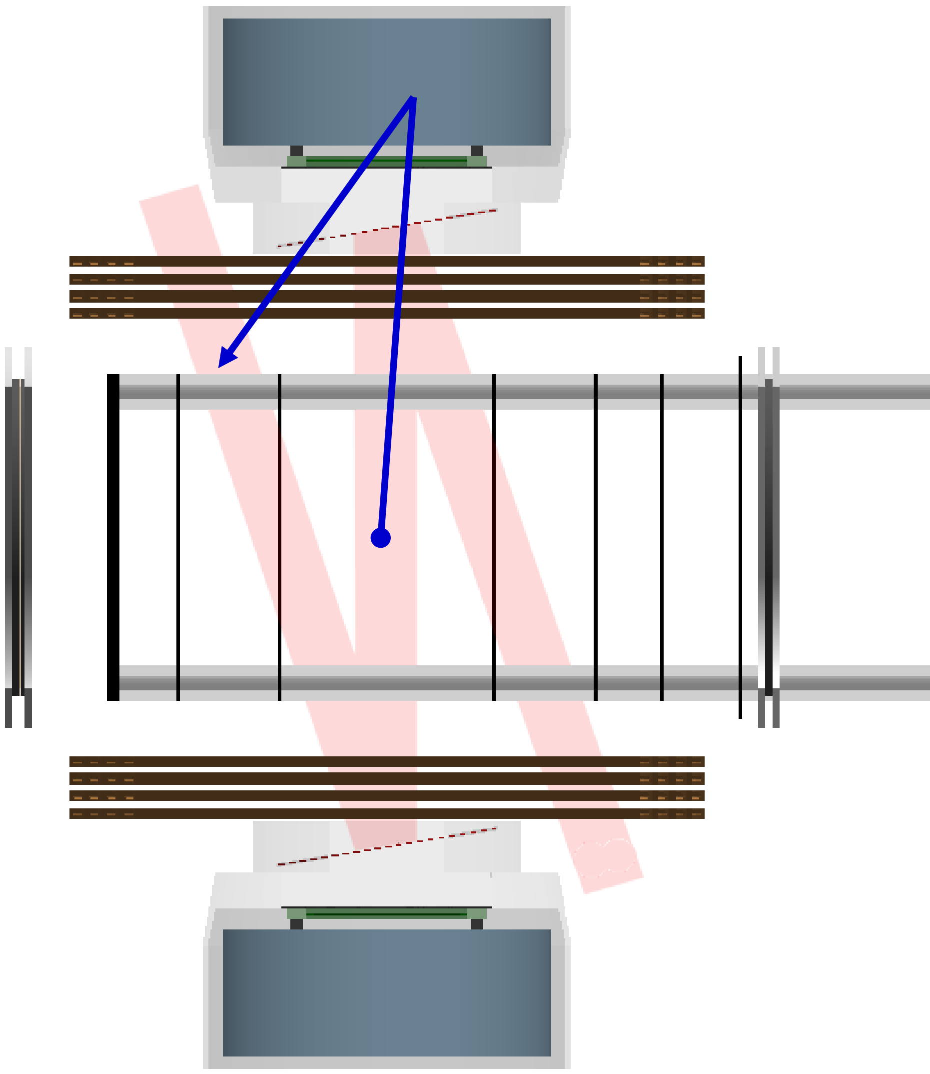
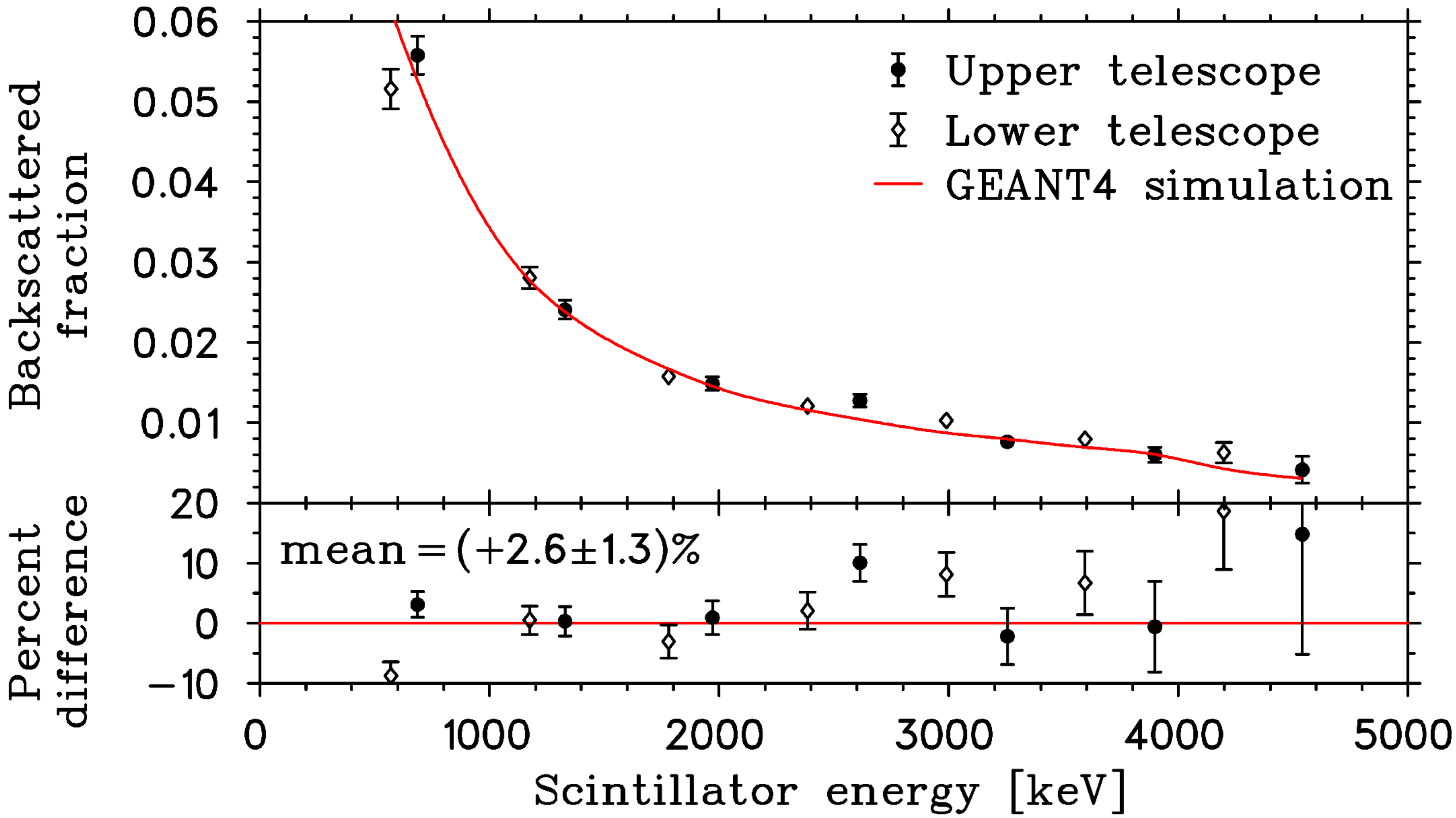
- Obvious, very clean check: both telescopes register a β event
- Due to small solid angle to go from one to the other ($\sim 0.25\%$), not enough statistics with current data set ($\sim 10^{-4}$ of non-scattered)
- Much more common: backscattered out of the scintillator
- Signature: two separate pixels in the double-sided Si-strip detector with energy deposited in the scintillator



How does GEANT4 do?

- With non-standard options: **Surprisingly well**!!
- Take 2σ limit on observed deviation, or 5.1%, for “backscattered” events



How does GEANT4 do?

- With non-standard options: **Surprisingly well**!!
- Take 2σ limit on observed deviation, or 5.1%, for "backscattered" events
- Assign 10% uncert to "scattered" events
- All together, a ± 0.0012 uncert on $\langle\cos\theta_{\text{eff}}\rangle$ and $\pm\mathbf{0.0007}$ **on** A_β