INSTITUTE FOR STRUCTURE AND NUCLEAR ASTROPHYSICS

St. George and SECAR

Manoel Couder

University of Notre Dame

Outline

- Facilities
- Ideas behind design
- Status of St. George
- Status of SECAR

- Questions/Discussion

St. George Science goals

- Study (with stable beam)
  - Reaction involved in Helium burning
  - Reaction involved in s-process
  - α radiative capture
  - Negative q-value (α,n) (at low energy)

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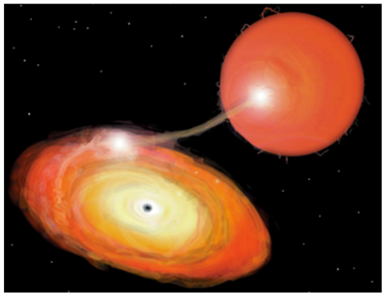
ISNAP

SECAR Science
Takes Advantage of Unique FRIB Capabilities

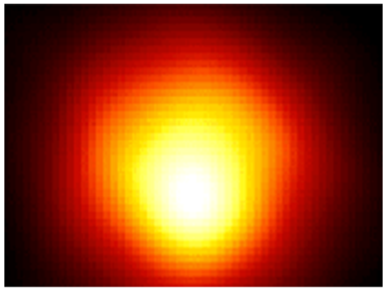
From H. Schatz

- SECAR enables the FRIB user community to take advantage of NSCL/FRIB's unique low energy RIB production capabilities to directly measure astrophysical reaction rates
- Focus on p/α induced reactions on neutron-deficient unstable nuclei
- Addresses a long standing goal of the community – not reached because of limited radioactive beam production capabilities, FRIB with SECAR addresses this



Accreting compact objects
- X-ray bursts
- Novae

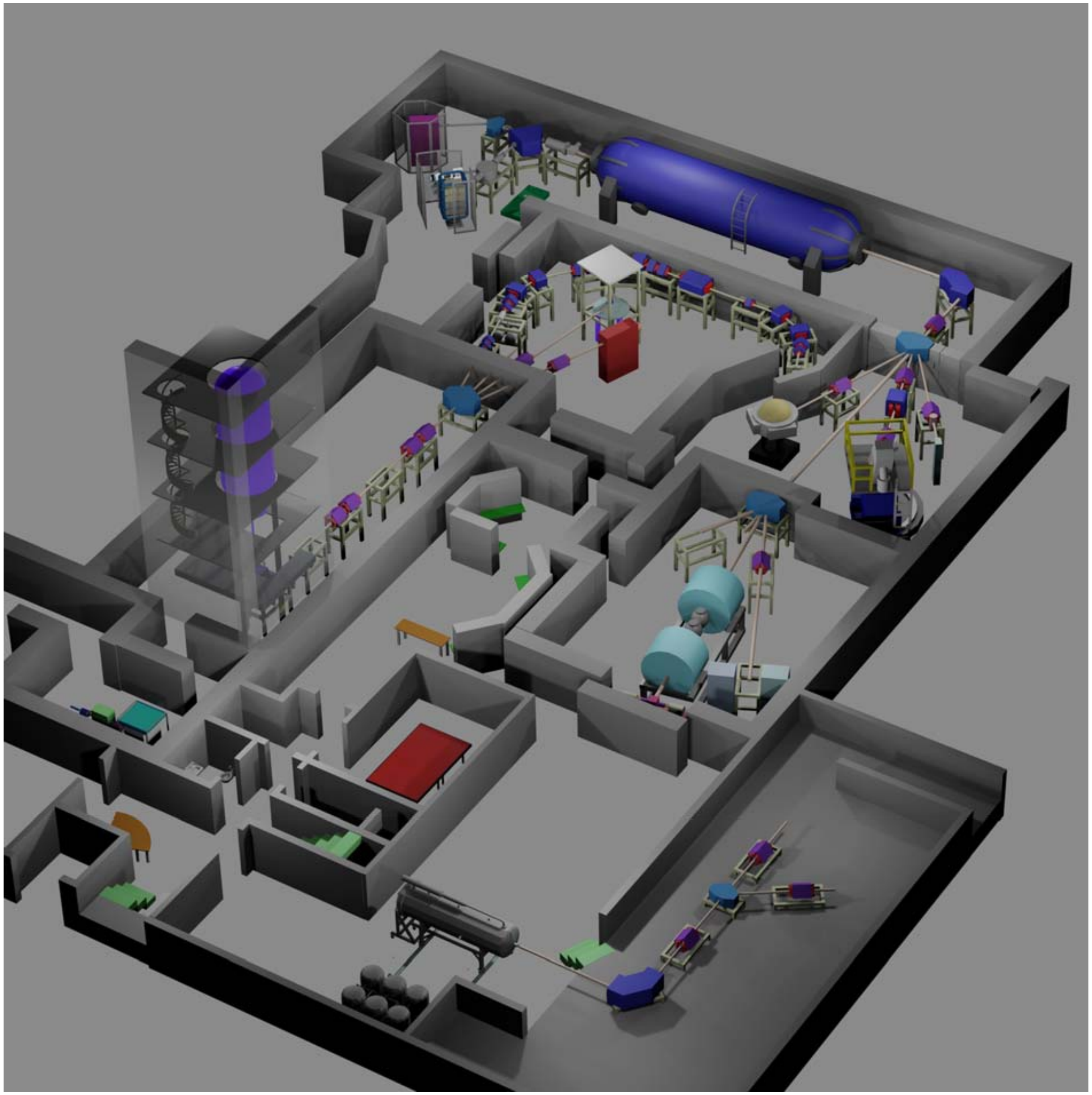
Supernovae
- νp-process
- p-process
- Explosive burn



Extreme Stars
- Thorne Żytkow objects?
- Massive first stars

St. George

- 5 MV single ended electrostatic accelerator
- ECR source with 4 **gas** bottles connected
- Intensity for Z>2 ~50 pμA
- ΔE_{max}=1keV



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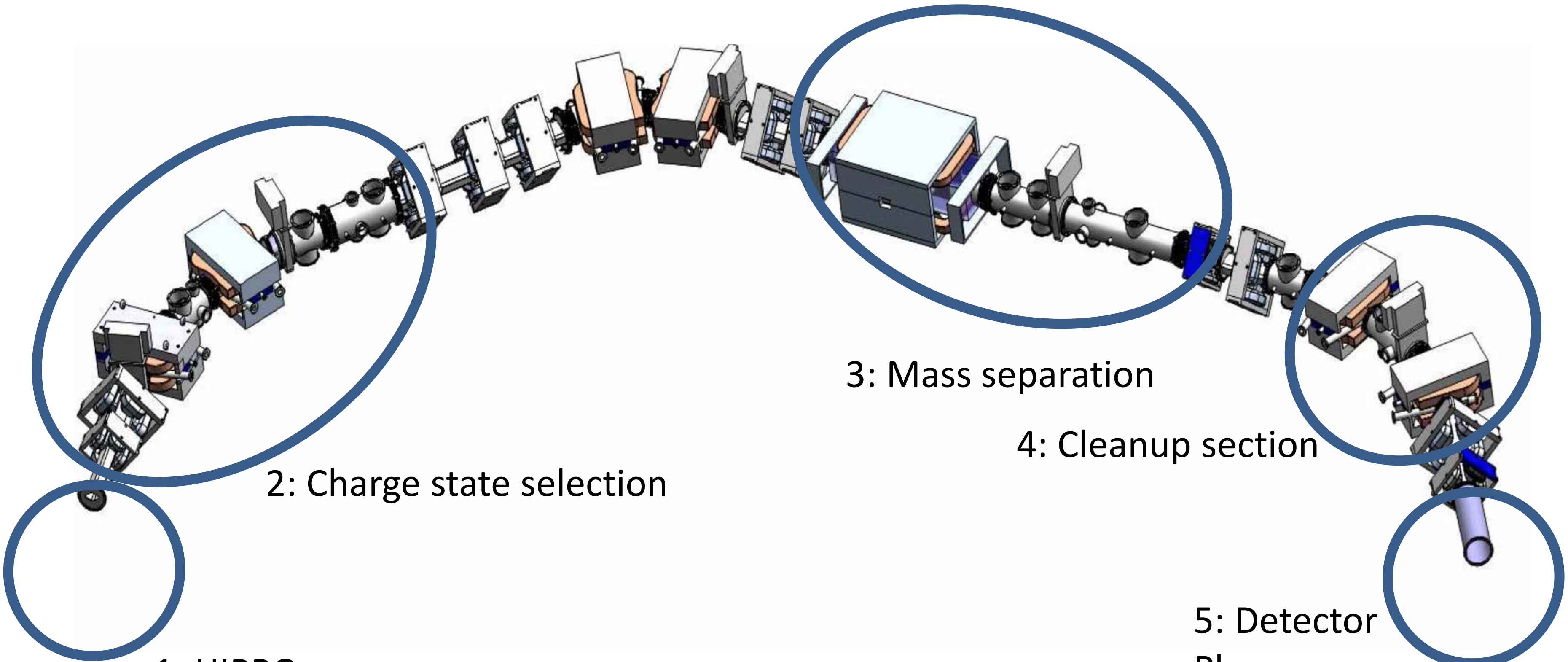
St. George



- St. George consists of:
  - 1 Wien filters
  - 6 Dipole magnets
  - 11 Quadrupoles

Max rigidity: 0.45 Tm

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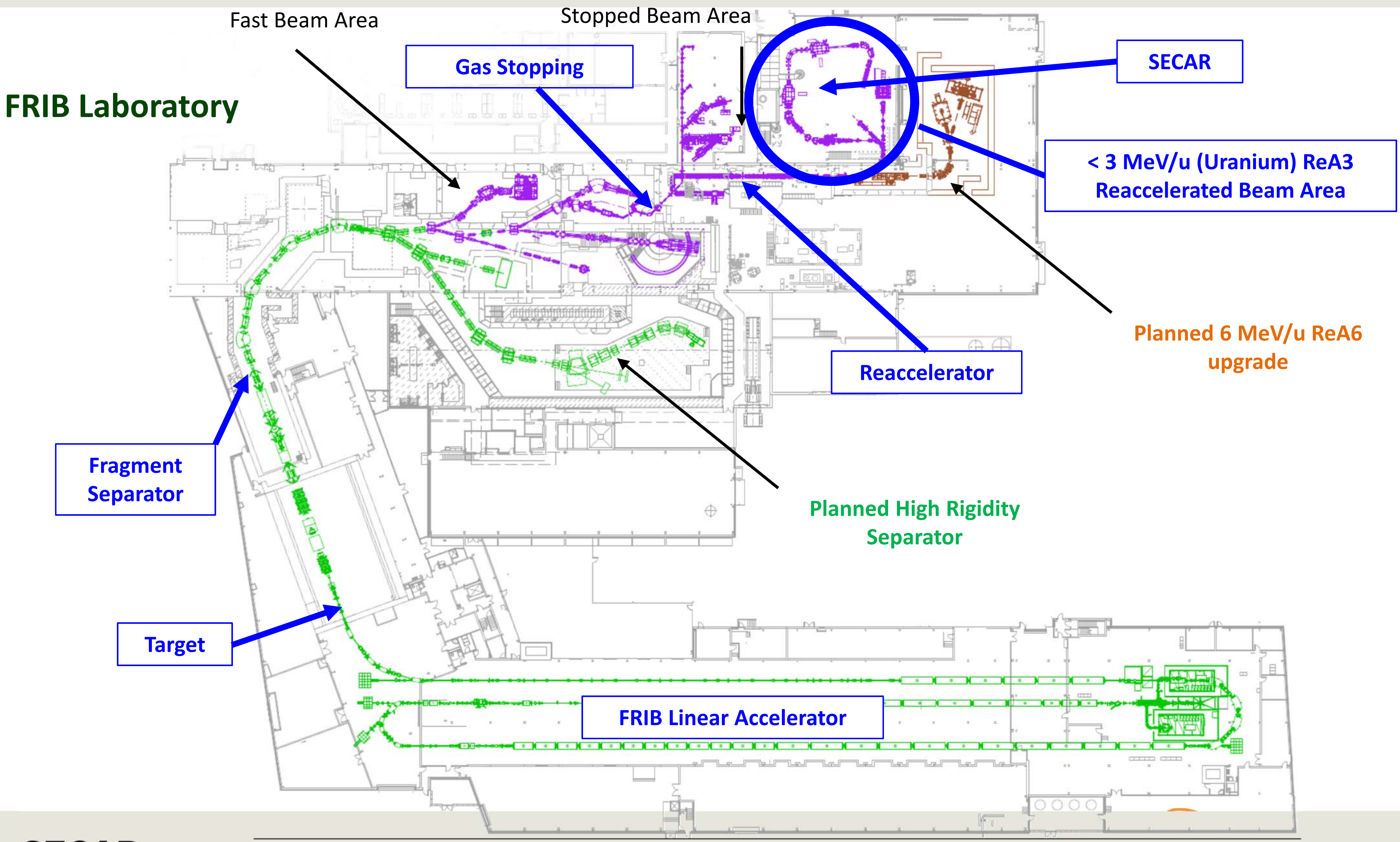
St George
WRIGHT 5

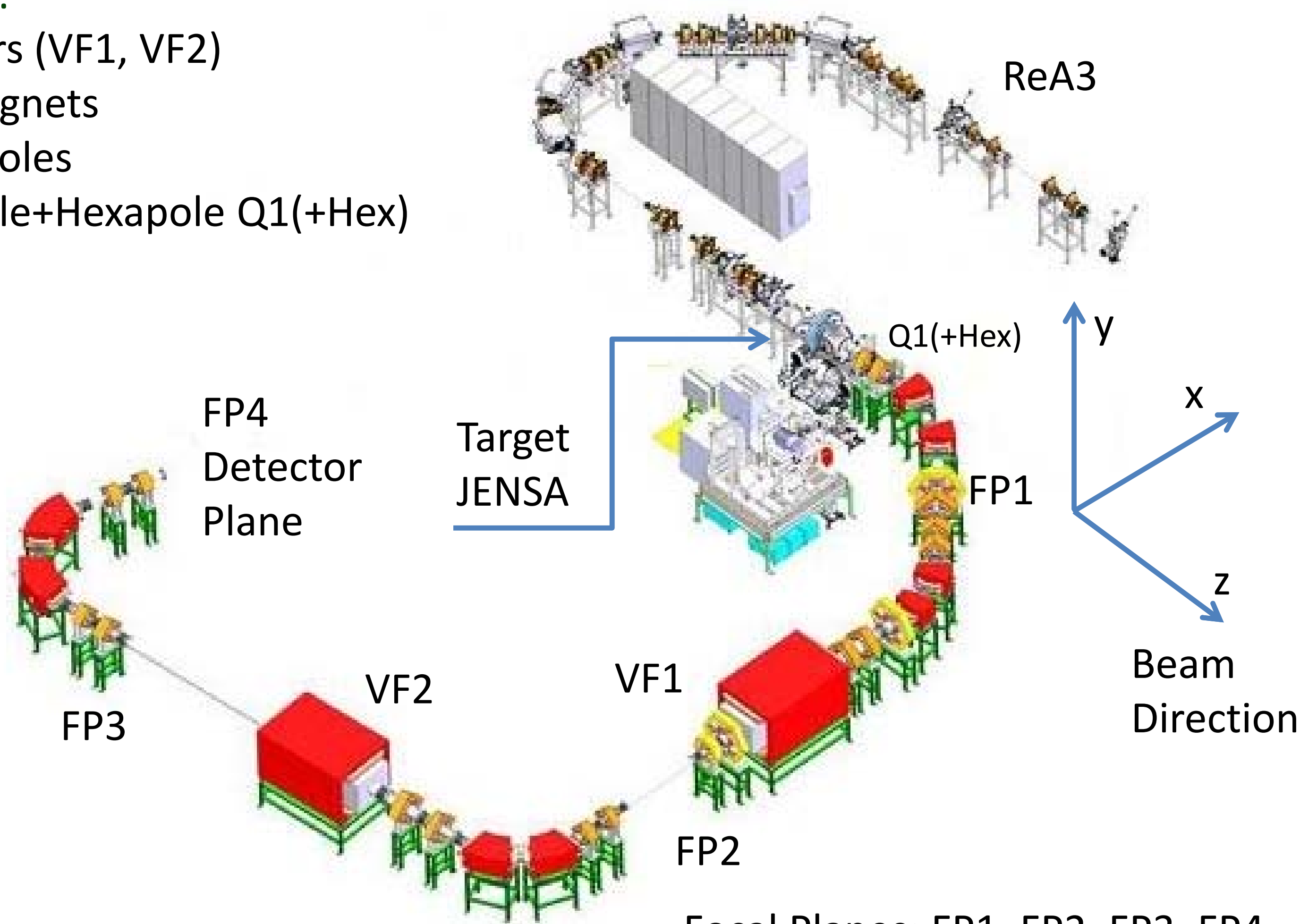
FRIB Laboratory

From G. Bollen



SECAR Layout

- SECAR consists of:
  - 2 Wien filters (VF1, VF2)
  - 8 Dipole magnets
  - 14 Quadrupoles
  - 1 Quadrupole+Hexapole Q1(+Hex)
  - 3 Hexapoles
  - 1 Octupole



Max magnetic rigidity: 0.8 Tm

Focal Planes: FP1, FP2, FP3, FP4

Gas Targets

- Jet important for mass separation
- St. George: HIPPO jet gas target ~10^{17} at/cm^2
- SECAR: JENSA (See K. Schmidt talk)
  - Jet gas target ~ 10^{19} at/cm^2
  - Extend gas target under construction

- γ-ray detection
  - St. George: Large NaI
  - SECAR: BGO array similar to DRAGON

Objective Criteria for Design of the Electromagnetic Separator

- 100% transmission of selected charge state
- Start with Charge state selection
  - Separation outside the envelop of the recoils
  - "Clean capture" of the other charge state
- Criteria for mass selection based on mass resolving power
  - All spectrometers are designed with this approach
  - Scaled resolving power of DRAGON (for SECAR)
  - Compatible with Gaussian approximation for beam
- The tune for the worse case scenario need to be fully scalable for all electric and magnetic rigidities
  - One can find different/better tune for the other less demanding cases

Mass Resolving Power

- $x_1 = x_0(x|x) + a_0(x|a) + {}^{\delta E}/_{E}\ (x|E) + {}^{\delta M}/_{M}\,(x|M)$

We want mass selection to be accomplished at a point were $(x|a) = 0$ a focus and $(x|E) = 0$ achromatic

We also want to maximize $(x|M)$

Resolving power $\sim R_m = \frac{M}{\delta M} = \frac{(x|M)}{Recoil\ spot\ size}$

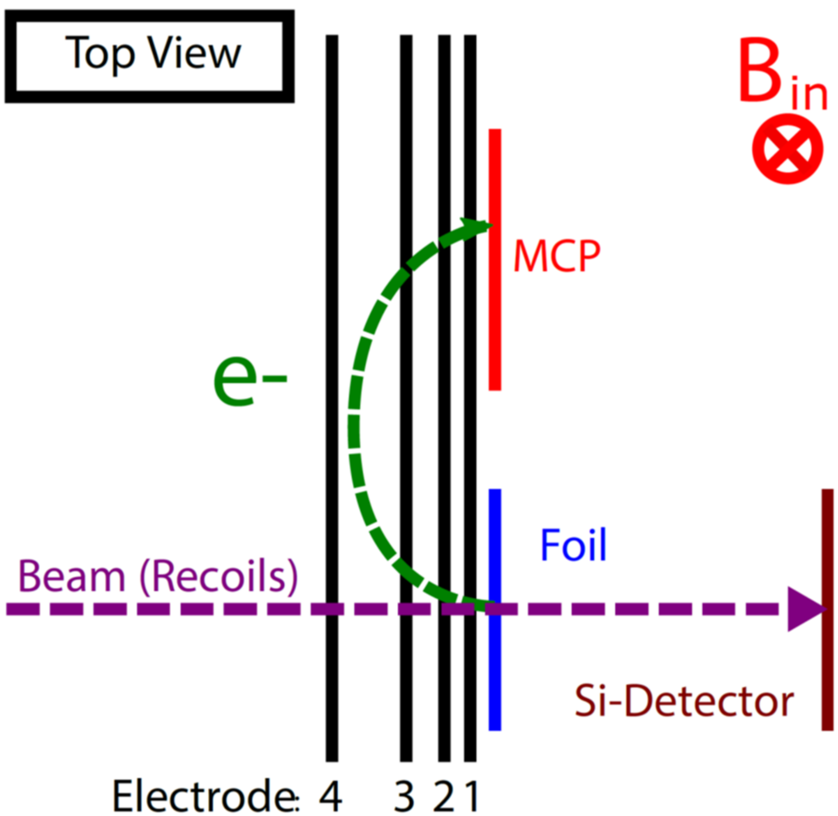
Mass Separation Approach

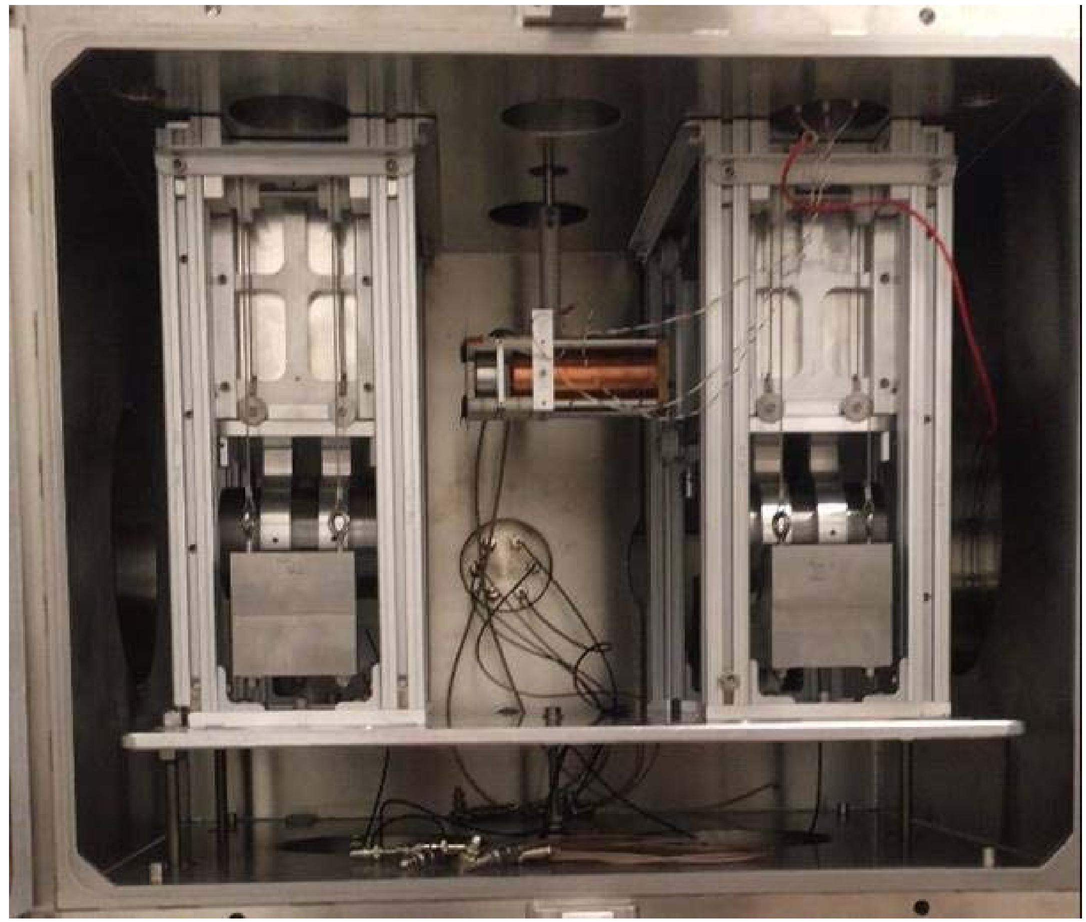
- Both separators use Wien filter
  - In combination with the preceding magnetic elements, achromatic focus is achieved
    - St. George +/-100 kV
    - SECAR +/-270 kV
    - SECAR uses two Wien filter sections
- A "Clean-up section" following the mass separation provides additional momentum selection

Particle ID Detection Systems

- The energies involved in the planned St. George measurements is too low for ΔE-E technique
  →tof vs E (1D) method
  1Dx1D position sensitivity 1mm resolution
- For SECAR a full portfolio of detectors
  - Tof
  - Ionization chamber
  - Silicon detector

St. George ToF





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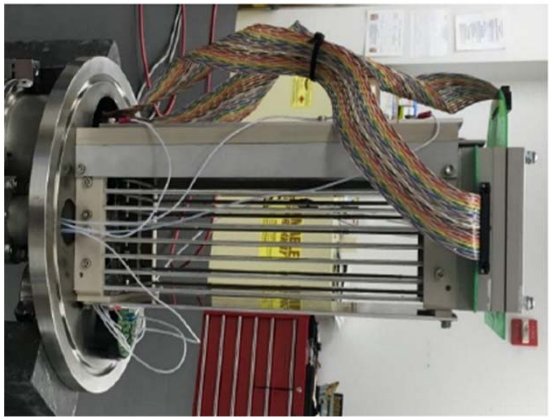
SECAR: Strategies Adopted to Meet Requirements

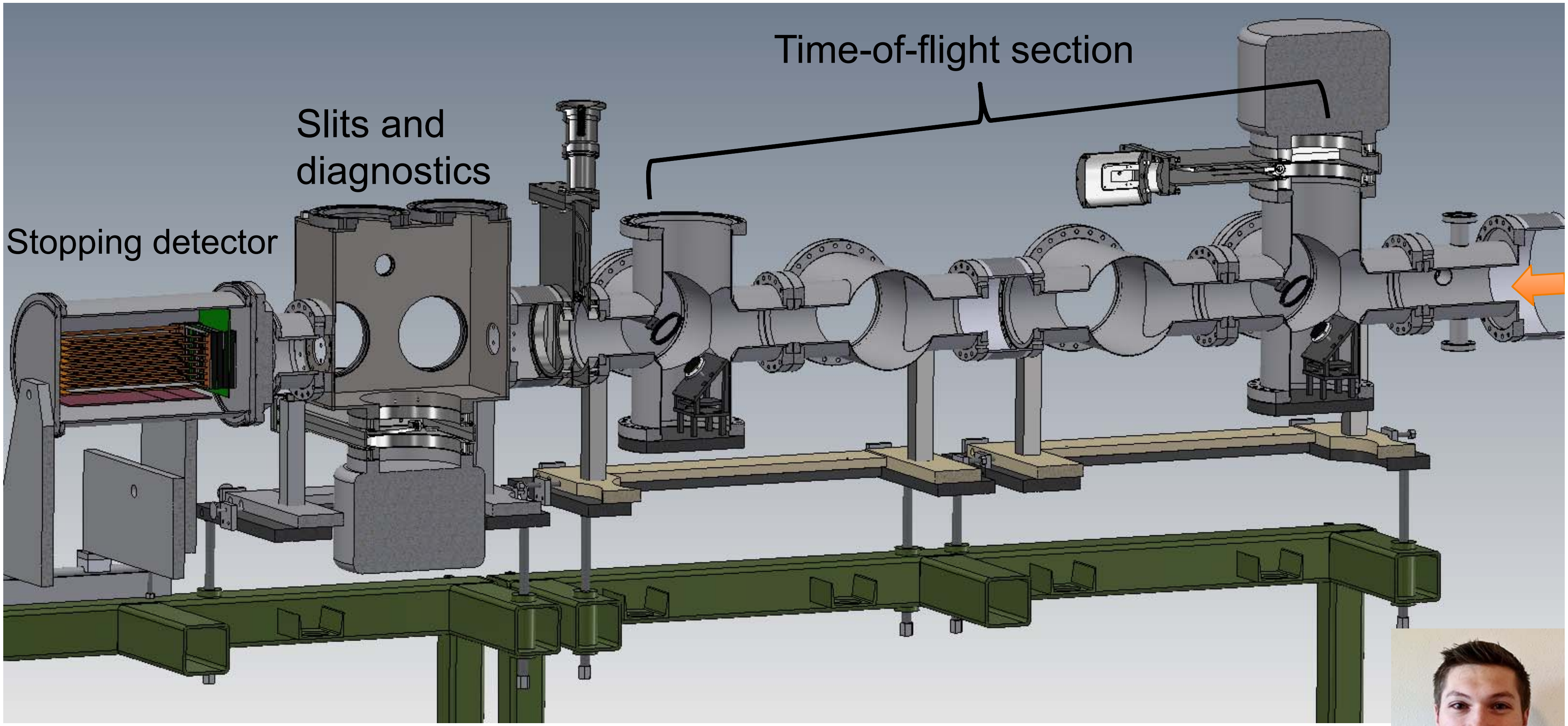
From Jeff Blackmon

- Z selection via relative energy loss in gas (DE-E)
  - Provides isotopic selection when combined with A/q
    - » Most effective for lower Z and higher E
- Total energy
  - Good discrimination between recoils and “leaky beam”
    - » Recoils have lower energy than beam
- Time-of-Flight (TOF) for velocity selection
  - SECAR time of flight
    - » Gamma detectors, target monitor or accelerator
  - Local TOF at 2 positions at focal plane
- Position
  - Position for A/q discrimination
  - Measure trajectory (2 or more positions)
    - » Correct aberrations
    - » Improve background rejection
- Different techniques are better suited to different cases
- Design allows for flexibility to optimize system to experimental requirements



Focal Plane Overview

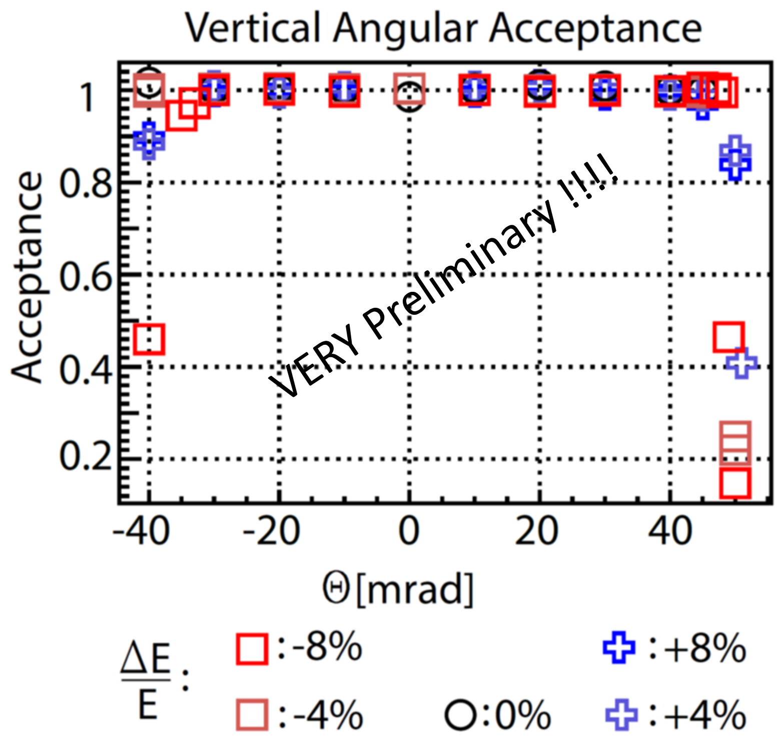
From Jeff Blackmon

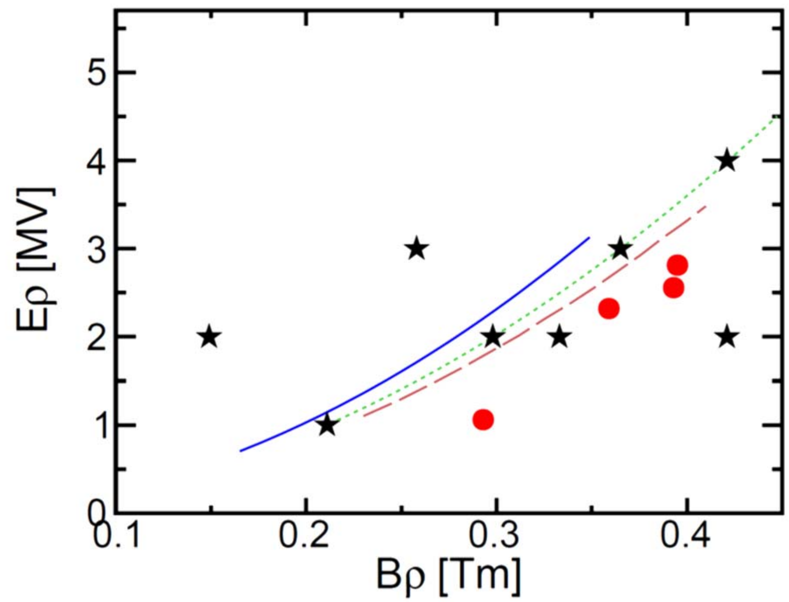


Kyle Joerres, M.S. (LSU, 2017)

Status of St. George

- 100% Energy acceptance over +/-8%
  - Over the whole electric/magnetic rigidity
- Measurement of the angular acceptance





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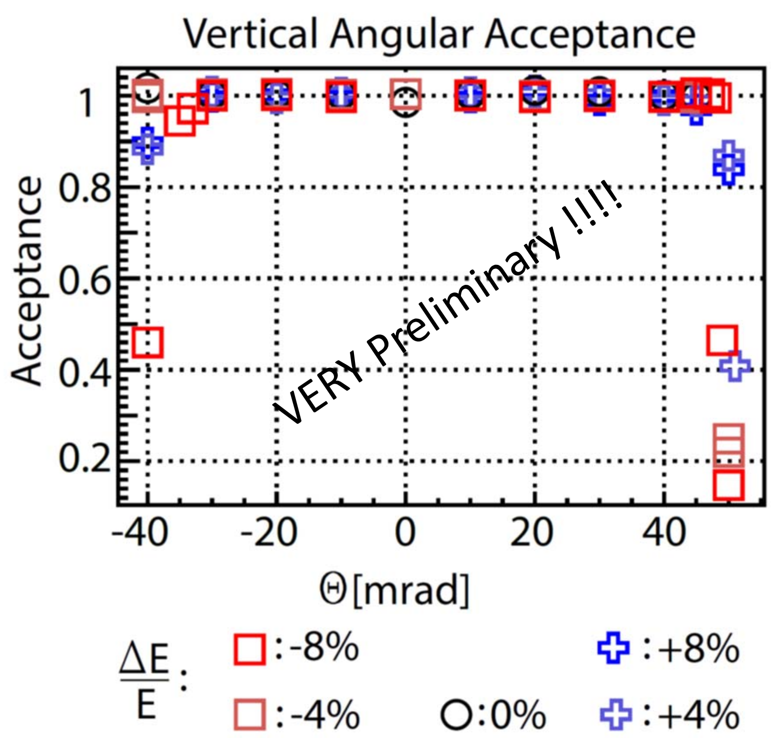

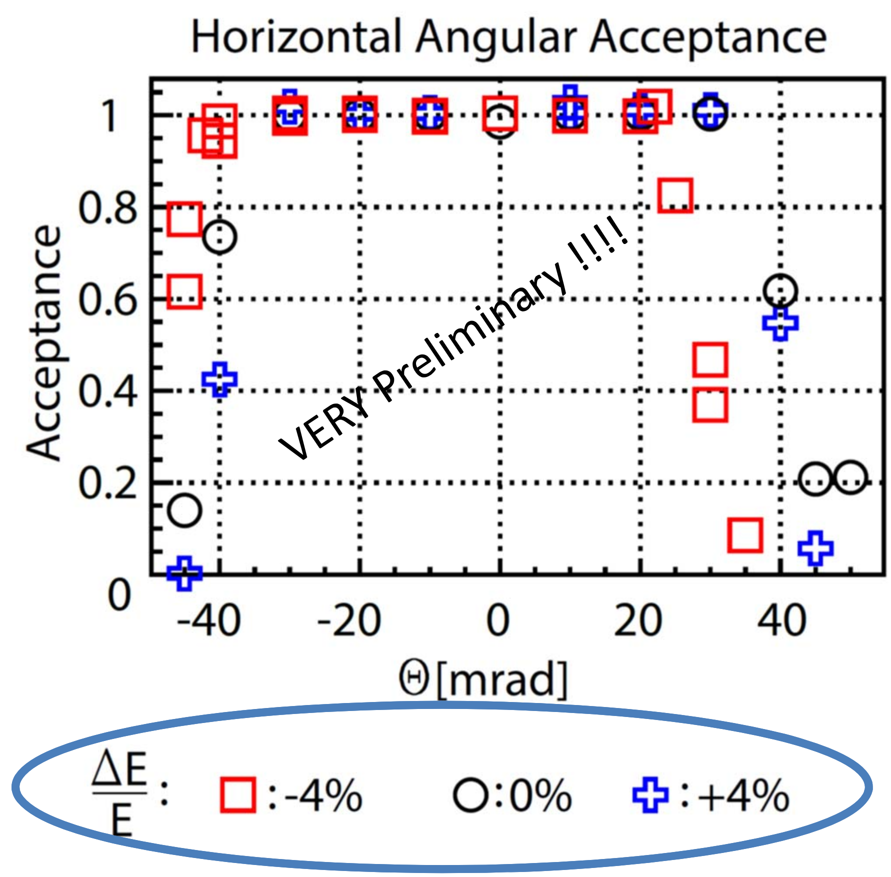

Status of St. George

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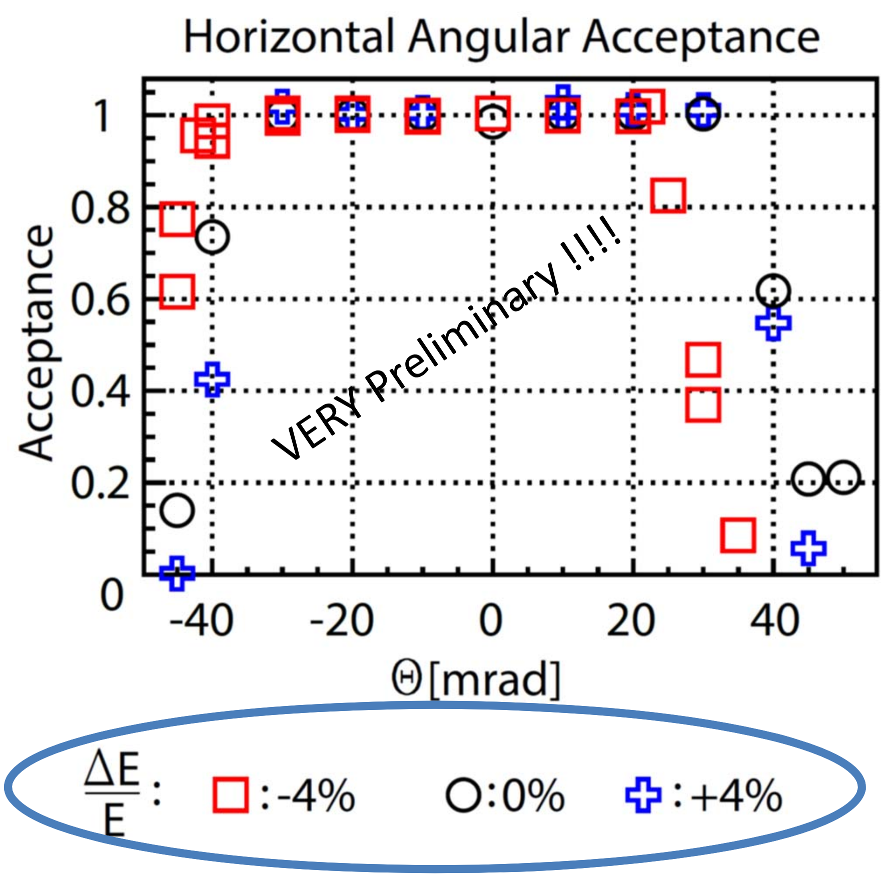
- Measurement of the angular acceptance
- Future: Focus on know reaction and rejection



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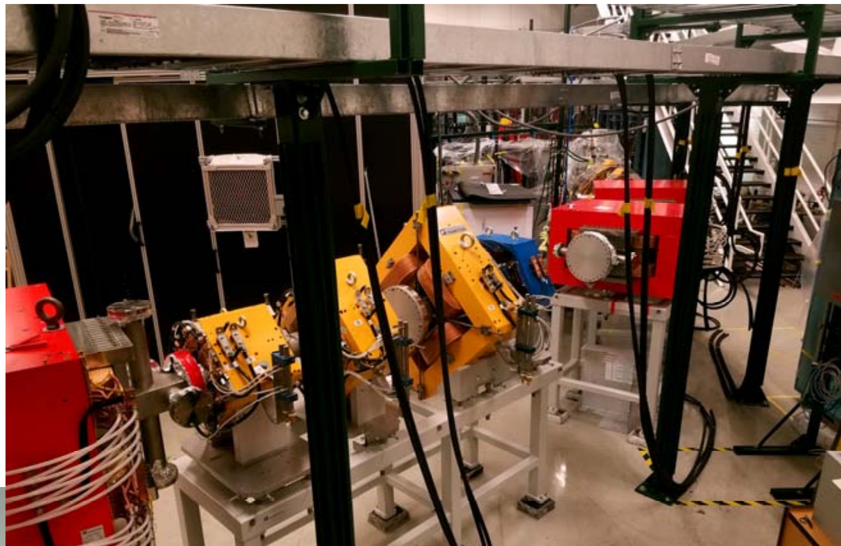
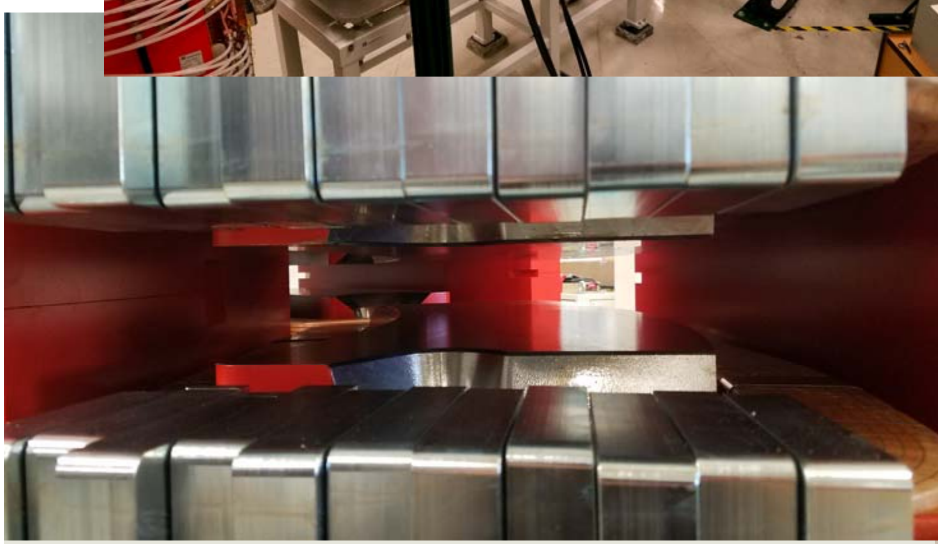
Status of SECAR

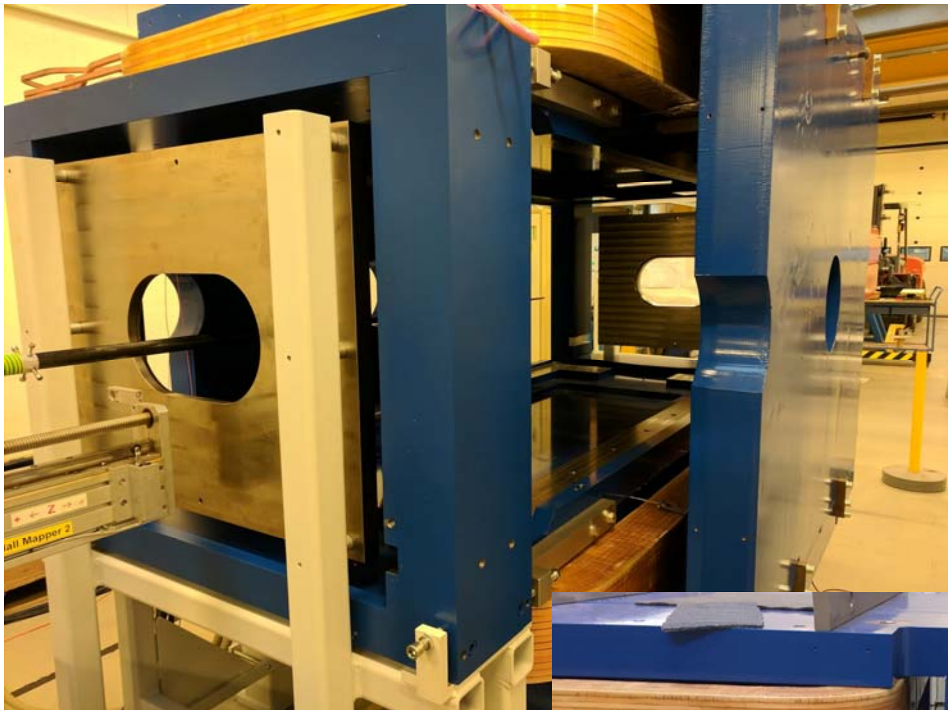
- All the magnets are constructed, delivered, accepted
- First 12 magnets installed

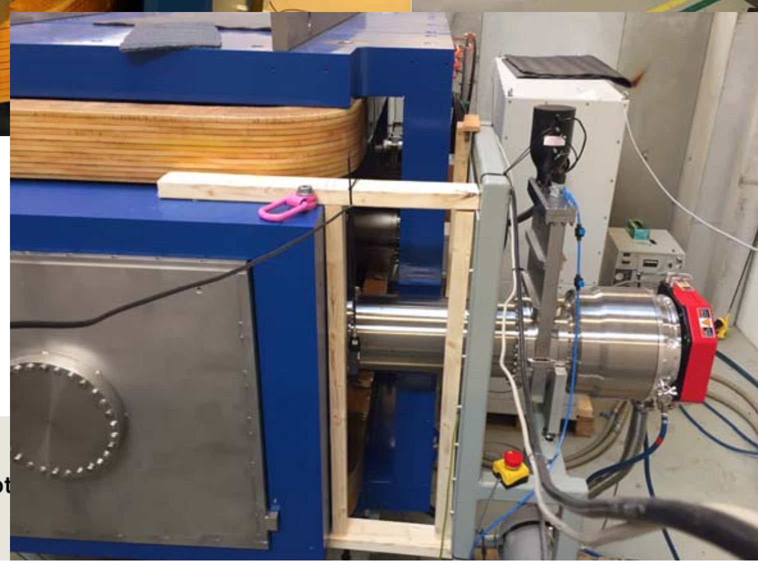




Status of SECAR

- The first Wien filter is under conditioning at the constructor





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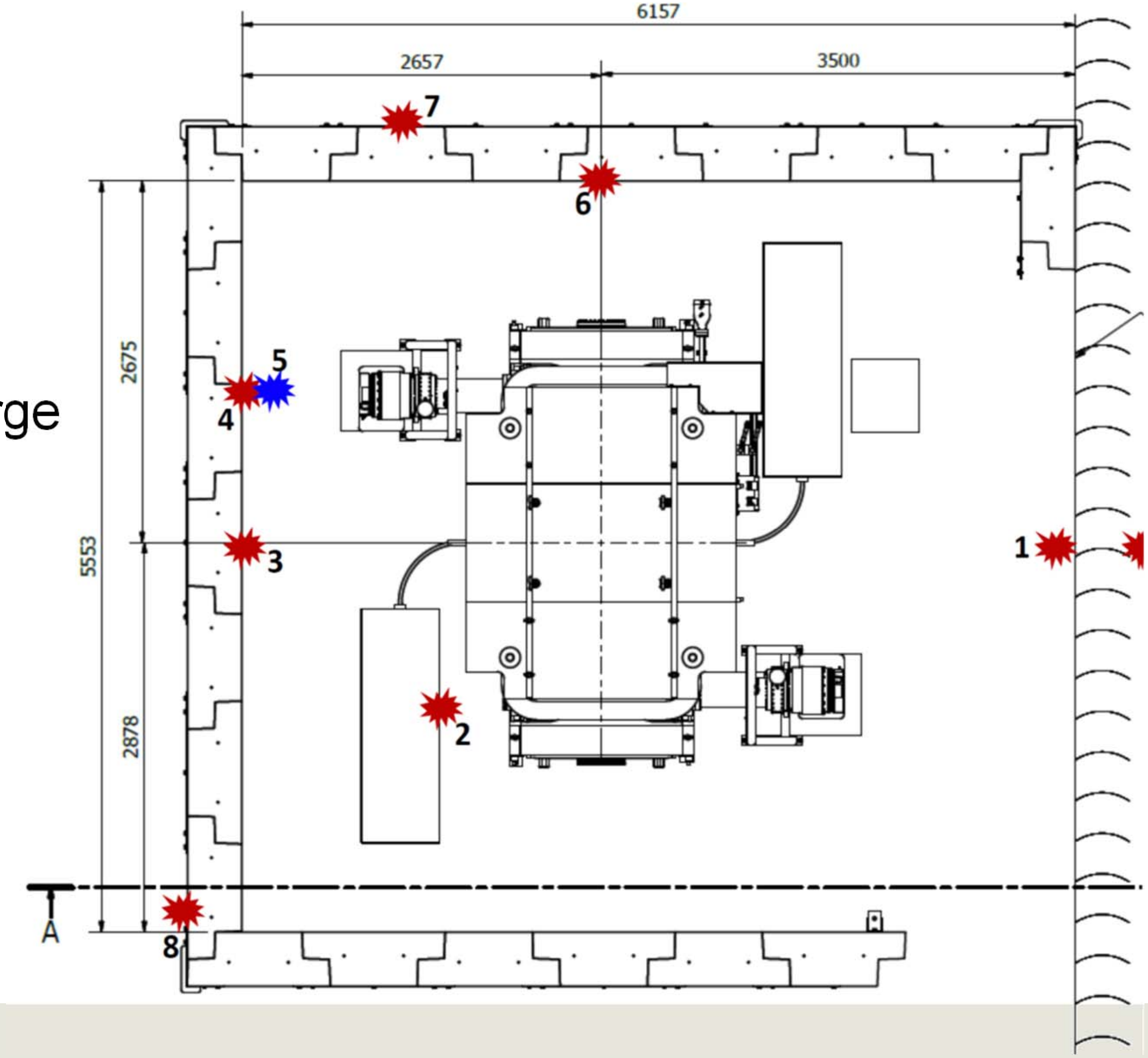
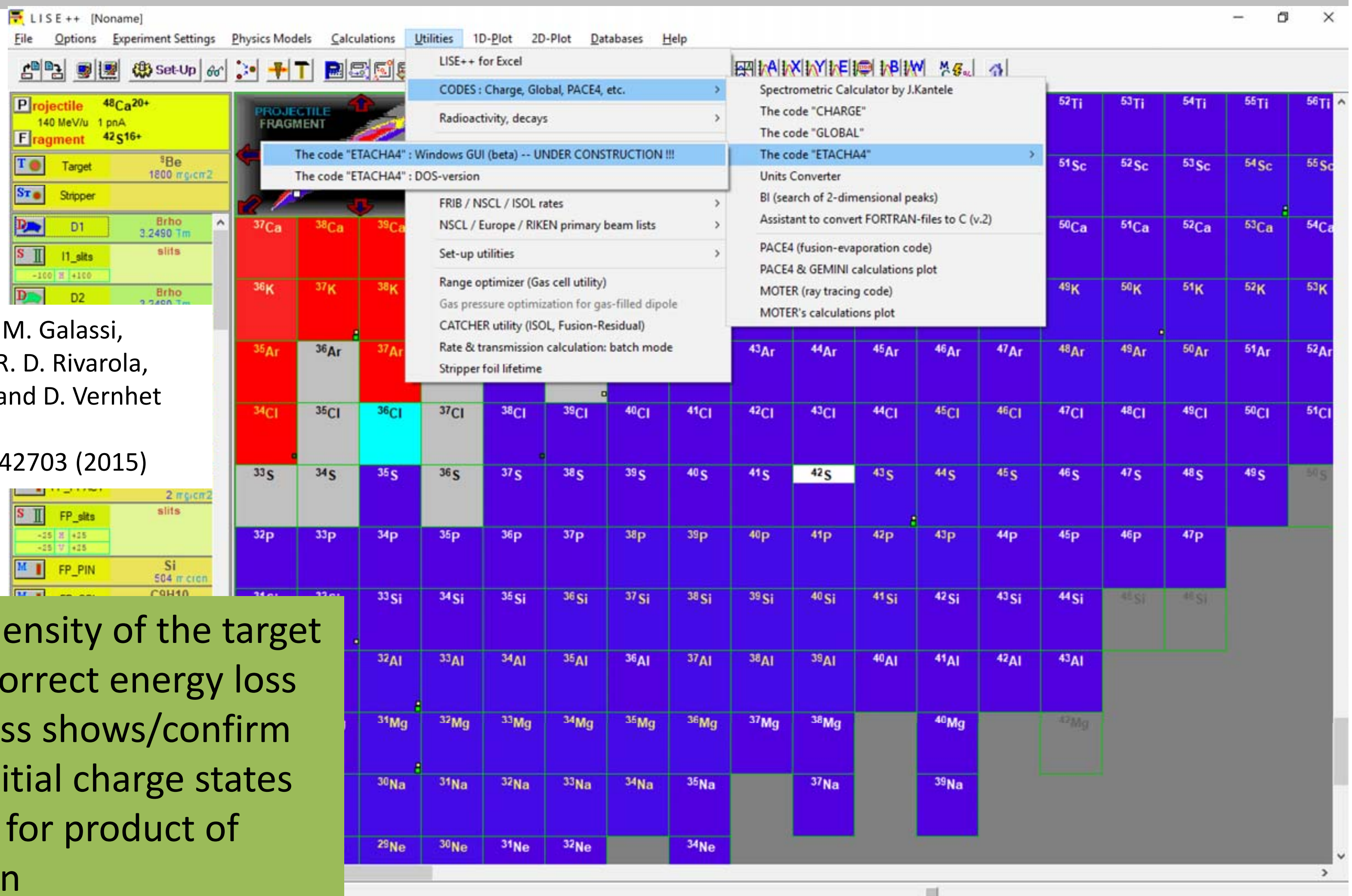


- Future:
  - Commissioning of the charge selection stage May 2018

Questions/Discussion

- Gas target (after Konrad's talk)
  - Characterization of the variable shape of jet
  - Fluid dynamic calculations
    - Limit of 2D
  - Post stripper
- Vacuum effect on rejection
- Method to tune aberration correction magnets
- Charge state distribution
  - Measurements and predictions
  - Joint effort? e.g. Slack Channel to share info & "track" progress

ETACHA



E. Lamour, P. D. Fainstein, M. Galassi, C. Prigent, C. A. Ramirez, R. D. Rivarola, J.-P. Rozet, M. Trassinelli, and D. Vernhet

PHYSICAL REVIEW A 92, 042703 (2015)

-Accounts for density of the target
-Accounts for correct energy loss
-At low thickness shows/confirm sensitivity to initial charge states
-Don’t account for product of nuclear reaction

http://www.insp.jussieu.fr/ETACHA-a-code-to-predict-the.html?lang=en

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