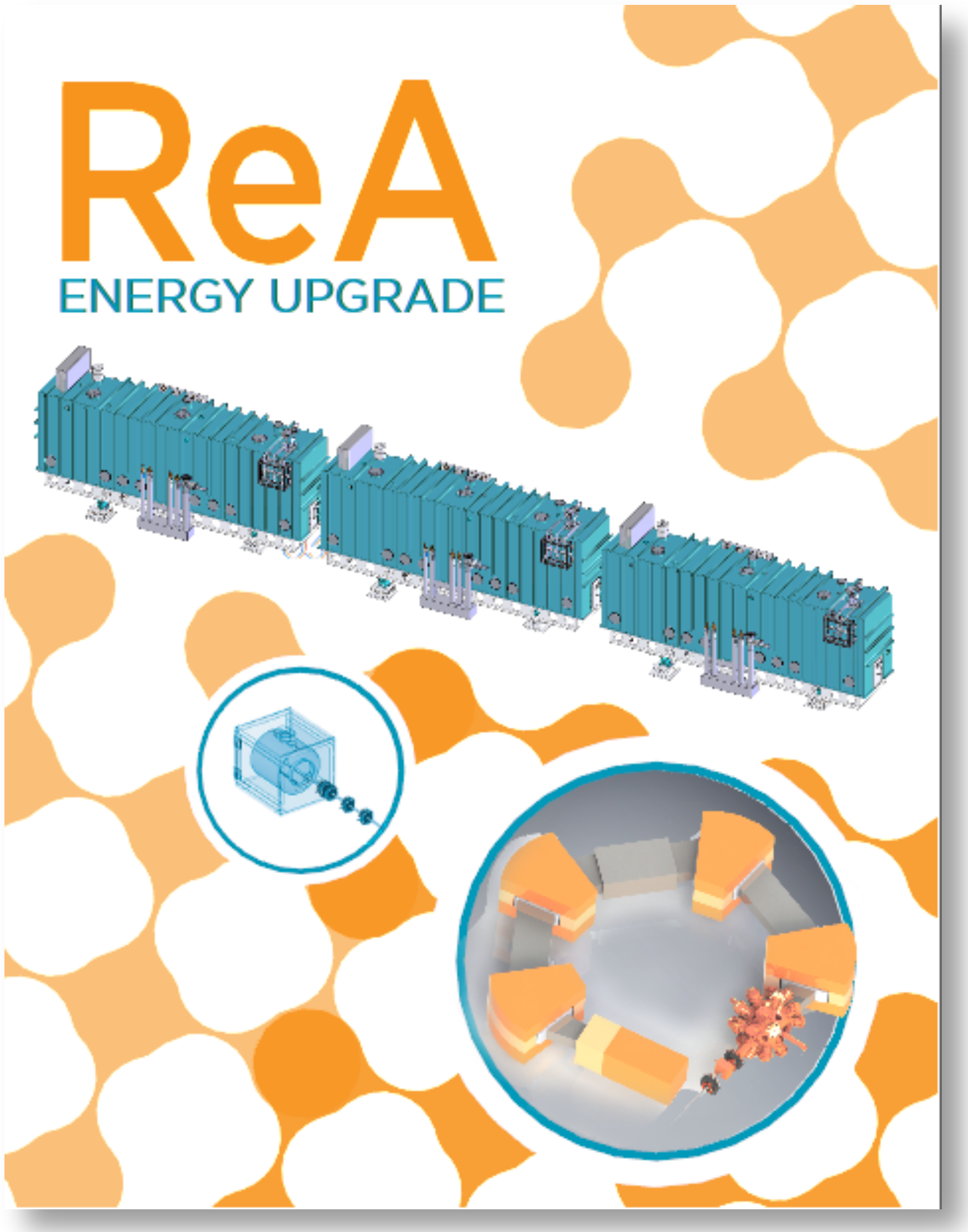
ISLA: a Recoil Separator for re-accelerated beams

D. Bazin

This material is based upon work supported by the U.S. Department of Energy Office of Science under Cooperative Agreement DE-SC0000661, the State of Michigan and Michigan State University. Michigan State University designs and establishes FRIB as a DOE Office of Science National User Facility in support of the mission of the Office of Nuclear Physics.

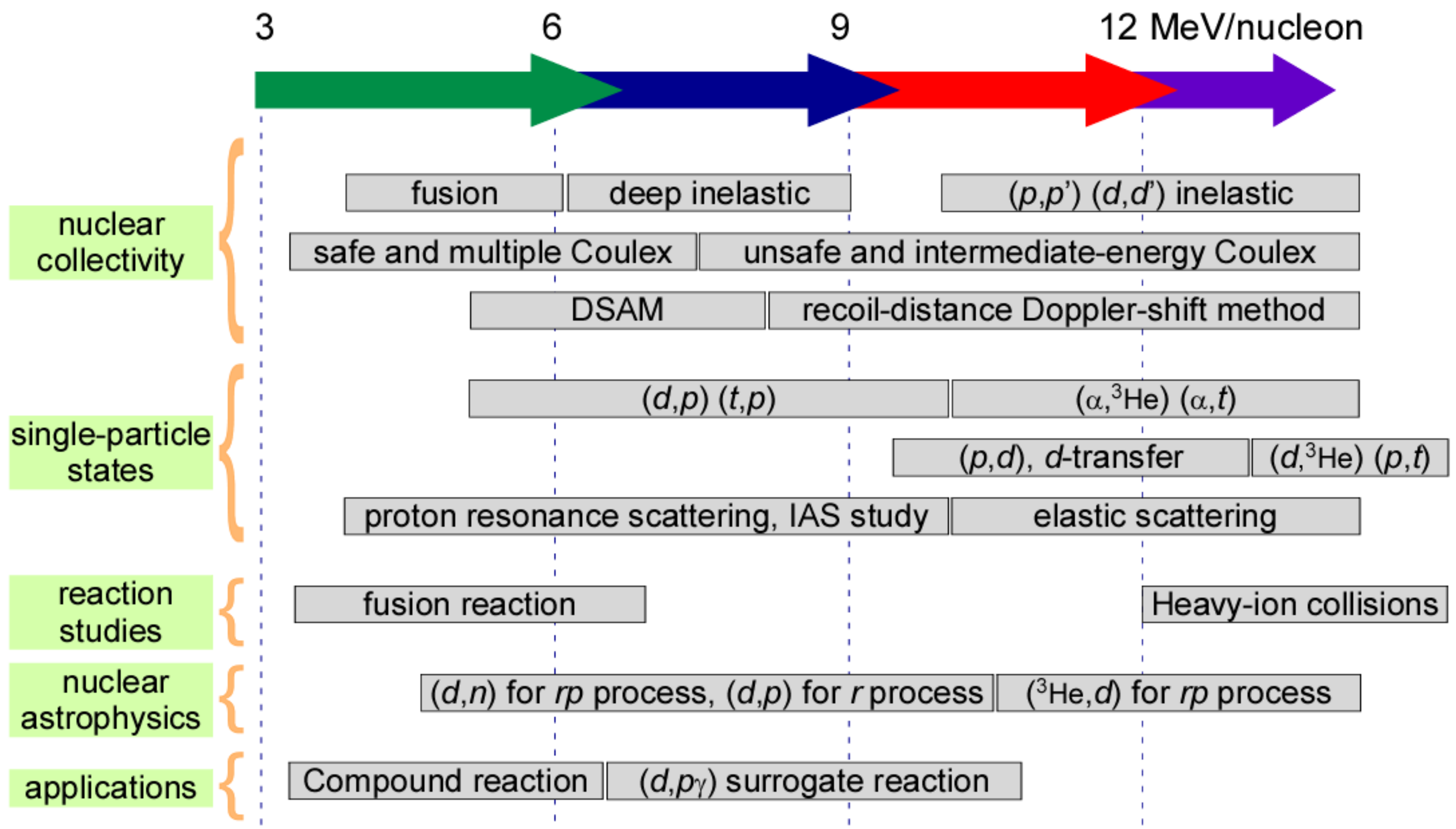
Short history

- 2008: first discussions about need for recoil separator(s) for ReA beams experiments
- 2013: publication about the ISLA concept
  - D. Bazin & W. Mittig, NIM B 317, 319 (2013)
- 2014: ISLA chosen by community as best design to fulfill science goals
- 2015: ISLA white paper released
  - fribusers.org/documents/2015/isla_WP.pdf
- 2016: ReA energy upgrade white paper released
- 2019: NSF Mid-scale pre-proposal not retained
- 2019: Conceptual dipole design finalized
- 2020: Study of multipole magnets

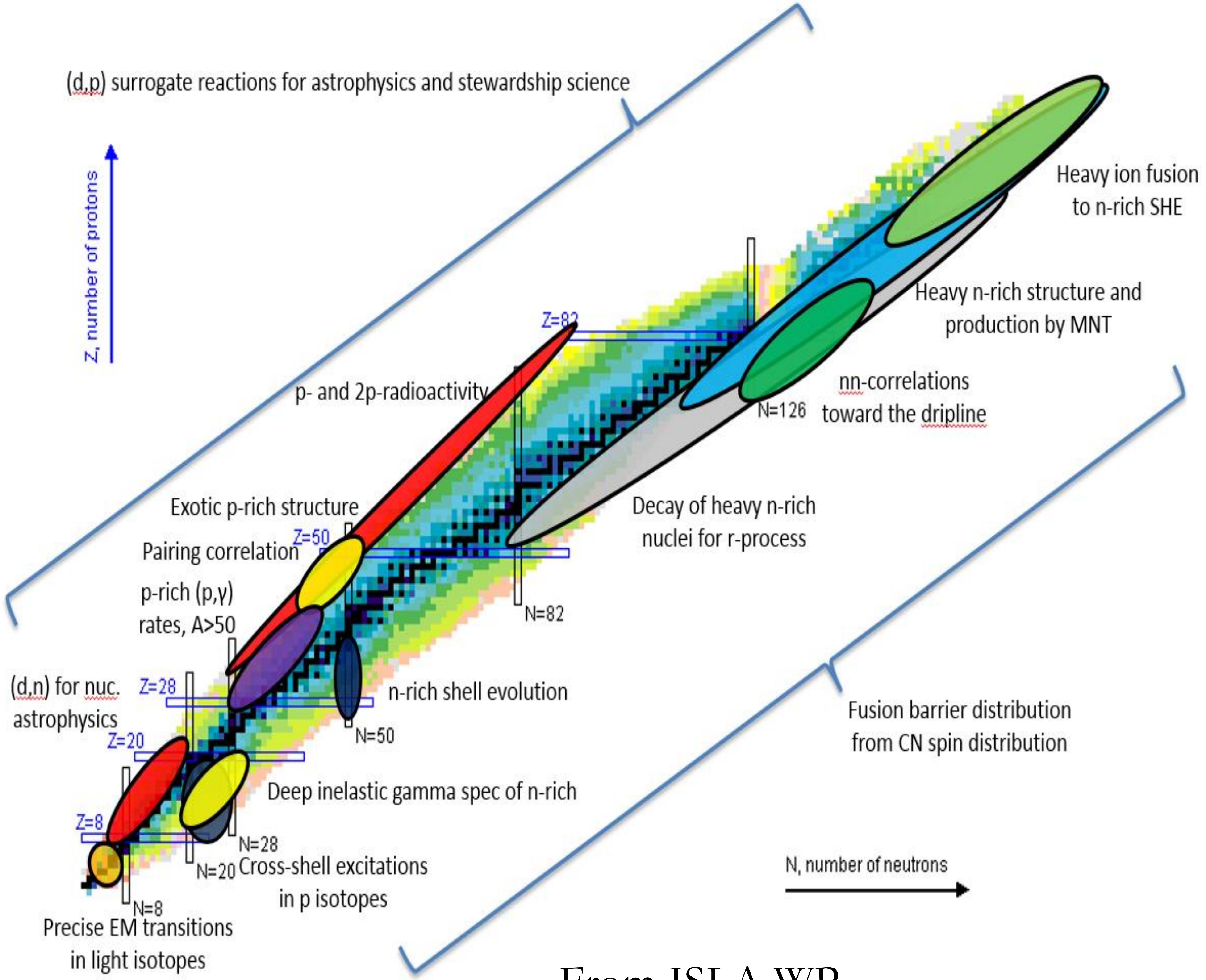


Science goals

- "ReA12 with FRIB beams makes these studies possible, but only if we have a flexible spectrometer to remove unreacted beam and identify the products"
- "ISLA meets the needs of ALL proposed physics cases"



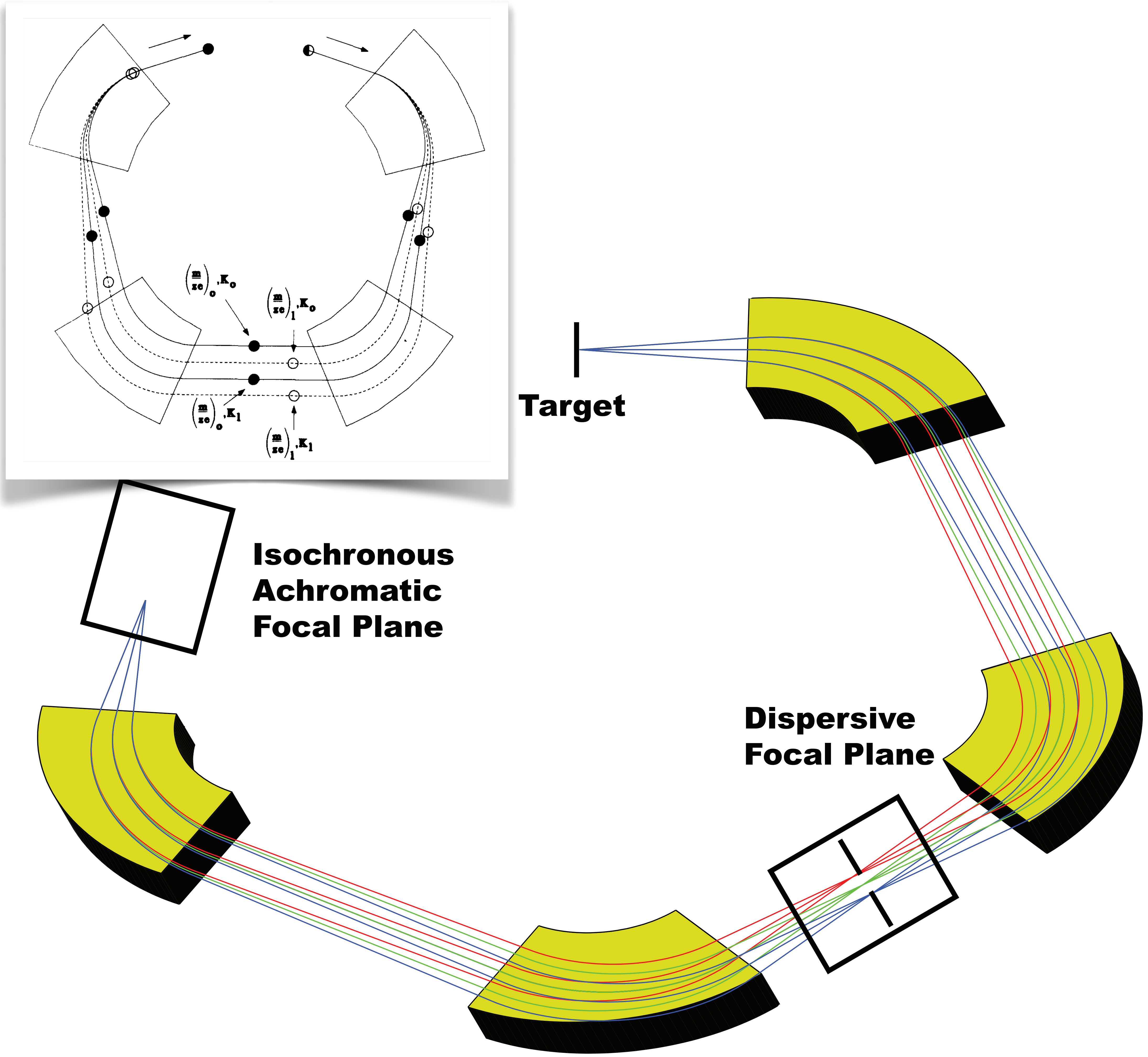
From ReA energy upgrade WP



From ISLA WP

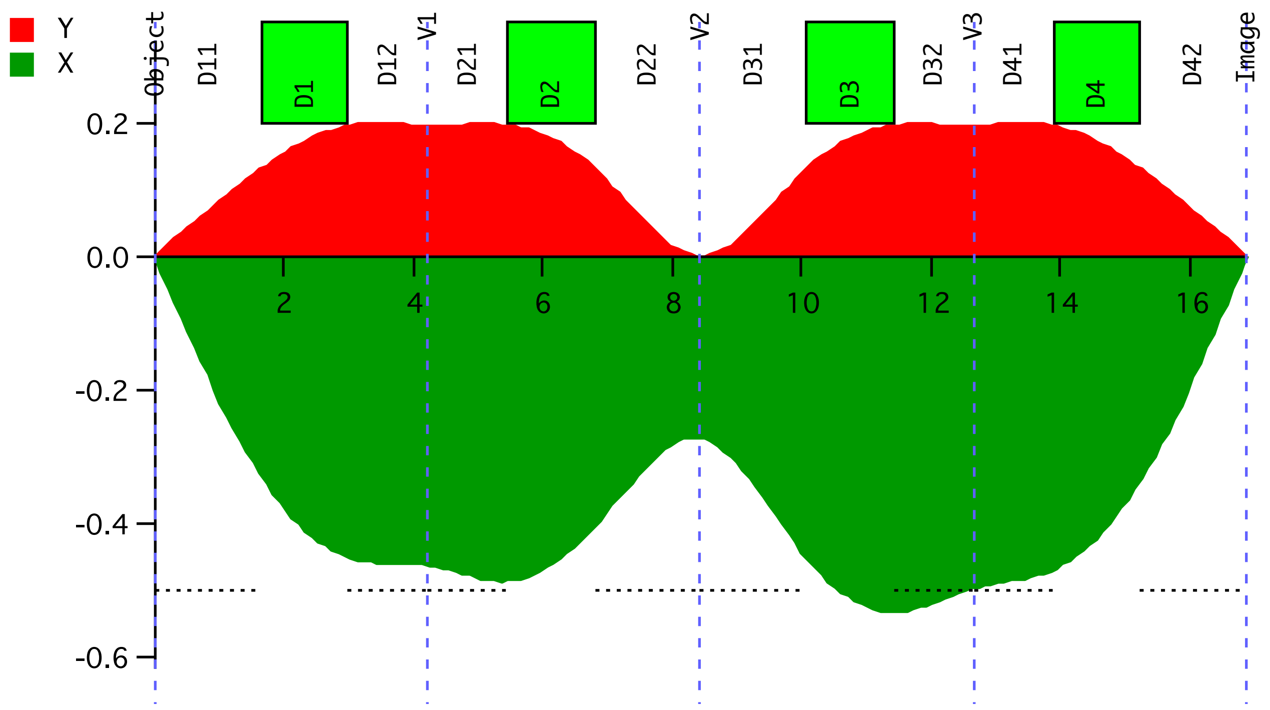
Basic concept

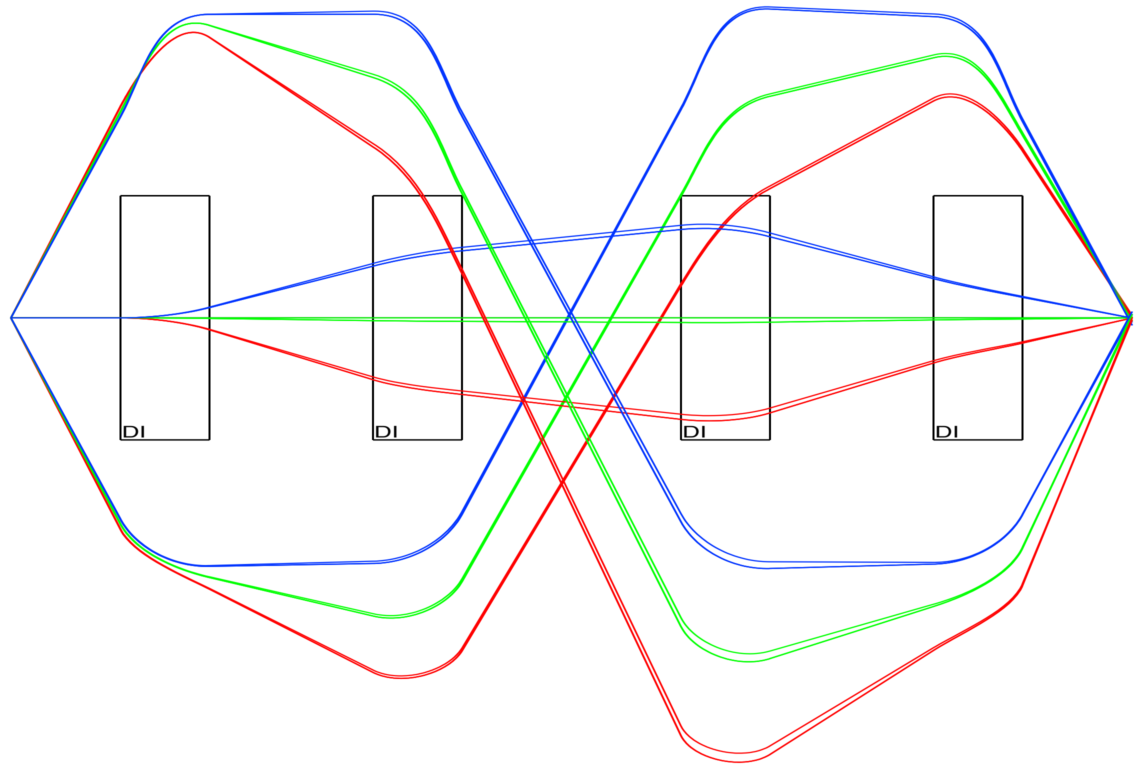
- Isochronous Separator with Large Acceptances
  - Provides M/Q separation of reaction products based on Time-of-flight measurement
  - Inspired from the TOFI mass spectrometer (LANL)
- Characteristics
  - High M/Q resolving power: R > 1000
  - Large acceptances
    - 64 msr
    - ± 10% momentum
  - Flexible
    - Coupling to multiple auxiliary systems
    - Possibility to change incoming beam angle

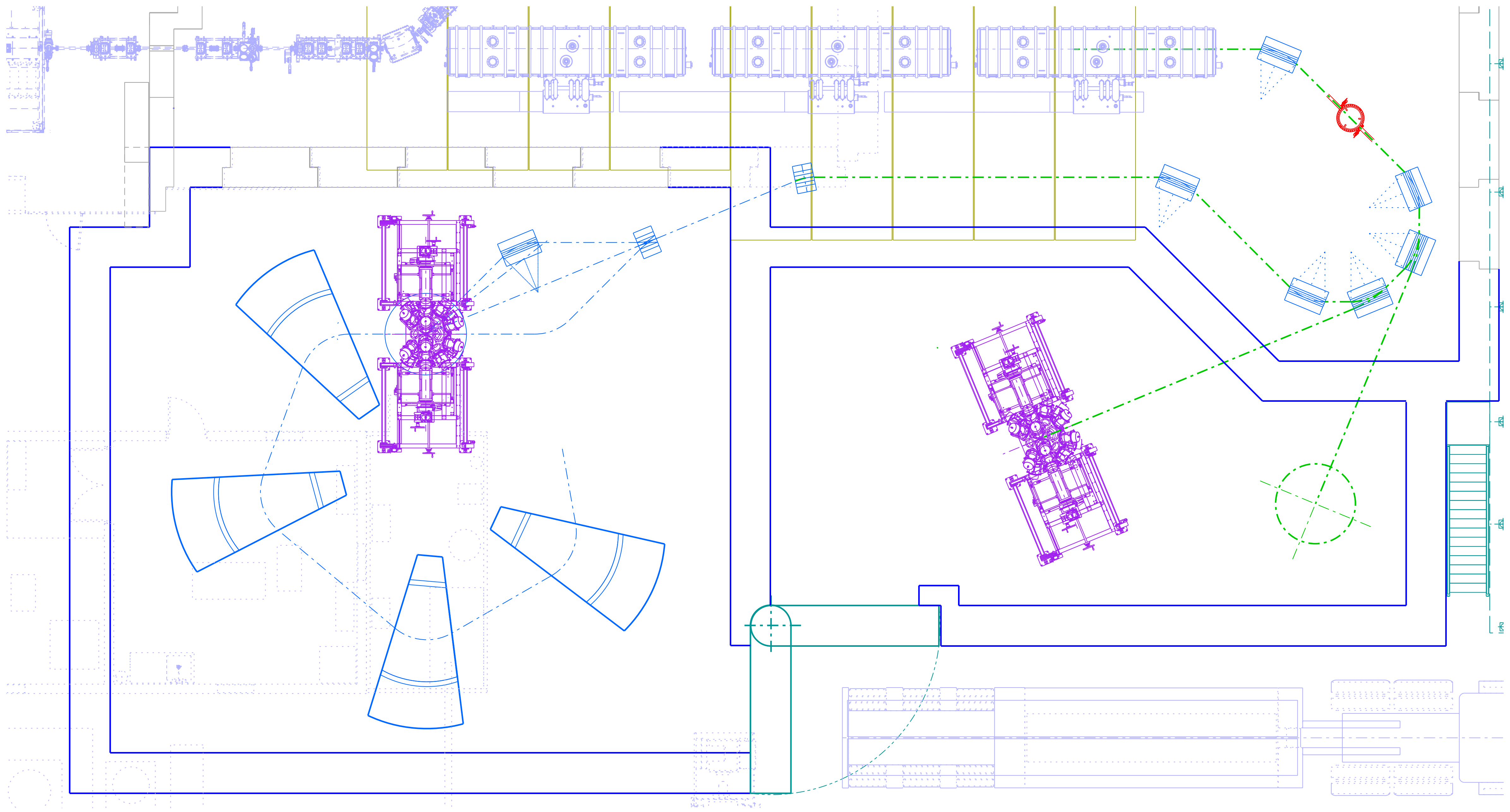


Layout and basic performance

- Symmetrical design
  - Cancel aberrations to allow large acceptance
  - Small focal plane to allow decay studies and/or further separation using RF kicker
  - Distance between target and first dipole large enough to accommodate auxiliary detectors (GRETA, …)
- Horizontal swinger
  - Movable dipole
  - Allow to change beam angle on target up to 45°
  - Access to maximum of cross section in deep inelastic reactions

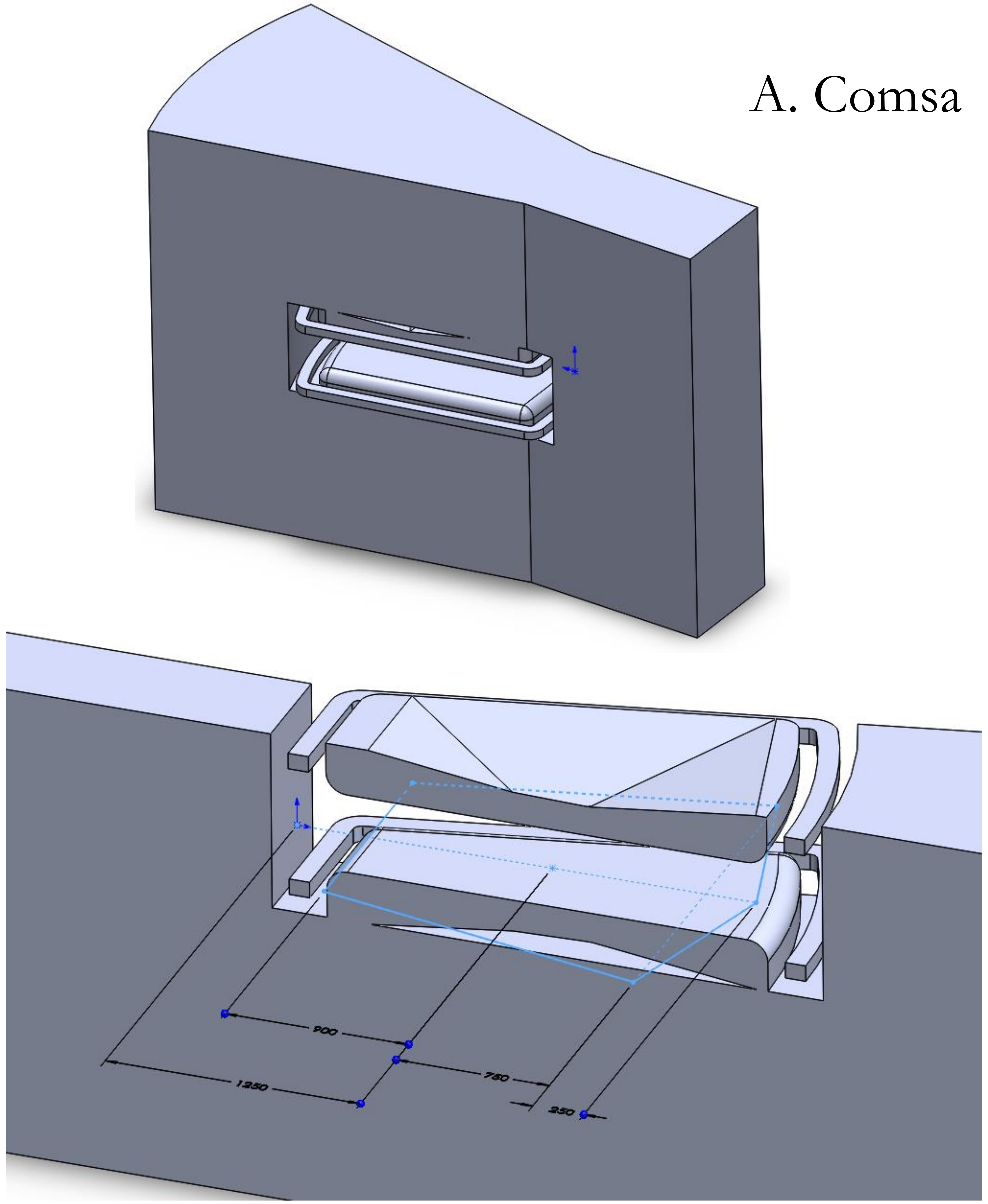




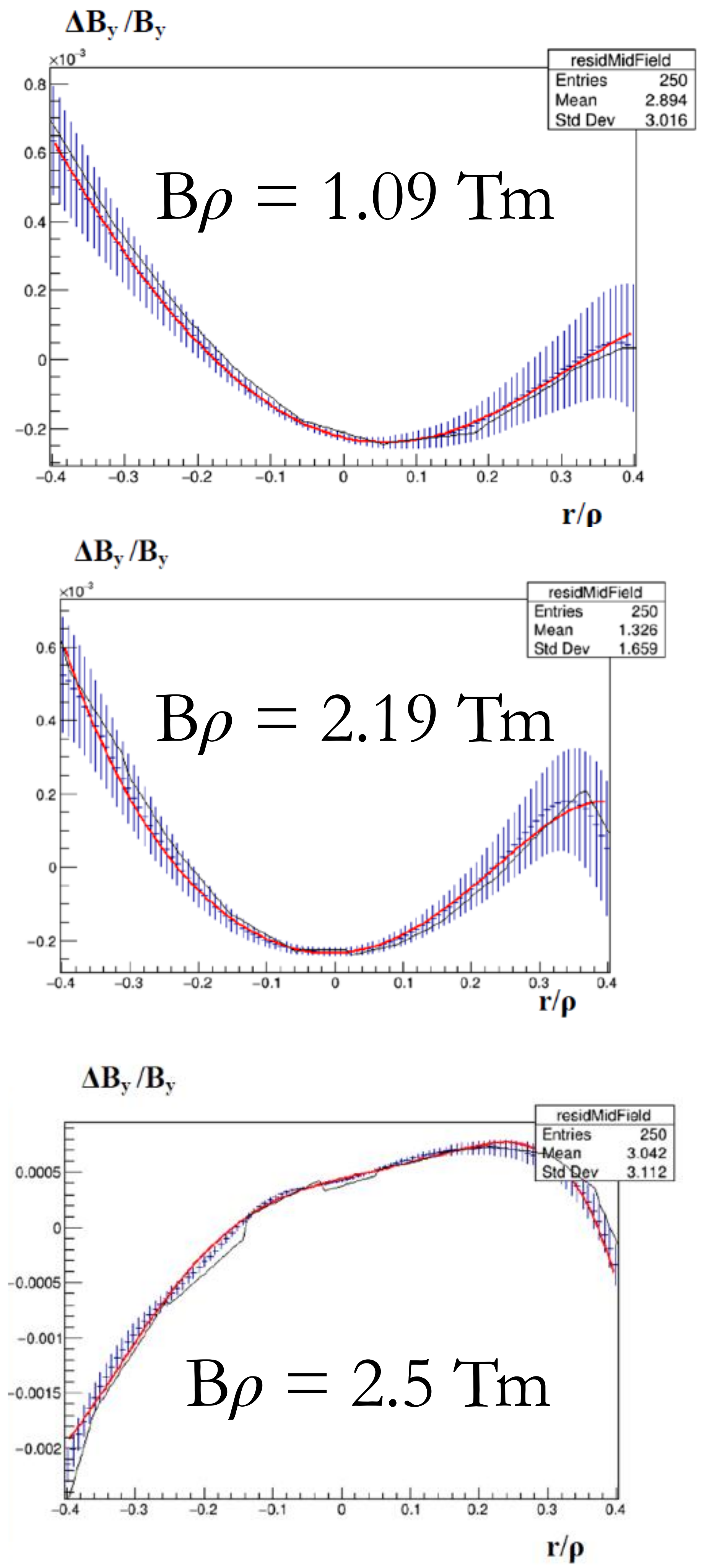


Dipole concept optimizations

- Main parameters
  - Bending angle: 70°
  - Bending radius: 1.25 m
  - Edge angles: 22.5°
  - Gap: 40 cm
  - Maximum field: 2 Tesla
  - Weight: 223 tons
- Pentagonal pyramidal internal void
  - Optimized to maintain more uniform field across radius for different fields
  - Field boundary shifts with magnetic field strength require tunable elements



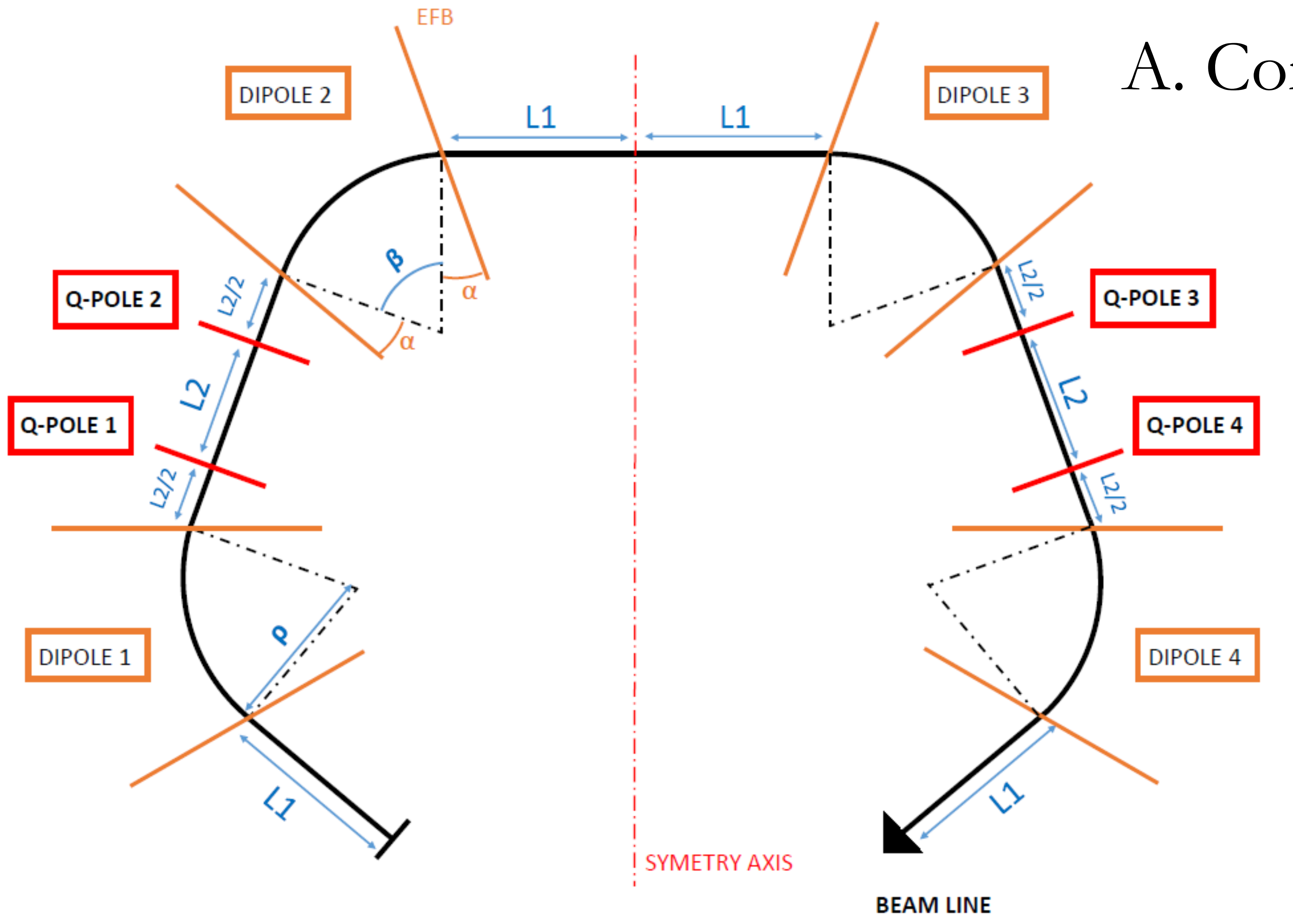
A. Comsa



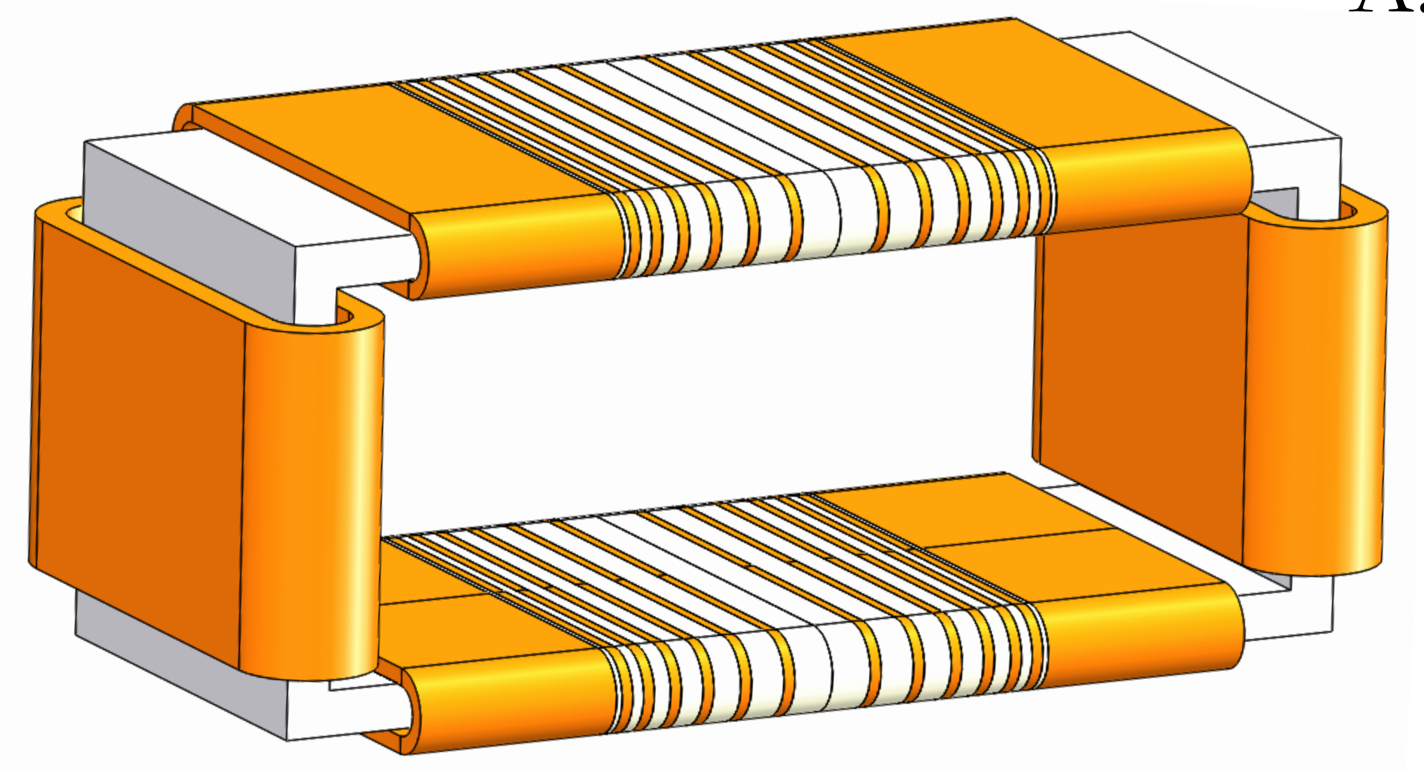
Tunable multipole elements

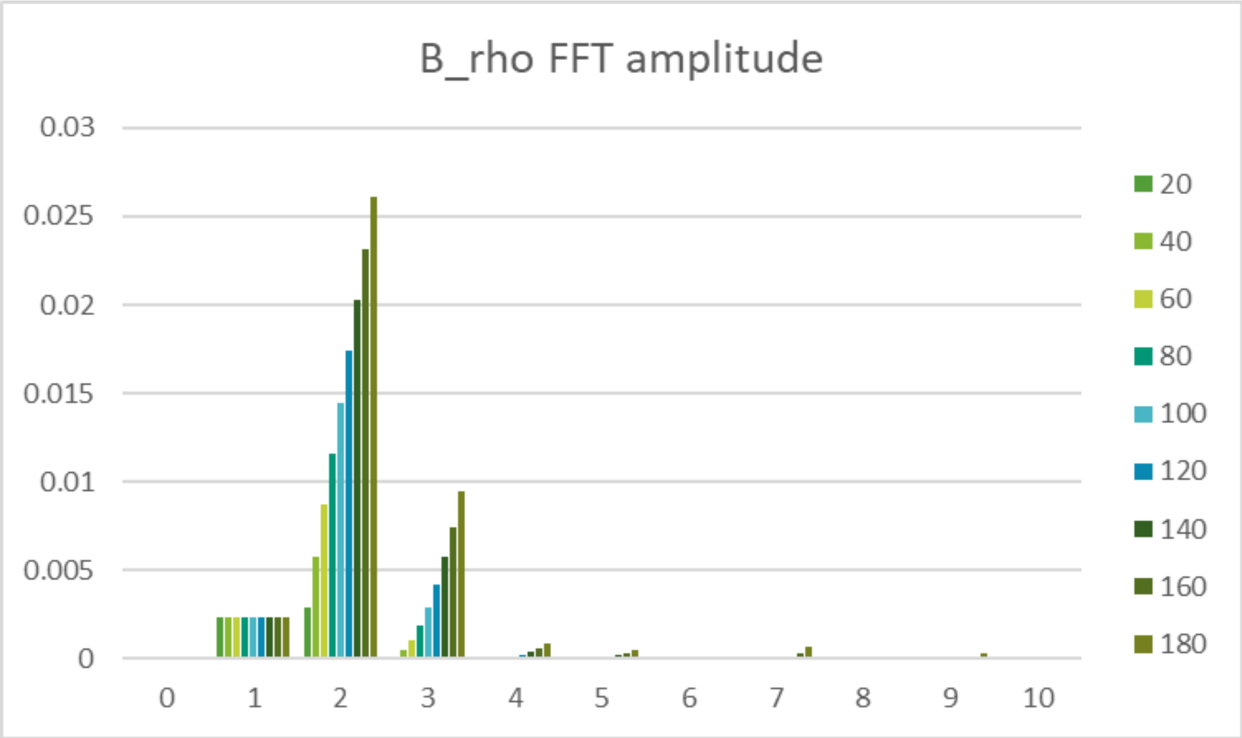
- Necessary to adjust focusing and isochronocity as a function of magnetic rigidity
- COSY infinity study: 4 multipoles needed with maximum gradient of ~ 4.10^3 Gauss/m
- Panofsky design retained
  - Rectangular shape well adapted to ISLA geometrical acceptance
  - Sufficient strength for room temperature operation
  - Quadrupole and Sextupole components with a small constant dipole

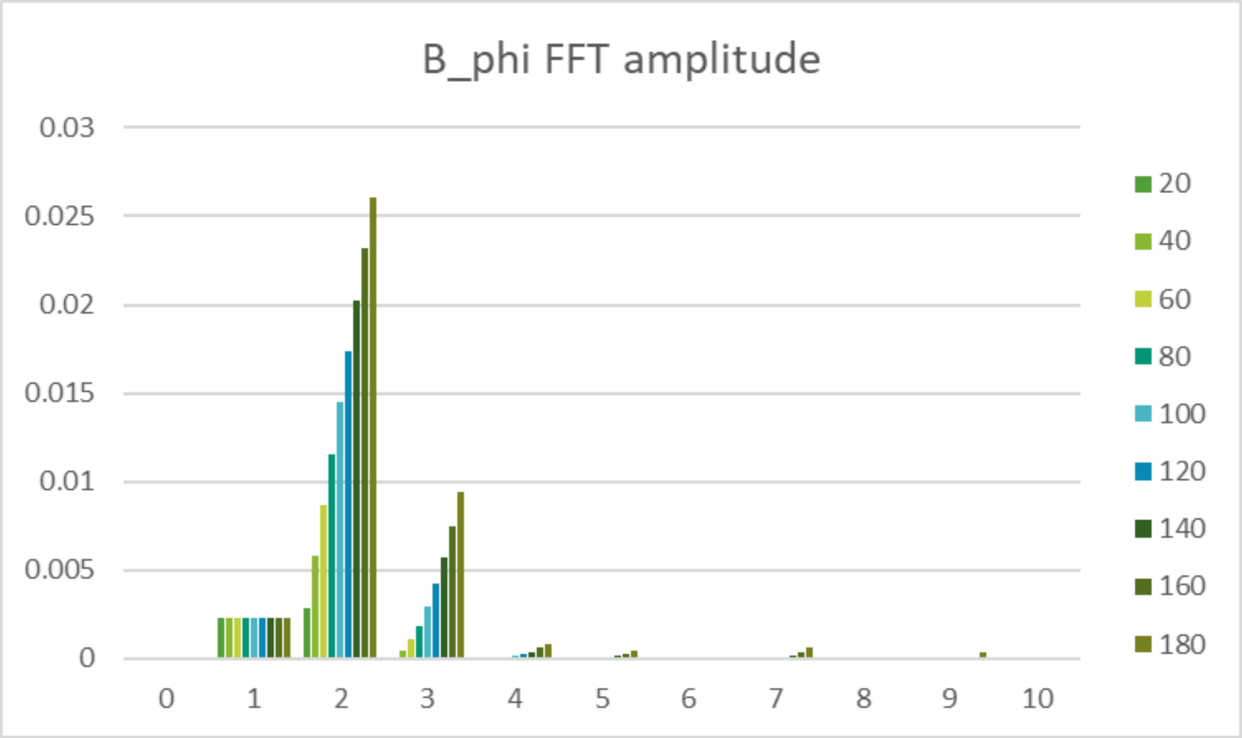
A. Comsa



A. Olive





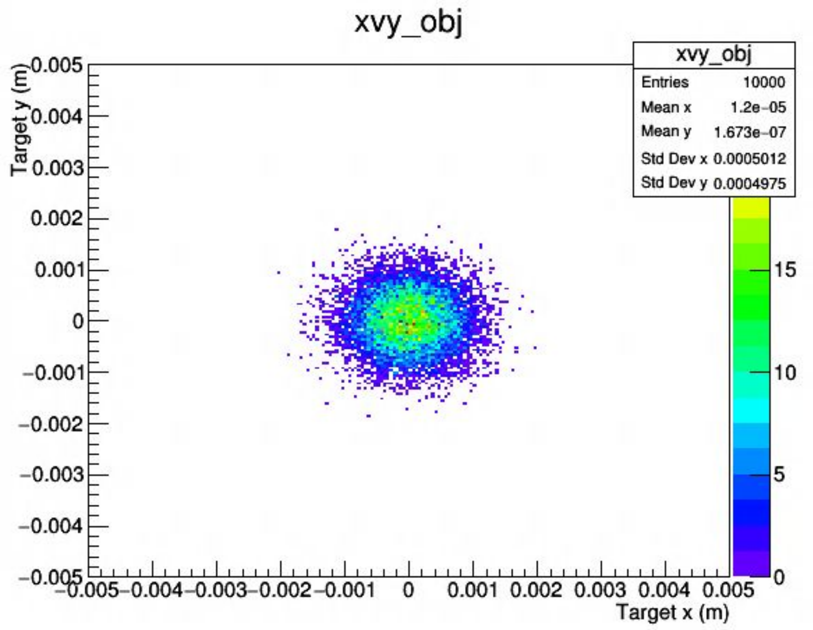


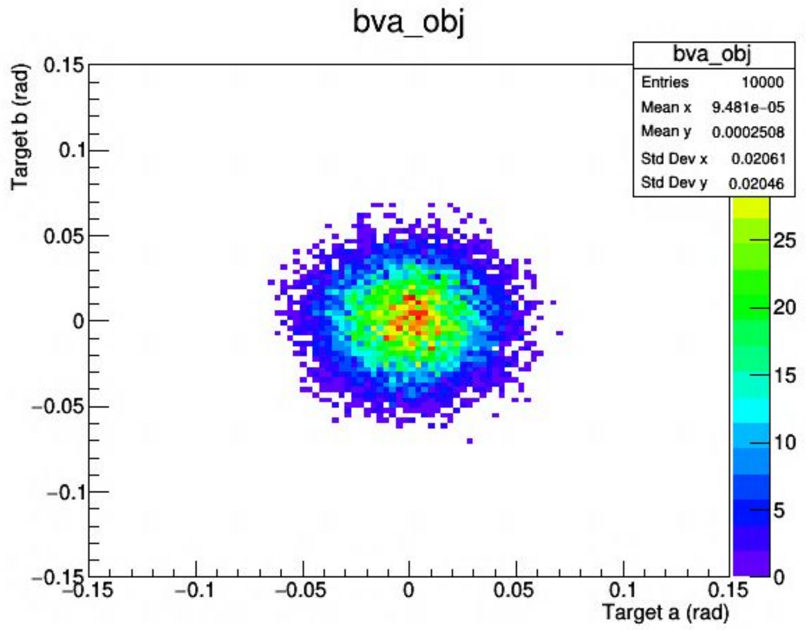
Optical studies

- Design goals
  - Resolving power > 1000
  - Beam spot at final focal plane within 5 cm x 5 cm
- 5th order COSY infinity calculations
  - Field shapes from magnet models (fringe fields)
  - Incoming beam Δt=0 ns, Δx=±.5 mm
  - System apertures included
  - Monte-Carlo input distributions
- Most difficult case: asymmetric fusion
  - 9 charge states transmitted
  - Resolving power around 1000
  - Vertical tails at focal plane due to uncorrected aberrations

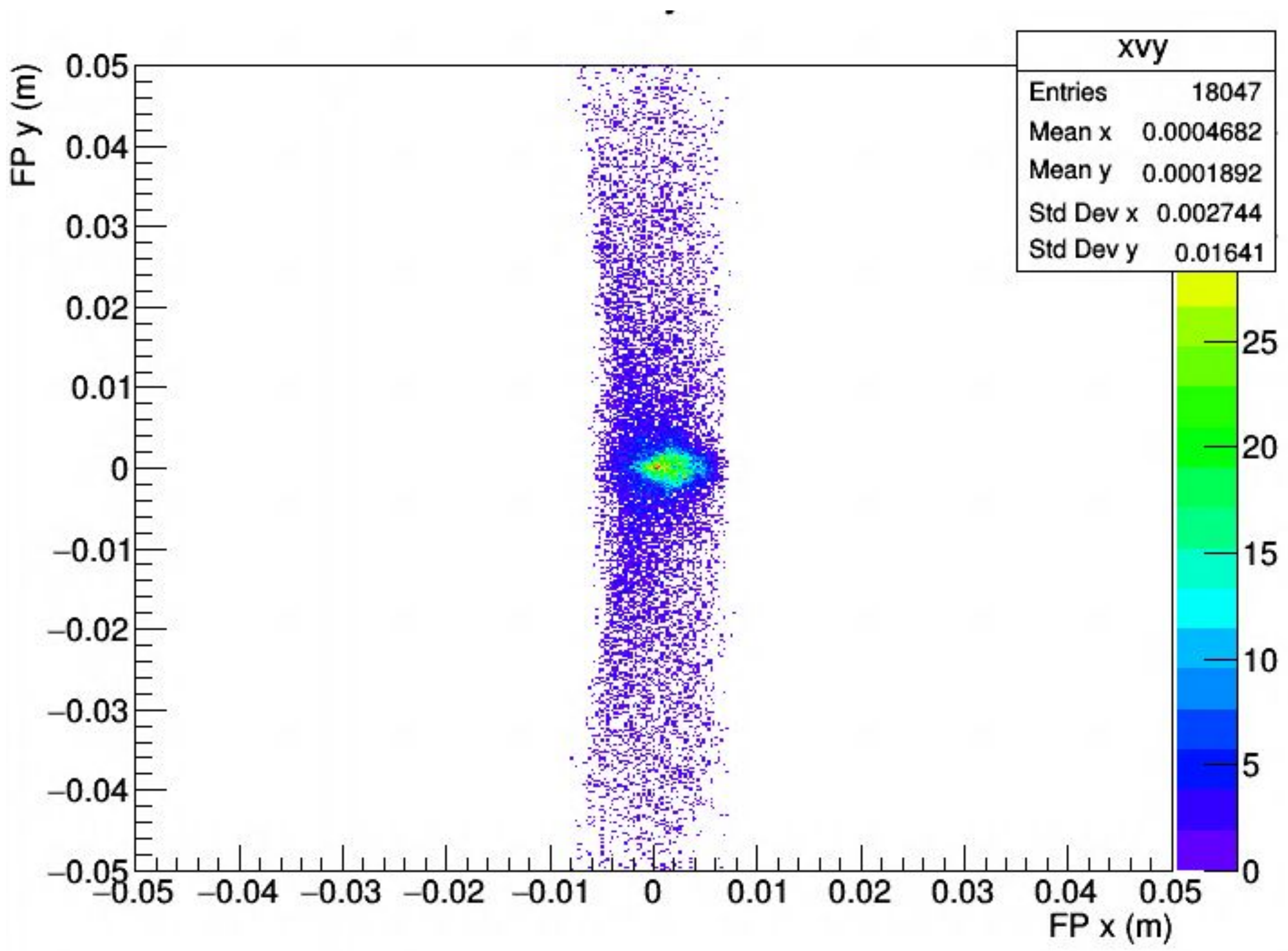
From M. Amthor

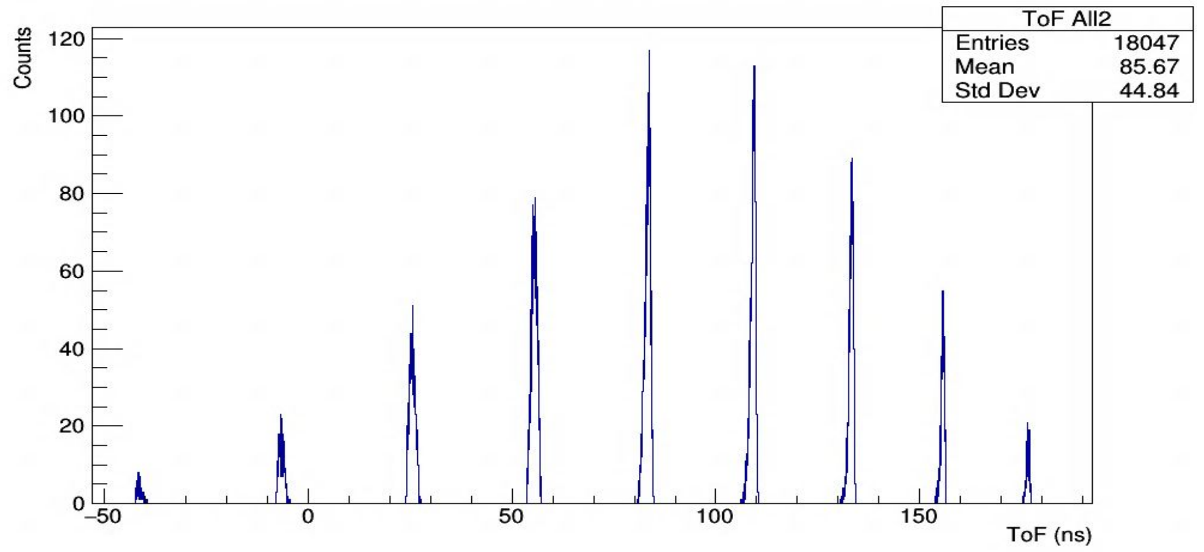
$^{58}\mathrm{Ni} + {}^{46}\mathrm{Ti} \rightarrow {}^{100}\mathrm{Sn} + 4n$

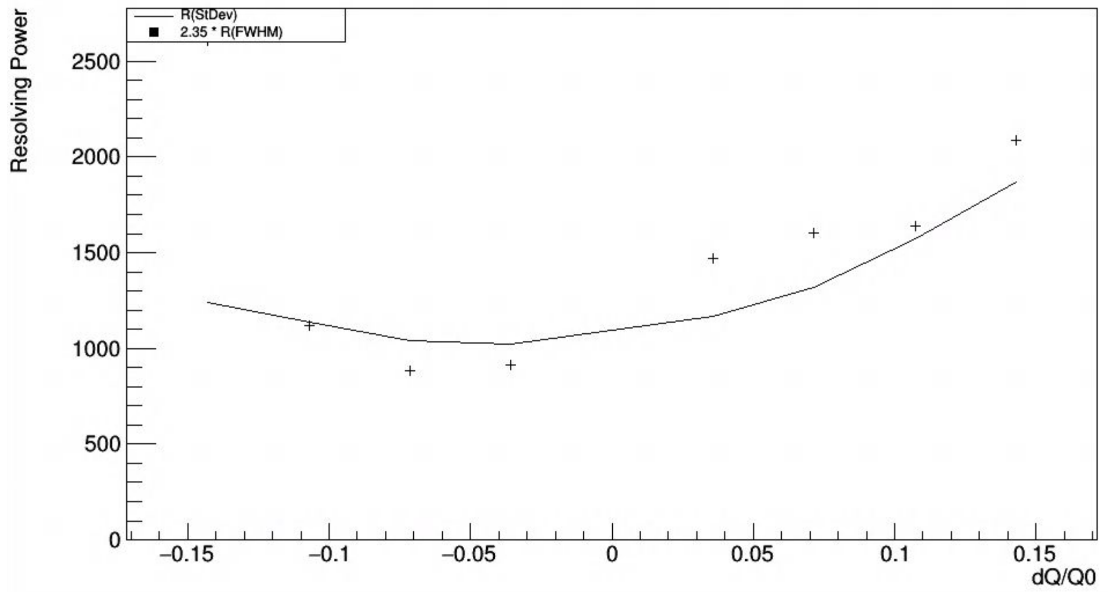




$^{22}\mathrm{Ne} + {}^{238}\mathrm{U} \rightarrow {}^{255}\mathrm{No} + 5n$

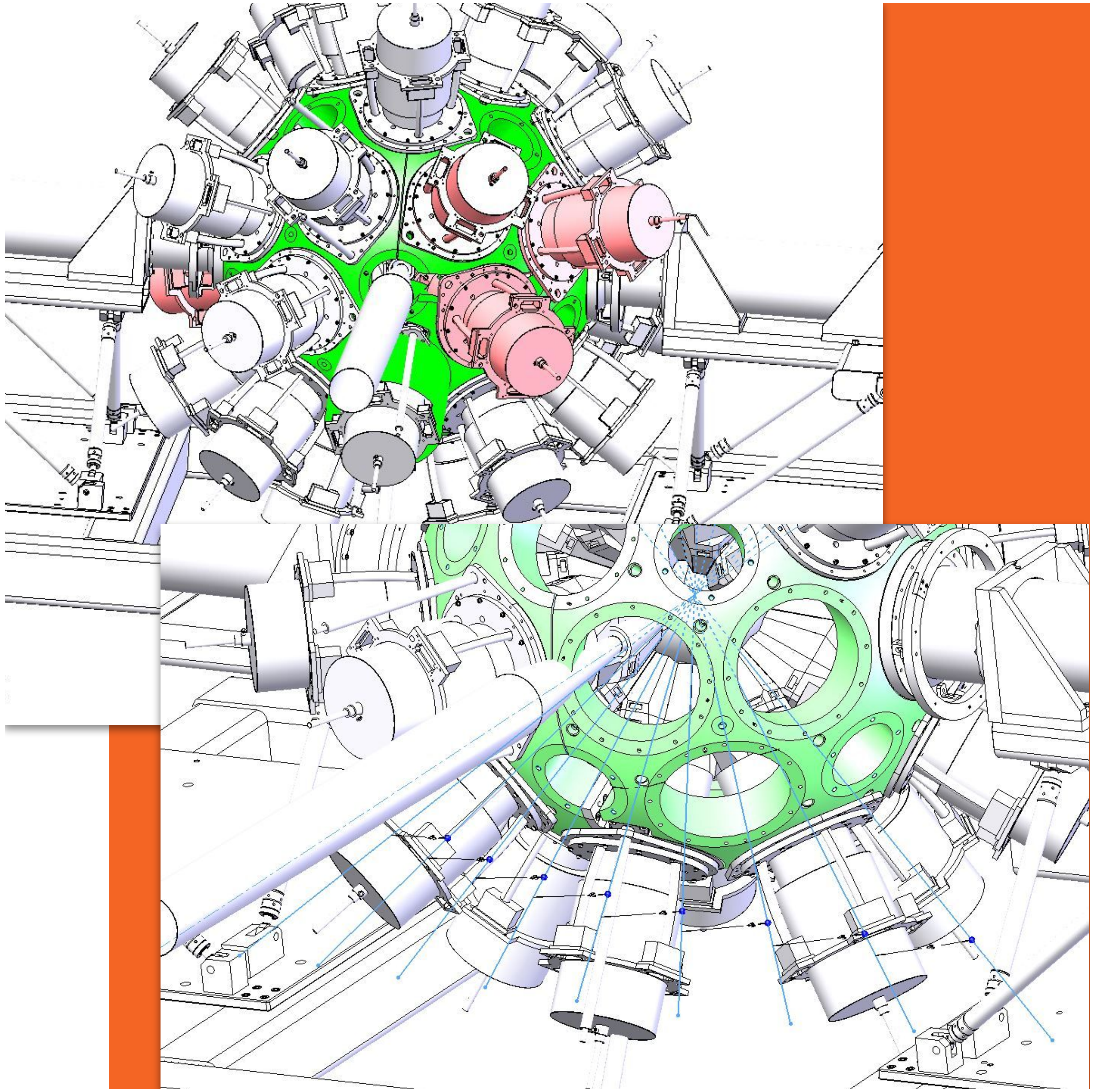






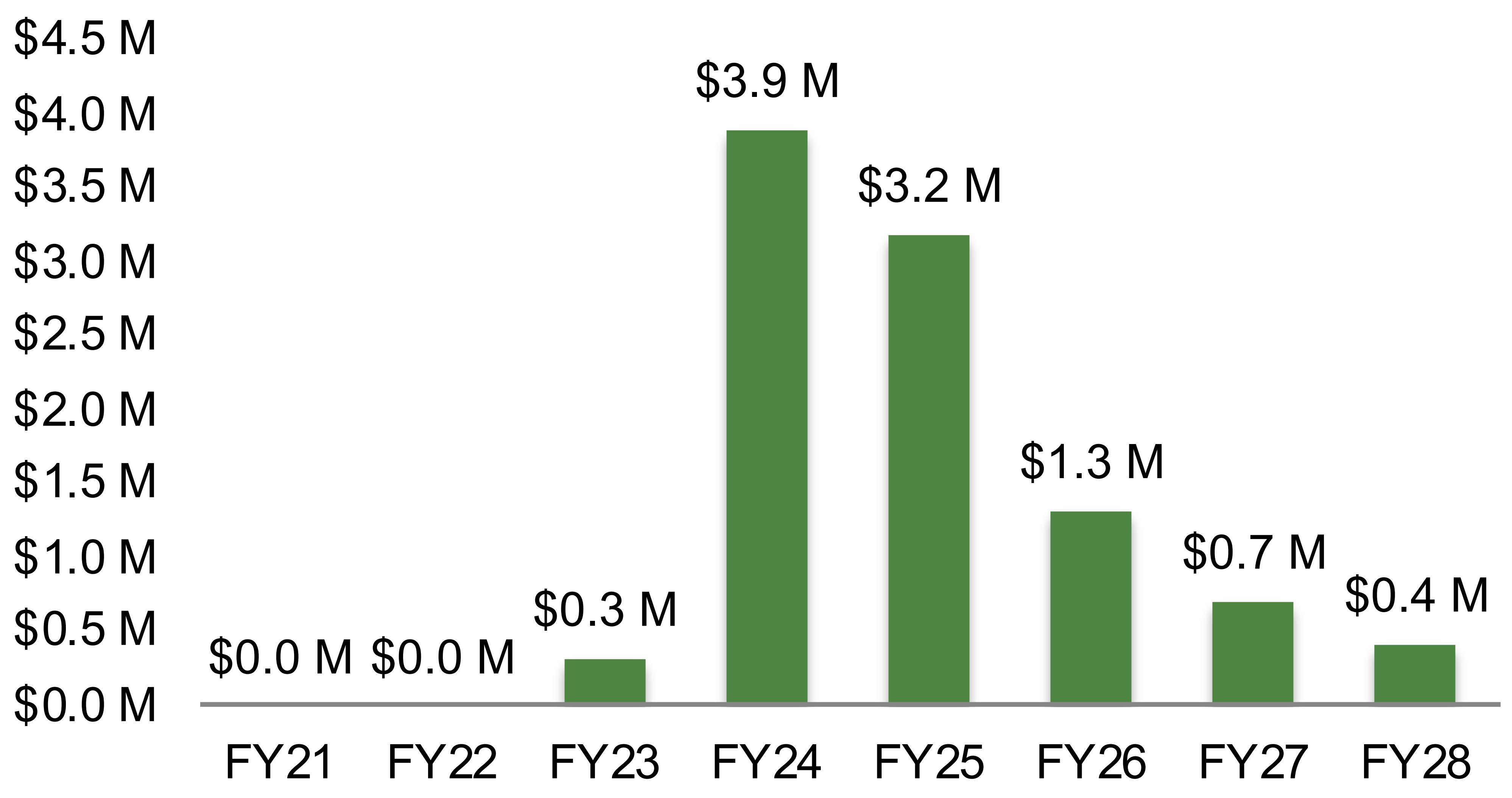
ISLA integration

- Target location
  - GRETA
  - CAESAR
  - SuN
  - HAGRiD
  - ORRUBA
  - LENDA
  - VANDLE
  - Plunger
  - Gas jet
  - Other…?
- Focal plane location
  - TOF, dE, TKE, range
  - Implantation/Decay
  - RF kicker
  - Other…?
- Challenges
  - Off 0° operation
  - Beam stopping
    - Charge states
- ISLA is designed for low intensity beams ($< 10^8$ pps)



Cost and funding opportunity

- Latest FY2022 MSU DOE-NP budget briefing
- Notional TPC of $9.8M
- 30% contingency in TPC
- Proposed project scope
  - 4 large acceptance superconducting dipole magnets
  - 4 Panofsky-type room temperature multipoles
  - Focal plane chamber and detectors
  - Beam swinger and incoming beam line
  - Infrastructure for ancillary detectors at target location
- Present funding opportunity
  - NSF mid-scale RI-1, pre-proposal due Jan 05, 2023



Activity	Forecast Date
Conceptual design complete	FY23
First Dipole Construction Complete and Magnet Test	FY25
Infrastructure and installation complete	FY26
Commissioning	FY28

Acknowledgements

- ISLA leadership team
  - D. Bazin (FRIB/MSU)
  - W. Mittig (FRIB/MSU)
  - M. Amthor (Bucknell University)
  - M. Couder (University Of Notre Dame)
  - A. Villari (FRIB)
  - S. Noji (FRIB)
- Student contributions
  - A. Ringhausen (2017)
  - A. Comsa (2018/2019)
  - C. Grigg (2020)
  - A. Olive (2019/2020)

U.S. Department of Energy Office of Science
National Science Foundation
Michigan State University