Pb Fragmentation
Planning Meeting Exp 15507
2019-01-24

Tom Ginter

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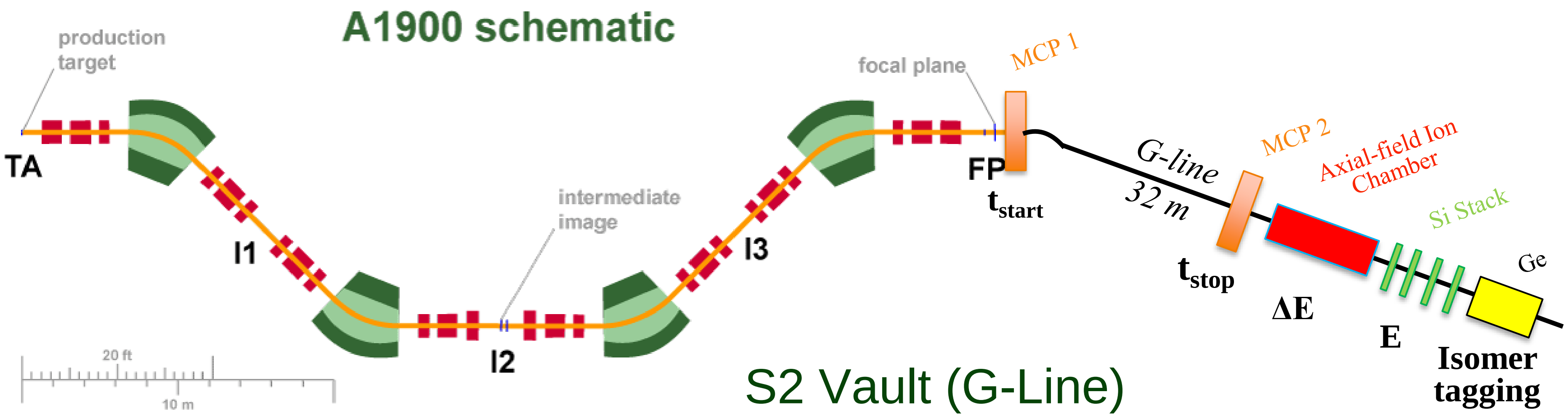
Goals

- Establish Particle Identification (PID)
  - » Need to see microsecond γ-isomers

- Find Tl-195
  - >1000 pps
  - >65 MeV/u after 2 axial Ion Chambers

We have almost no experience with Pb Fragmentation

Setup



A1900

- Target
- Slits at I2
  - » Reduce momentum for PID
  - » Block primary beam q-states
- Wedge at I2 (purity)
- MCP1 (TOF start)

S2 Vault (G-Line)

- MCP2 (TOF stop)
- 2 Axial Ion Chambers
- Implantation Point
  - » Option I: PIN Stack
    - 500 Microns
    - 1000 microns
  - » Option II: Catcher (passive)
- Ge detector
  - » To catch γ's in coincidence with implants

Nominal Setting

- Primary Beam: Pb-208(63+) – 19 electrons
- Fragment: Tl-195(79+,79+) (He-like after target, wedge)
- Target: Be 23 mg/cm^2
- Wedge: Kapton 20 mg/cm^2
- Image 2 slits: 2 mm gap (0.03% momentum acceptance)

LISE file: 15507_195Tl79+79+_Be23_Kapton20_10mmFPgap.lpp

in folder:
\\intranet\files\departments\operations\a1900\projects\15507\15507Mtg_20190124

Nominal Setting (Cont.)

Tl-195(79+,79+)

- LISE rates (10 mm gap at A1900 Focal Plane)
  - Total: 9530 pps/pnA
  - Tl-195(79+,79+): 945 pps/pnA (10% purity)
  - Pb-196(80+,80+) (γ-isomer): 20 pps/pnA (0.2% purity)
  - Pb-197(80+,80+) (γ-isomer): 470 pps/pnA (5% purity)
  - Pb-198(80+,80+) (γ-isomer): 650 pps/pnA (7% purity)
  - Tl-200(80+,80+) (γ-isomer): 30 pps/pnA (0.3% purity)
- MCP1 Rigidity
  - Upstream: 3.1615 Tm
  - Downstream: 3.1612 Tm (assuming no charge state change in MCP)
- After Axial IC's
  - Rigidity = 2.9986 Tm
  - Energy = 68.7 MeV/u
  - Range in Si = 1060 micron

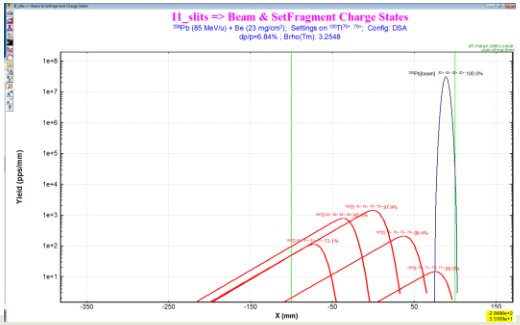
Nominal Setting Doubts/Questions

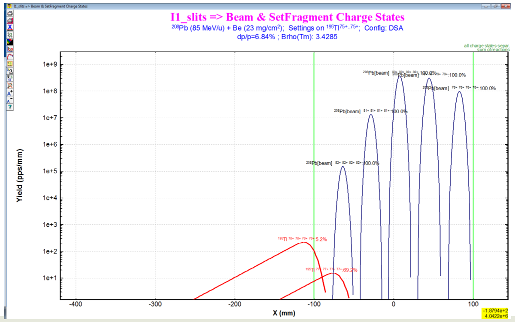
Tl-195(79+,79+)

- Are charges states (q-states) populated as LISE predicts?
  - LISE assumes equilibrium charge state distribution from target
  - Minimum target thickness for equilibrium: ~120 mg/cm^2
  - Our target: 23 mg/cm^2
- Are rates as LISE predicts?
  - For analogous reactions from primary beams where we have experience LISE over-predicts by ~1 order of magnitude
- Are isomers really populated?
  - Because of the rate or q-state doubts just listed
  - Isomeric states might not be populated in our production reaction

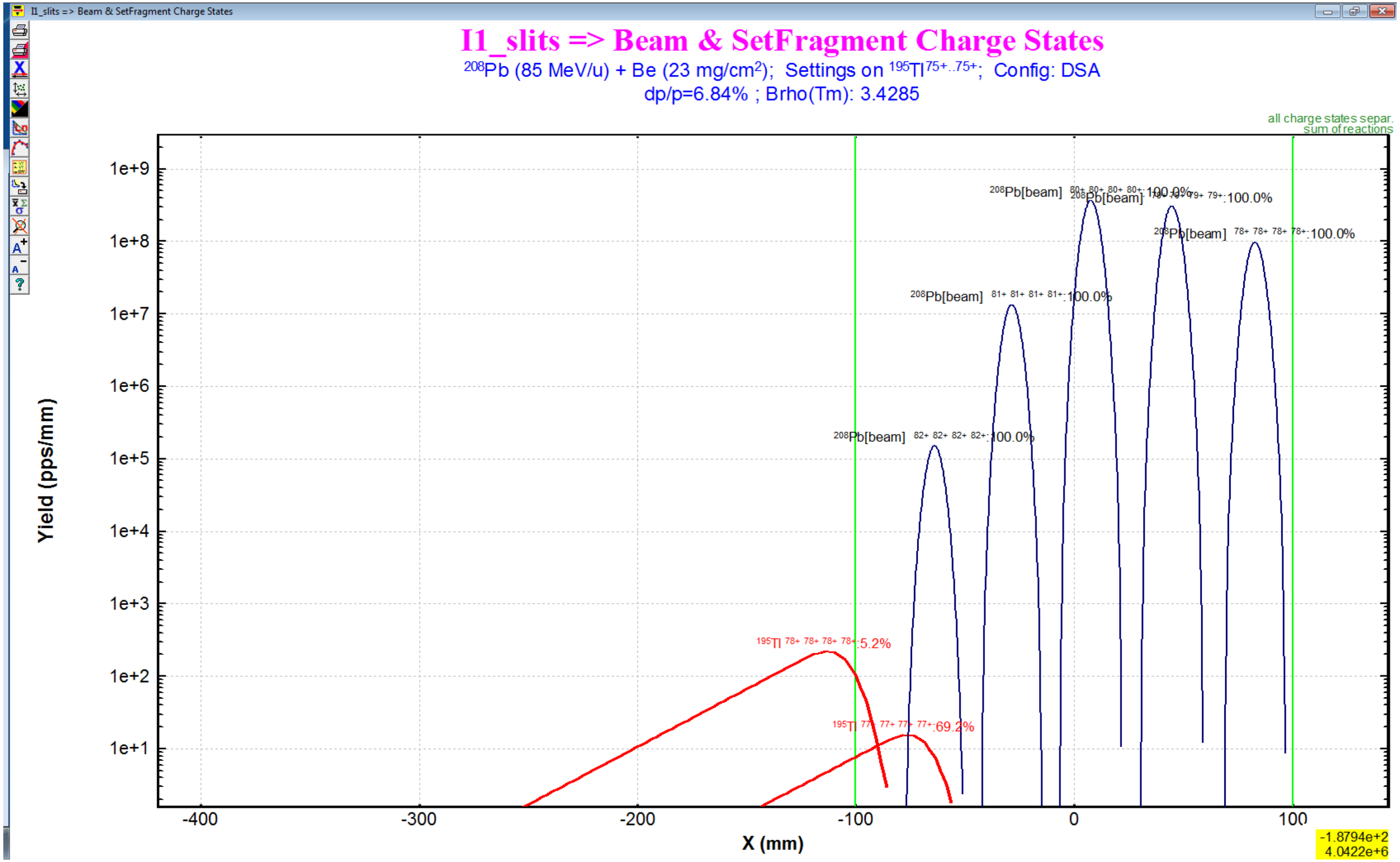
Options for Reacting to Q-State Doubt

- Measure q-state distribution of Pb-208 from target, wedge, and MCP foil to make a first best guess as to where to set the A1900
  - Assumes q-state behavior of fragments will be the same as primary beam
    - Probably OK in terms of Z: Z for Pb is 82 and Z for Tl is 81
    - May not be OK given that Pb starts with 19 electrons
- Move towards equilibrium target thickness
  - But we drop below the Tl-195 energy requirement after IC's with 47 mg/cm^2 Be target
- Look for q-states closer to primary beam q-state (63+)
  - We must dodge Pb q-states as we increase rigidity
  - 20 mm gap between q-states should be OK with our 2 mm slit gap





Tl-195 q-states wrt Pb-208 q-states



Options for Reacting to Isomer Doubt

- We need to check literature for more info on expected isomers
  - Rates
  - How populated
  - Level schemes and γ-spectra
  - Our isomer list is from NNDC through LISE
- Be ready to see any nearby isomer in any setting given the uncertainty about q-state population
- Maybe nudge Tl-195 setting to see Pb-196 isomer better

Nearby γ-Isomers

- Isomer list from LISE:
  - Pb-205: T1/2 = 0.22 μs; Eγ = 1175 keV
  - Pb-204: T1/2 = 0.265 μs; Eγ = 374.72, 1273.87 keV
  - Pb-204: T1/2 = 0.45 μs; Eγ = 990.34 keV
  - Pb-198: T1/2 = 4.19 μs; Eγ = 317.9 keV
  - Pb-197: T1/2 = 1.15 μs; Eγ = 589 keV
  - Pb-196: T1/2 = 1.0 μs; Eγ = 288.7, 689, 1049.21 keV
  - Pb-196: T1/2 = 0.14 μs; Eγ = 748.4 keV
  - Pb-195: T1/2 = 10 μs; Eγ = 586.5 keV
  - Pb-194: T1/2 = 0.124 μs; Eγ = 305, 352.2, 496 keV
  - Tl-205: T1/2 = 2.6 μs; Eγ = 739.16 keV
  - Tl-204: T1/2 = 63 μs; Eγ = 689.9 keV
  - Tl-200: T1/2 = 0.33 μs; Eγ = 221.1 keV
  - Hg-206: T1/2 = 2.15 μs; Eγ = 1034.01 keV
  - Hg-203: T1/2 = 24 μs; Eγ = 341.5 keV
  - Hg-201: T1/2 = 94 μs; Eγ = 218.9, keV

Option for Reacting to Rate Doubt

Look nearer to the primary beam

- Tl-200(79+,79+)
  - Likely Isomers:
    - » Tl-200(79+,79+): 11% purity
    - » Pb-204(80+,80+): 4% purity
  - LISE: 15507_200Tl79+79+_Be23_Kapton20_10mmFPgap.lpp
- Tl-205(79+,79+)
  - Likely Isomers:
    - » Tl-205(79+,79+): 5% purity
    - » Pb-204(79+,79+): 0.9% purity
    - » Pb-205(79+,79+): 0.9% purity
    - » Hg-203(78+,78+): 0.5% purity
  - LISE: 15507_205Tl79+79+_Be23_Kapton20_10mmFPgap.lpp

Primary Beam for Setup/Calibration

- Provides simple conditions for detector setup/debugging
- Ideally, use same rigidity as production setting
  - » Probably not possible given that we won't know where production setting is
- One or more degraded Pb-208 beams
  - We will send one anyway as a "pilot beam" to setup the beamline magnets
  - We will probably need to check the q-state distribution from the pilot target to be able to know what q-state we're sending
- Do we also need to send undegraded primary beam (no target) to have a background free beam (from fragments)?

Remaining A1900 Prep

- Image 2
  - Install copy of MCP foil for q-state investigation
  - Thinner slits
    - » Deisgn
    - » Machine
    - » Install
- Focal Plane
  - Install MCP foil (MCP alreay in)
  - Re-install FP_PIN
  - Measure magnetic field from MCP
  - With Beam??
    - » Check MCP influence on beam downstream from A1900
    - » Check MCP

MCP will have to be removed if it interferes with A1900 beam delivery before experiment

Run Plan Overview – 1 of 3

- Measure beam energy
- ?? Undegraded primary beam to S2 vault (to give fragment-free conditions for optimizing detector setup)
- Measure target thickness/determine q-states from target (using I2_Sci)
- Measure wedge thickness/determine q-states from wedge (using FP detectors)
- Measure MCP foil thickness/determine q-states from MCP foil (at FP detectors with foil mounted at I2)
- Use LISE to define best shot at Tl-194 production setting based on q-state results

Run Plan Overview – 2 of 3

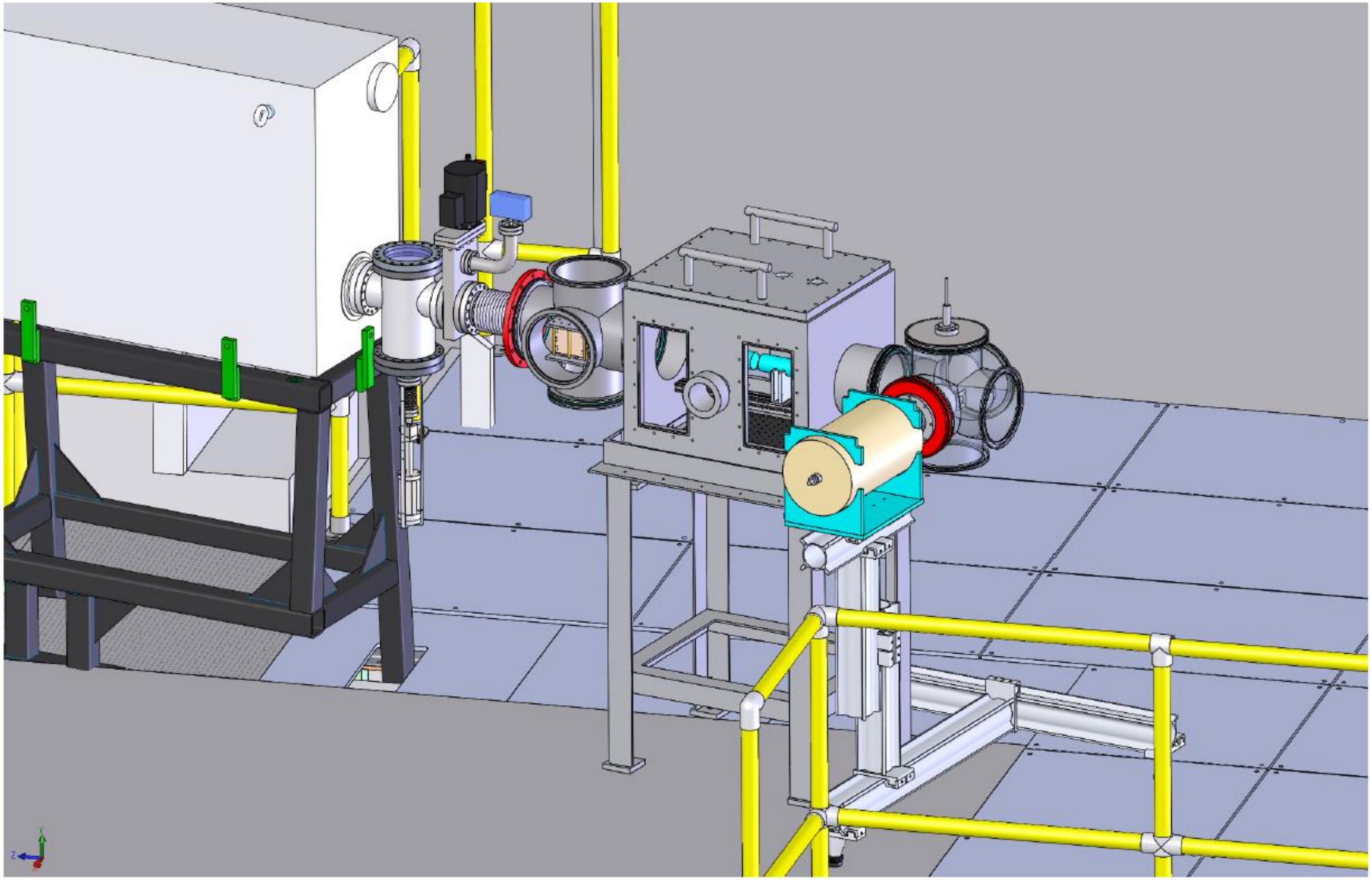
- Pilot beam
  - Might need to measure full q-state distribution to tell which one we're sending
  - Beam size/position evaluation
  - Look for changes to beam size/intensity when FP MCP foil is inserted (to get a visual indication of impact of using MCP foil or not without shifting rigidity)
  - Use for detector setup (avoids confusion from multiple beam components)
  - Evaluate for bad impacts from scattering on narrow I2 slits (i.e., run with and without narrow slits)
  - Provides at least one point for setup calibration
    - » MCP/TOF/Axial_IC/PIN detector setup
    - » detector setup point without confusion from multiple beam species
- If needed, send alternate calibration beams

Run Plan Overview 3 of 3

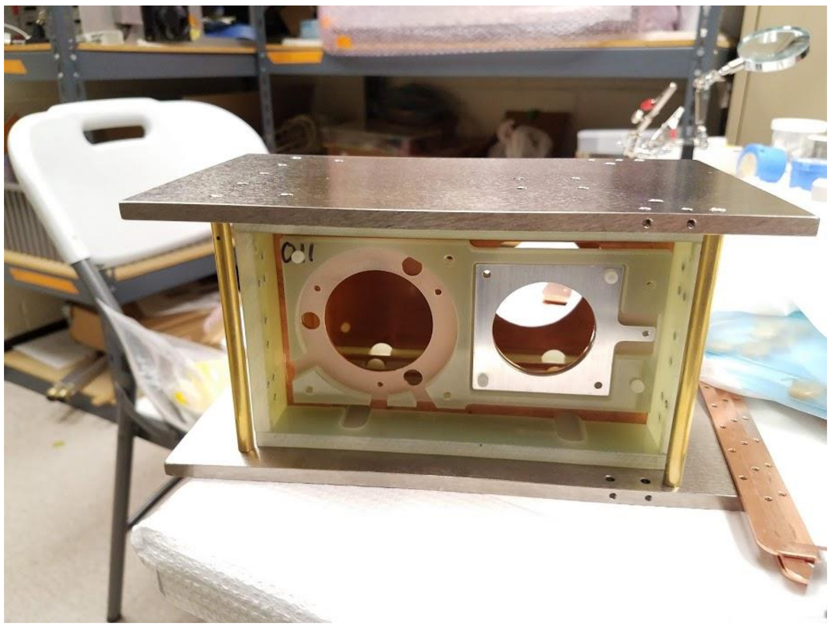
- Tl-195 production setting
  - MCP/TOF/Axial_IC/PIN/Ge detector
    - » Establish PID with PIN implantation setup (including isomers)
  - If needed, revert to appropriate “Plan B” settings
  - MCP/TOP/Axial_IC/catcher/Ge detector
    - » Demonstrate PID (confirmed with isomers) with transmission detector setup (i.e., passive catcher)
- Some data from selected production setting on A1900 FP detectors for context/reference

Backup Slides

S2 Vault Setup

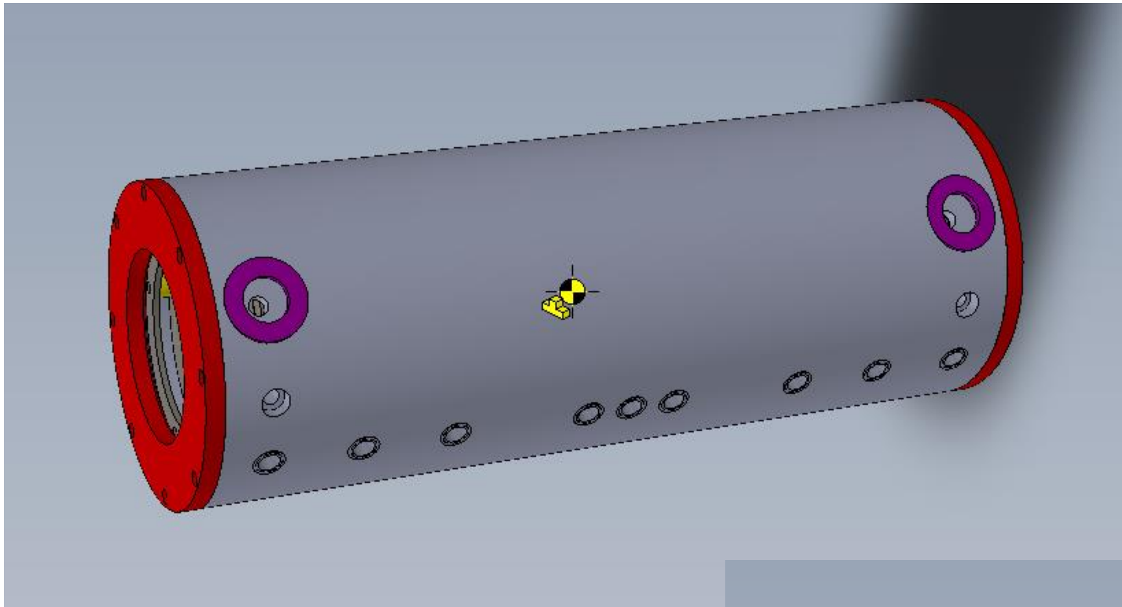


MCP

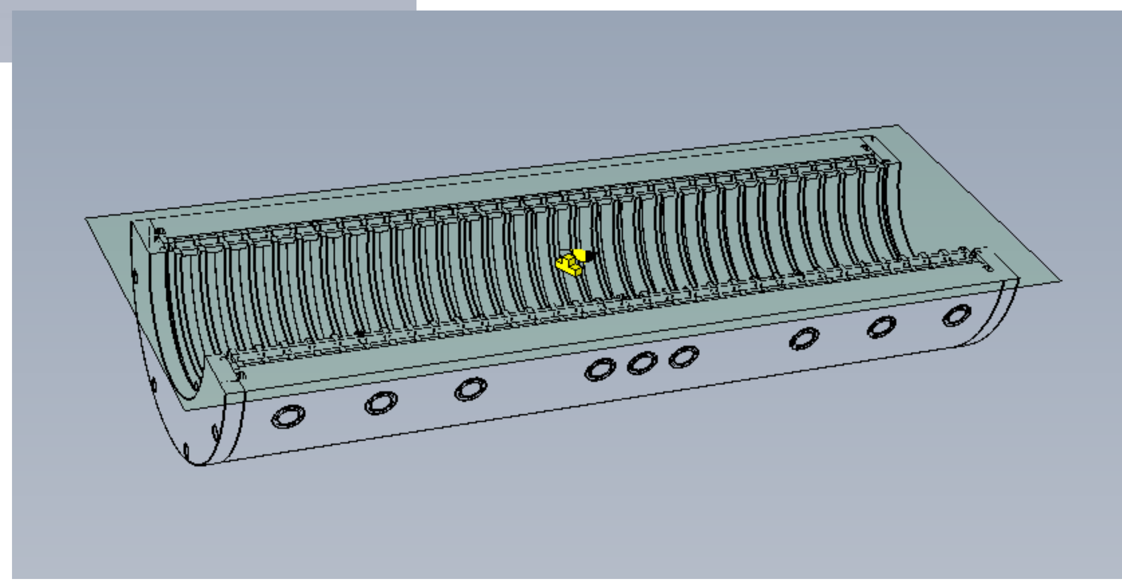


- ExB design
  - Magnetic field transverse to beam direction
    - »Made by permanent magnets and steel plates
  - Electric field parallel to beam direction
  - Electrons are emitted from a thin foil and bent onto the 40 mm MCP surface
  - Amplified electrons are collected on a segmented anode
  - Each piece of the anode is connected to a delay line for position resolution in 1D
- Position resolution <= 500 μm
- Timing resolution ~ 200-300 ps

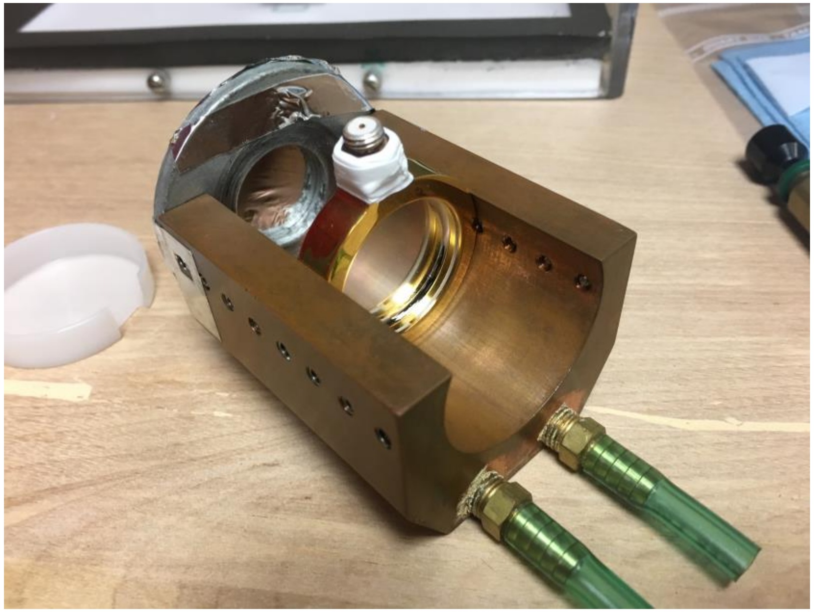
Axial-field Ion Chamber

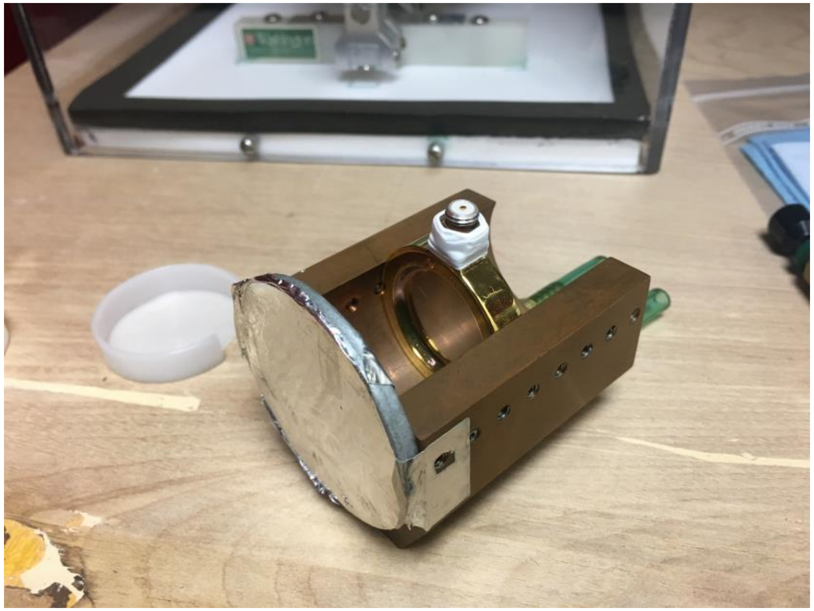


- Gas volume is 134 mm long
- Isobutane gas, 1/3 atm.
- 4 segments
- Energy resolution ~1%



Si Stack





- Need three 300-µm & one 500-µm thick transmission surface-barrier detectors from Ortec
- Dynamic range: 5 GeV
- Energy Resolution: 1%

Beam	Energy after IC	300 µm	300 µm	300 µm	500 µm
$^{195}Tl^{79+}$	75.2	2.74	3.06	3.57	5.3
$^{192}Hg^{78+}$	75.8	2.67	2.98	3.46	5.42
$^{198}Pb^{80+}$	75	2.8	3.12	3.65	5.27