Status and plans for recoil separators for experiments with intense stable beams from ATLAS

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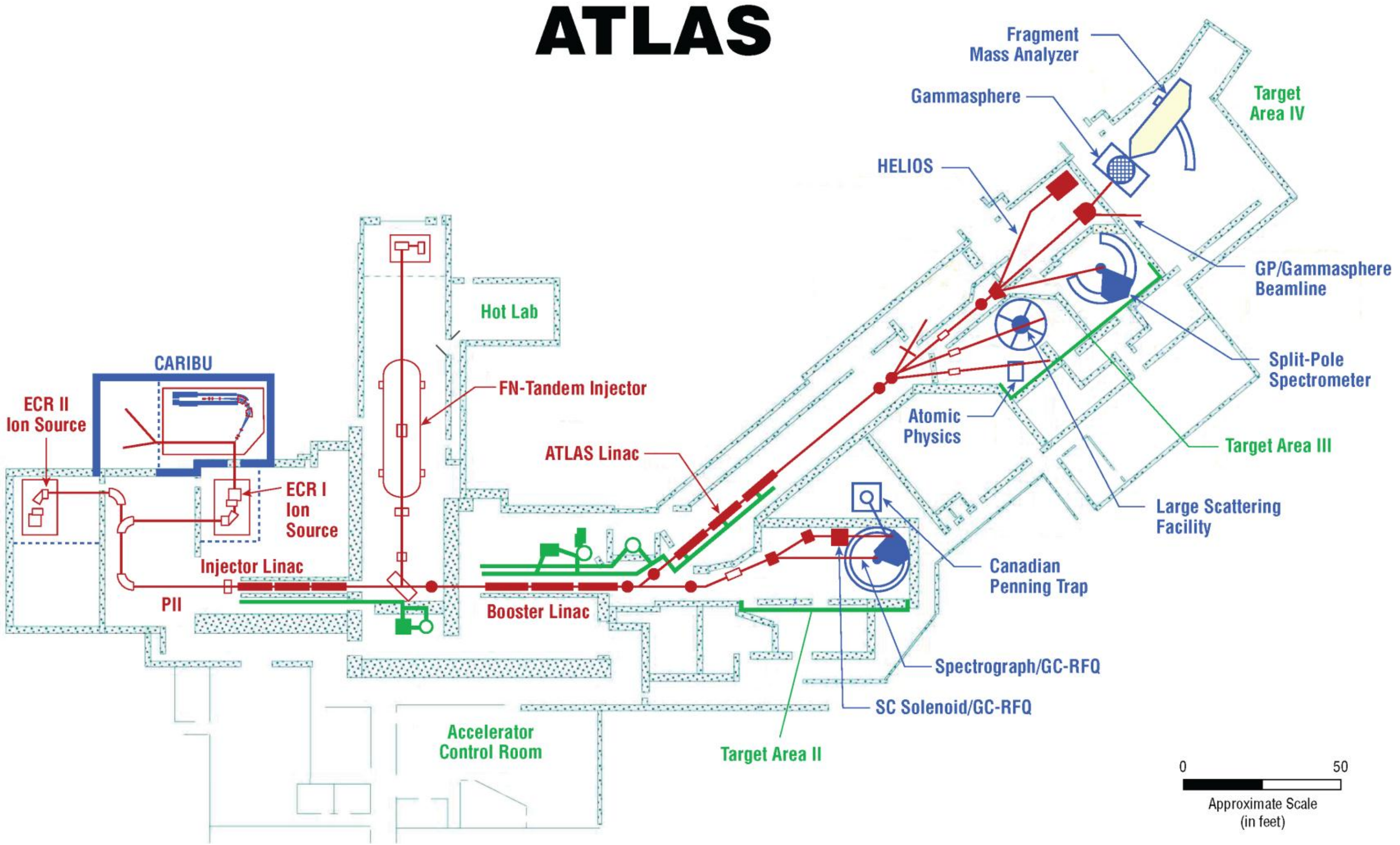
EMIS 2012, December 2-7, 2012

Outline

- ATLAS
- Argonne Fragment Mass Analyzer
- ATLAS upgrade
- FMA upgrades
  - Beam dump
  - New entrance quads
  - MCP
  - 160X160 DSSD
  - Digital DAQ
- Argonne Gas-Filled separator
- SUPERB

Argonne Tandem Linac Accelerator System



Beams from protons to Uranium with energies 10MeV/nucleon+

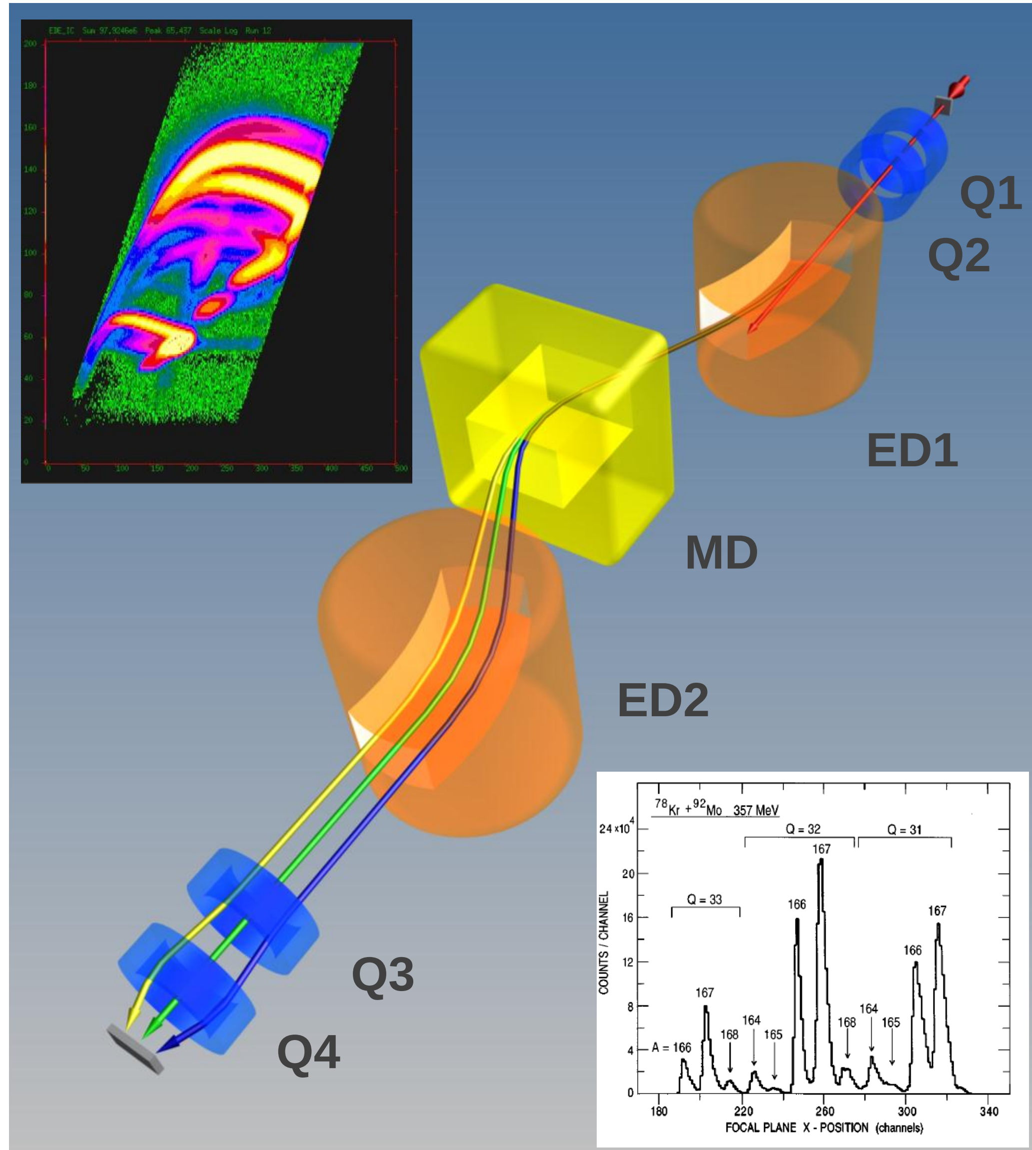
See talk by Richard Pardo on Friday about radioactive beams

Argonne Fragment Mass Analyzer

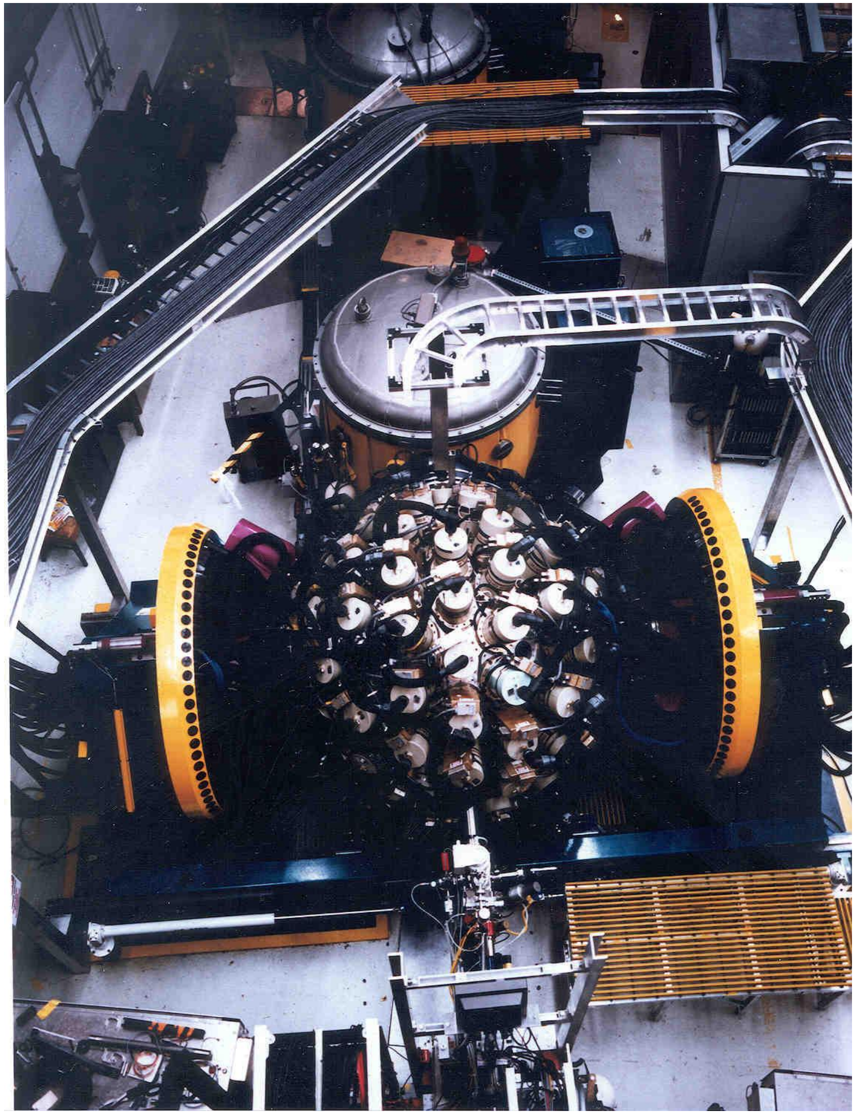
C. N. Davids *et al.*, Nucl. Instr. Meth., B **70**, 358 (1992).

Argonne Fragment Mass Analyzer

Mass resolution:
 $\delta M/M \sim 1/350$
Angular acceptance:
 $\Delta\Omega$=8 msr(2 msr)
Energy acceptance:
 $\Delta\mathcal{E}/\mathcal{E}$=+/-20%
M/Q acceptance:
Δ(M/Q)/(M/Q)=10%
Flight path 8.2m
Max(Bρ)=1.1Tm
Max(Eρ)=20MV
Can be rotated off 0 degrees
Can be moved along the axis
Different focusing modes



GAMMASPHERE+FMA



Important component of the experimental program at ATLAS since its commissioning in 1992 (~200 papers)

- Proton drip-line
  - Proton emitters
  - new α emitters
  - In-beam γ rays
- ^{101}Sn
- Transfermium nuclei: No, Lr, Rf
- Transfer on ^{56}Ni and ^{44}Ti
- …

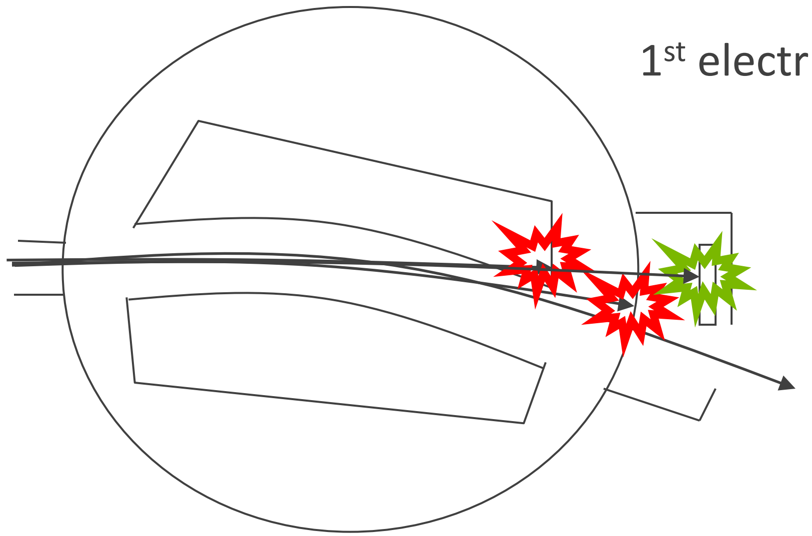
Fusion-evaporation, deep-inelastic, transfer reactions

Preparation for high intensity ATLAS beams

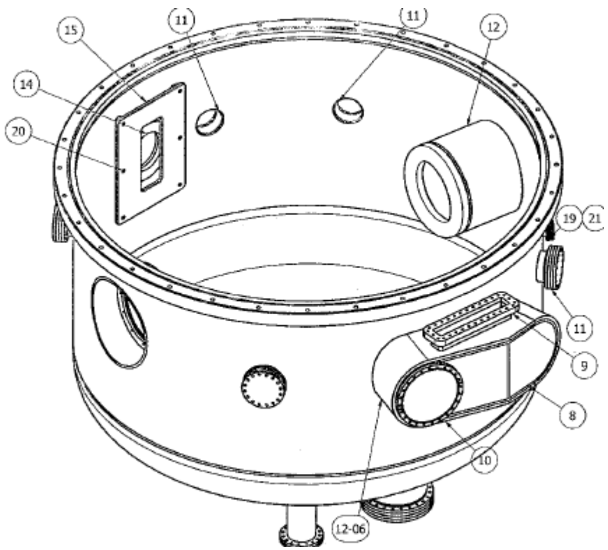
- Undergoing ATLAS efficiency and intensity upgrade to be completed in 2013 will provide ~10x more intense beams (see talk by R. Pardo)
  - New positive ion injector
  - New cryo module to replace some split-ring resonators
- FMA experiments (with heavy nuclei)
  - Current ~10s pnAs (~100s pnA), implantation rates ~several kHz
  - Future ~100 pnAs (~1000s pnA), implantation rates ~several 10s kHz
- Experimental upgrades
  - FMA upgrades
  - Focal plane detector upgrades
  - Argonne Gas-Filled Separator (design)

New beam dump

- First electric dipole limited the beam intensity for certain reactions
- Segmented anode was installed in 2002
- However, beam used to strike the inside of the anode and the tank near the exit relatively close to the anode
- Now the beam leaves the tank through a slit and is stopped in a suppressed Faraday cup outside of the tank

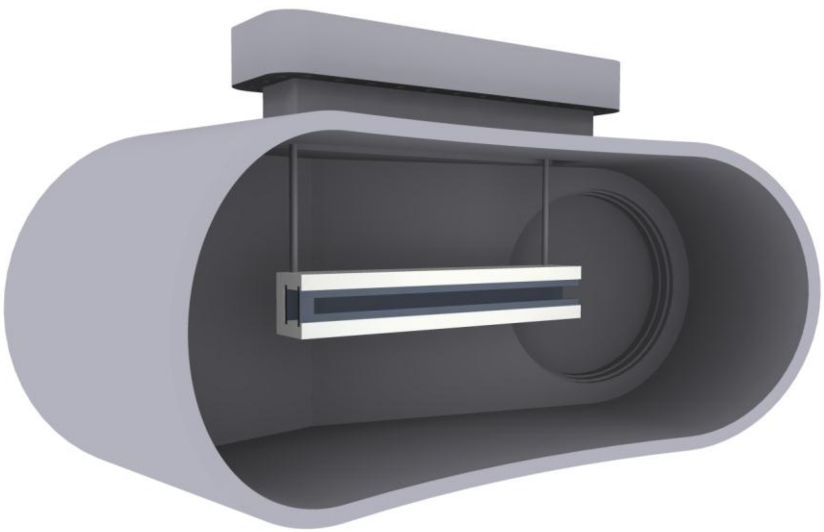


New ED1 tank



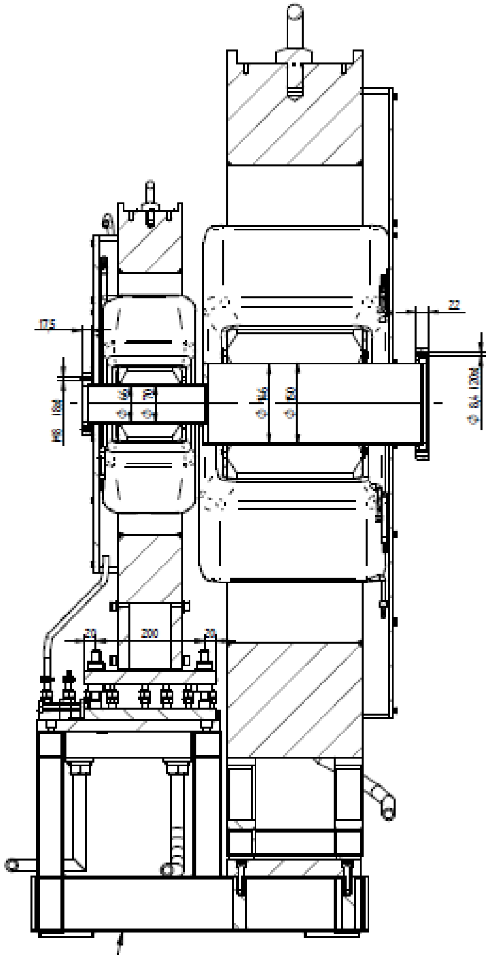
Faraday Cup

- Slit in the tank wall
- Beam dumped on a Ta plate
- Entrance slit kept at positive potential with respect to the Ta plate to suppress electrons knocked out of the plate



New entrance quads

- 1^{st} quad shorter with larger tip field
- similar concept was used in EMMA
- Increases the solid angle from 8 msr to 12 msr at 30 cm between target and FMA
- Only small gain at 90 cm



Courtesy of B. Davids

FMA at 293 mm

OLD:

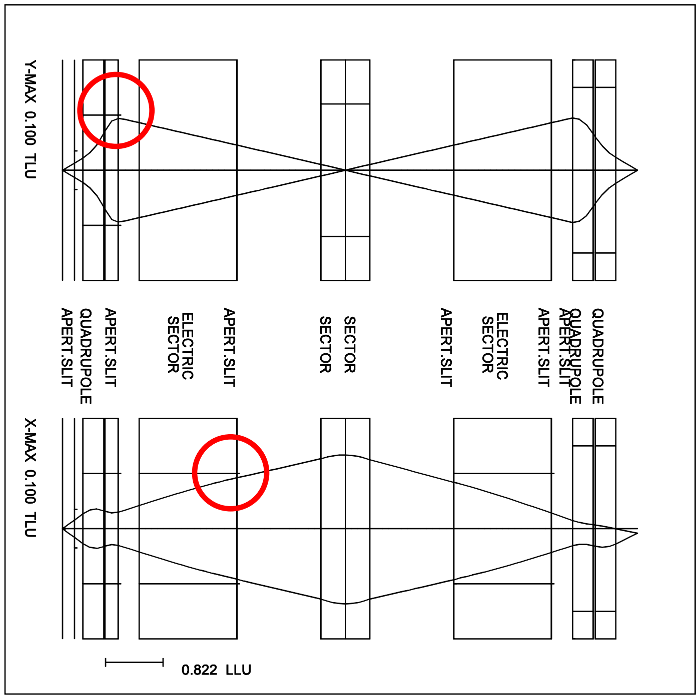
Θ_y=0.038 rad

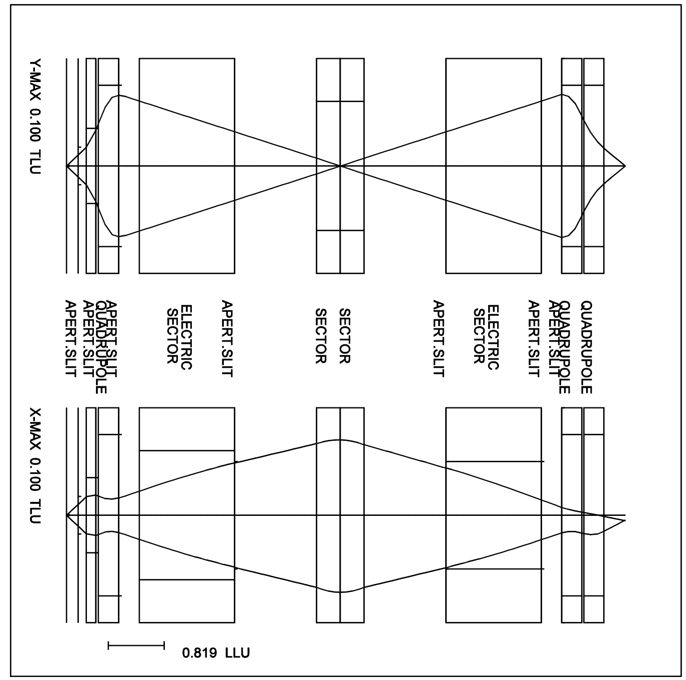
$\Theta_{y,max}$=0.0401 rad

NEW:

Θ_y=0.060 rad

$\Theta_{y,max}$=0.0634 rad





Q_x=0.046 rad

$\Theta_{x,max}$=0.0495 rad

Ω=7.4 msr

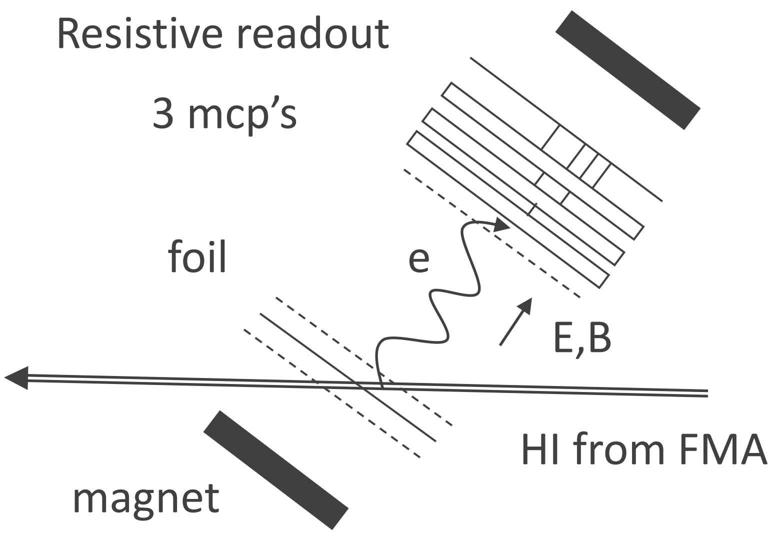
Q_x=0.059 rad

$\Theta_{x,max}$=0.0591 rad

Ω=11.8 msr

Large-area high-resolution micro-channel plate focal plane detector

- Large area to cover the whole focal plane (4X12 cm^2)
- Position resolution < 1mm
- High rate capabilty (100 kHz)
- Three micro channel plates for large multiplication/efficiency

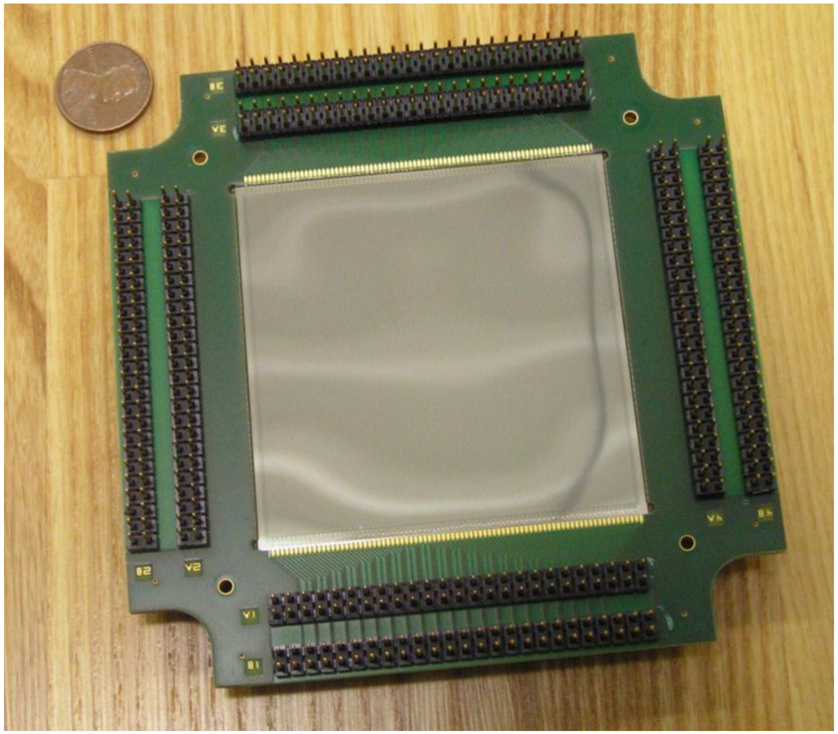


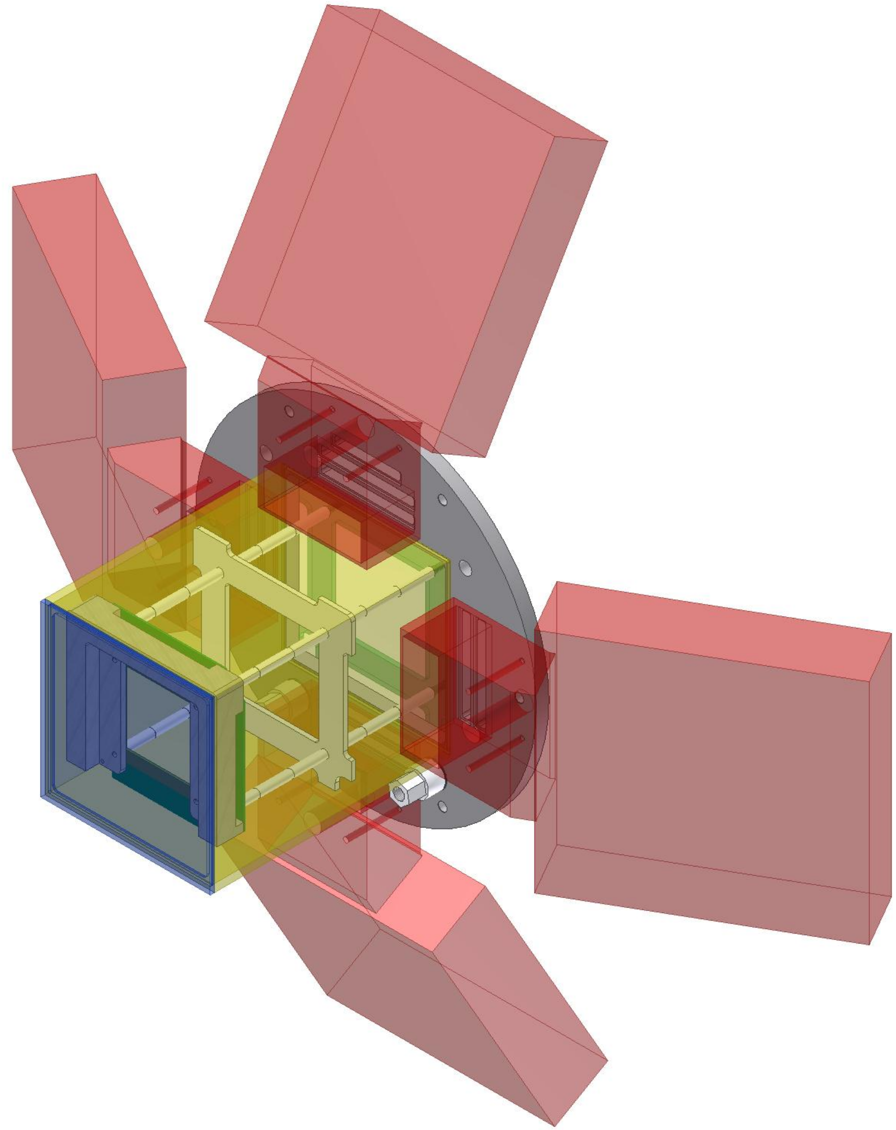
Photonis Inc., USA

Permanent magnets to limit diffusion of electrons to achieve better position resolution

D.Shapira etal., Nucl. Instr. and Meth. in Phys. Res. A 454 (2000) 409

High-granularity implantation-decay DSSD

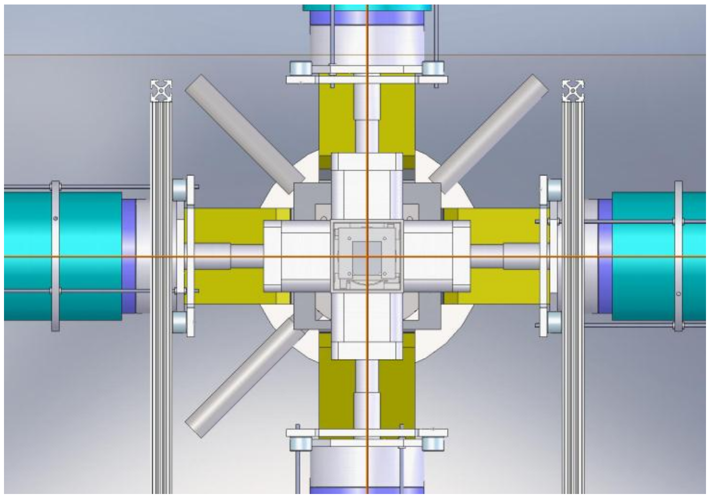


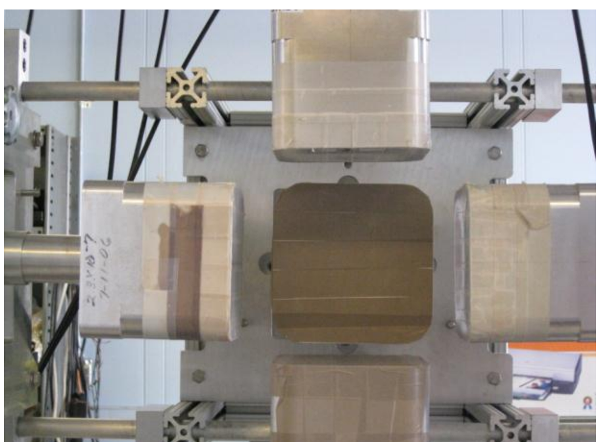


160x160 strips
64mm x 64 mm
100, 140, 1000 μm thick

X-array

- 5 clover detectors in a box geometry
- 64x64 mm, 160x160 DSSD
- Mobile frame



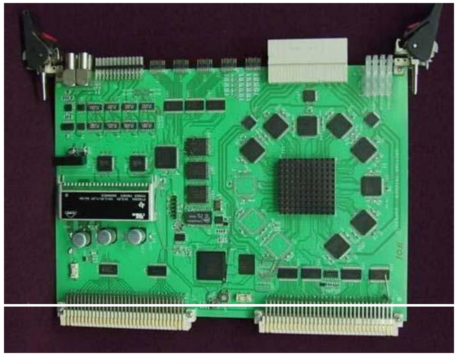


FMA Digital DAQ
(based on GRETINA)

- Trigerless
- DSSD (320 chans)
- X-array (20 chans)
- focal plane (20 chans)
- Resolution comparable to analog (Ge/Si)
- Pulse shape analysis
- 100 kHz/DSSD possible

100MHz, 14-bit Digitizer

M. Cromaz et al., A 597 (2008) 233–237



Trigger and Time control module

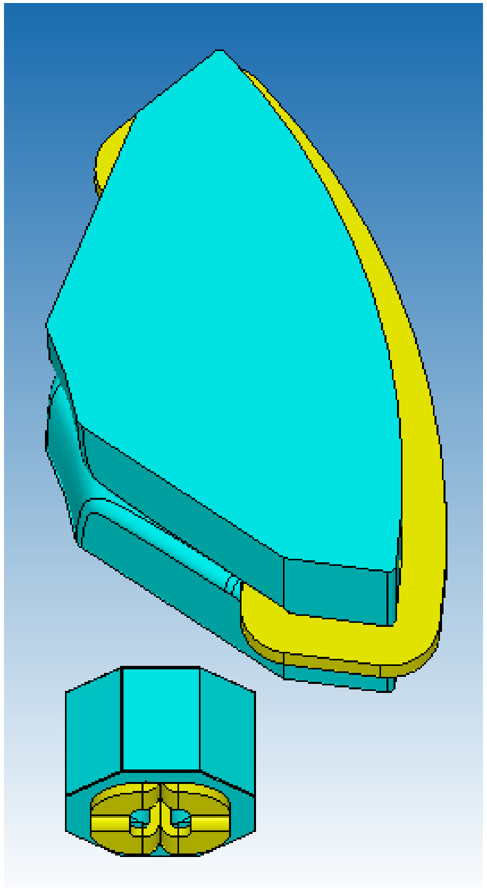
J.T. Anderson et al., 2007, IEEE Nuclear Science Symposium Conference Record, p. 1751

Argonne Gas-Filled Separator - AGFA

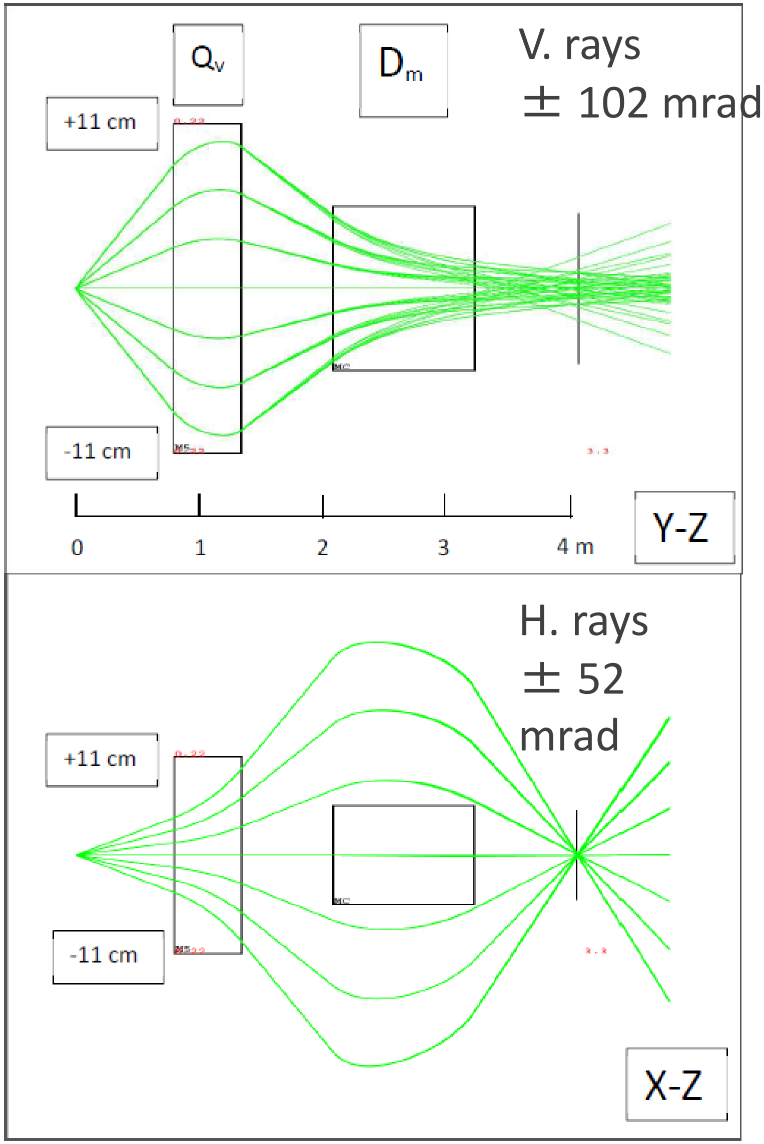
[1]B.B. Back, [1]R.V.F. Janssens, [1]W.F. Henning, [1]T.L. Khoo, [1]J.A. Nolen, [1]D.H. Potterveld, [1]G. Savard, [1]D. Seweryniak, [3]M. Paul, [2]P. Chowdhury, [4]W.B. Walters, [5]P.J. Woods, [6]K. Gregorich

[1]Argonne National Laboratory, Argonne, [2]University of Massachusetts Lowell, [3]Hebrew University,
[4]University of Maryland, [5]University of Edinburgh, [6]Lawrence Berkeley National Laboratory

- Use combined-function magnets
  - Overlapping bending, focusing fields
  - Fewer magnets, ultra compact design
  - Innovative QvDm design
- Design parameters
  - 33° bend
  - 2.5 Tm
  - 4.0 m total length (3.7 m at 40 cm)
  - 80 cm target-separator (Gammasphere) 22.5 msr
  - 40 cm target-separator (stand-alone) 42 masr
  - Compact focal plane(~5cm x 5 cm)

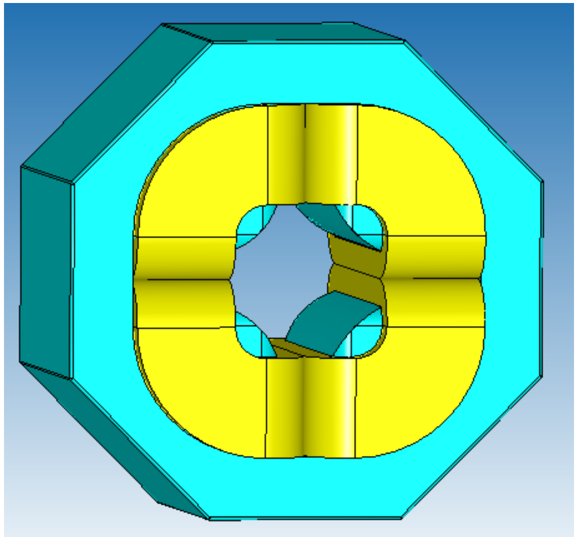


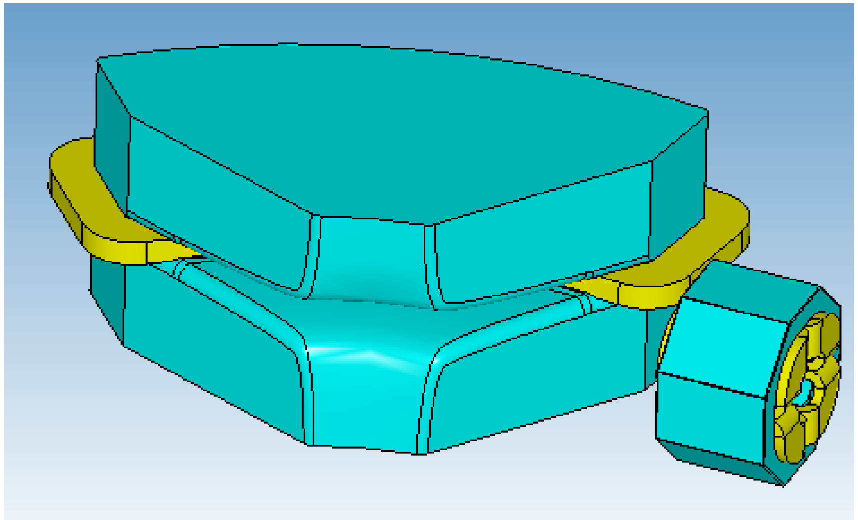
AGFA optics and parameters

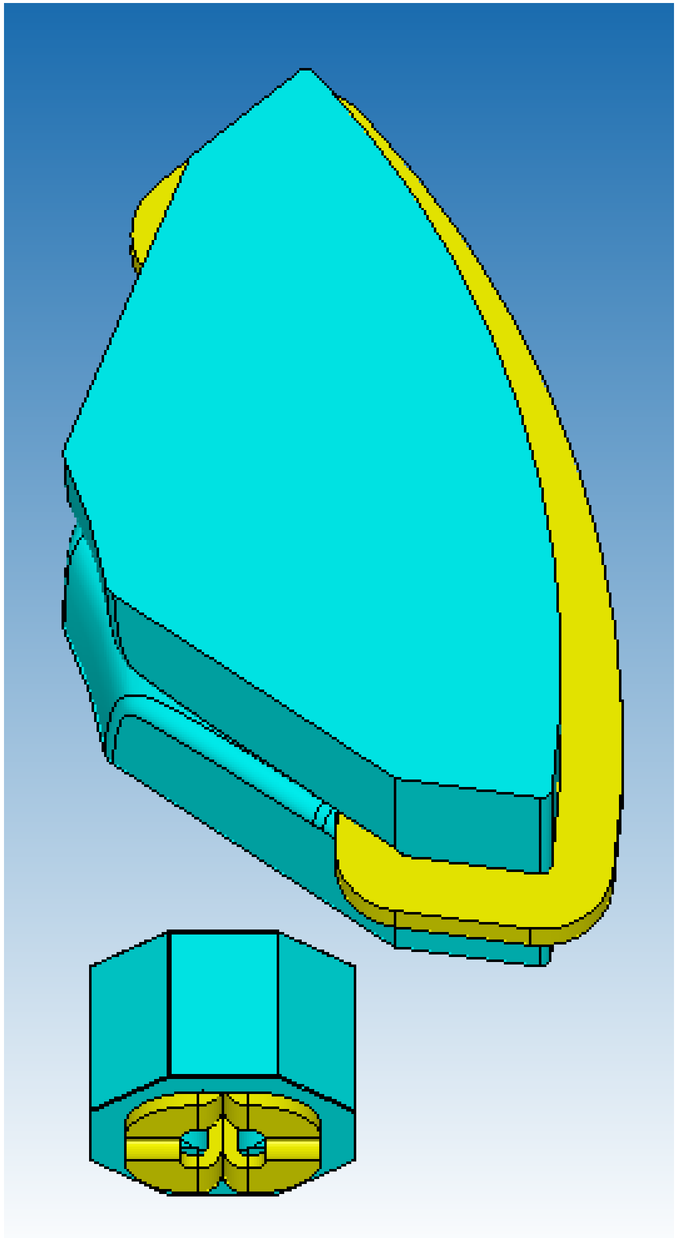


Quad length	48 cm
Quad bore	22 cm
Quad peak pole-tip field	1.24 T (2.5 Tm, 40 cm tgt)
Quad-dipole separation	75 cm
Dipole center gap	11 cm
Dipole bend angle	33 deg
Dipole bend radius	2.0 m
Dipole edge angle	-36 deg
Dipole peak field	1.7 T (2.5 Tm)
Peak X excursion	± 30 cm
Dipole-F.P. separation	92 cm (40 cm to tgt), 83 cm (80 cm to tgt)
Beam profile at target	ΔX = 5.0 mm FWHM ΔY = 2.0 mm FWHM

AGFA – 3D magnet design





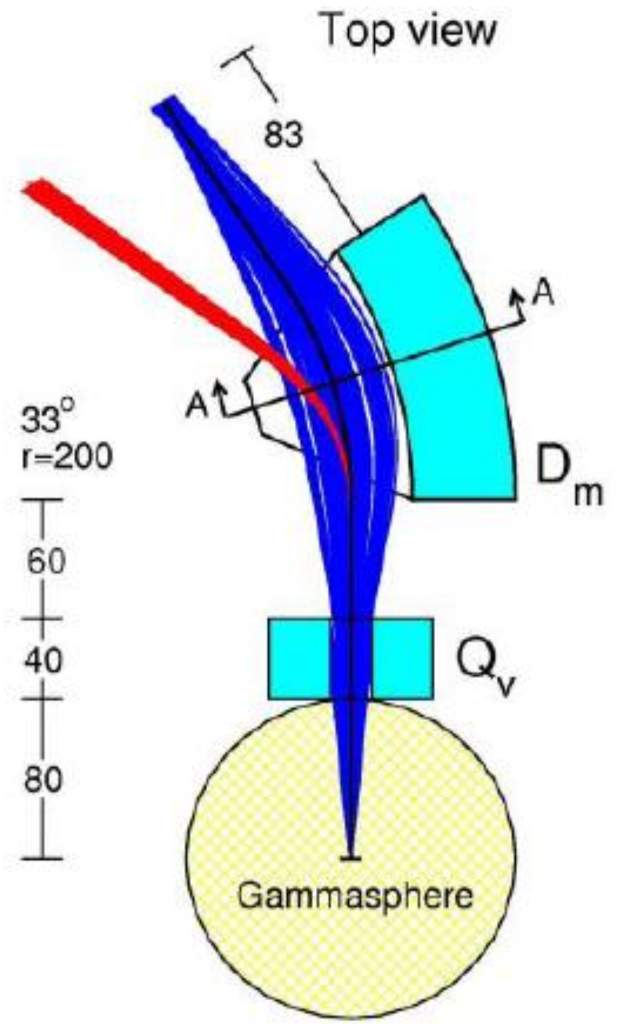


^{254}No test case

$^{48}Ca + ^{208}Pb \rightarrow ^{254}No + 2n$

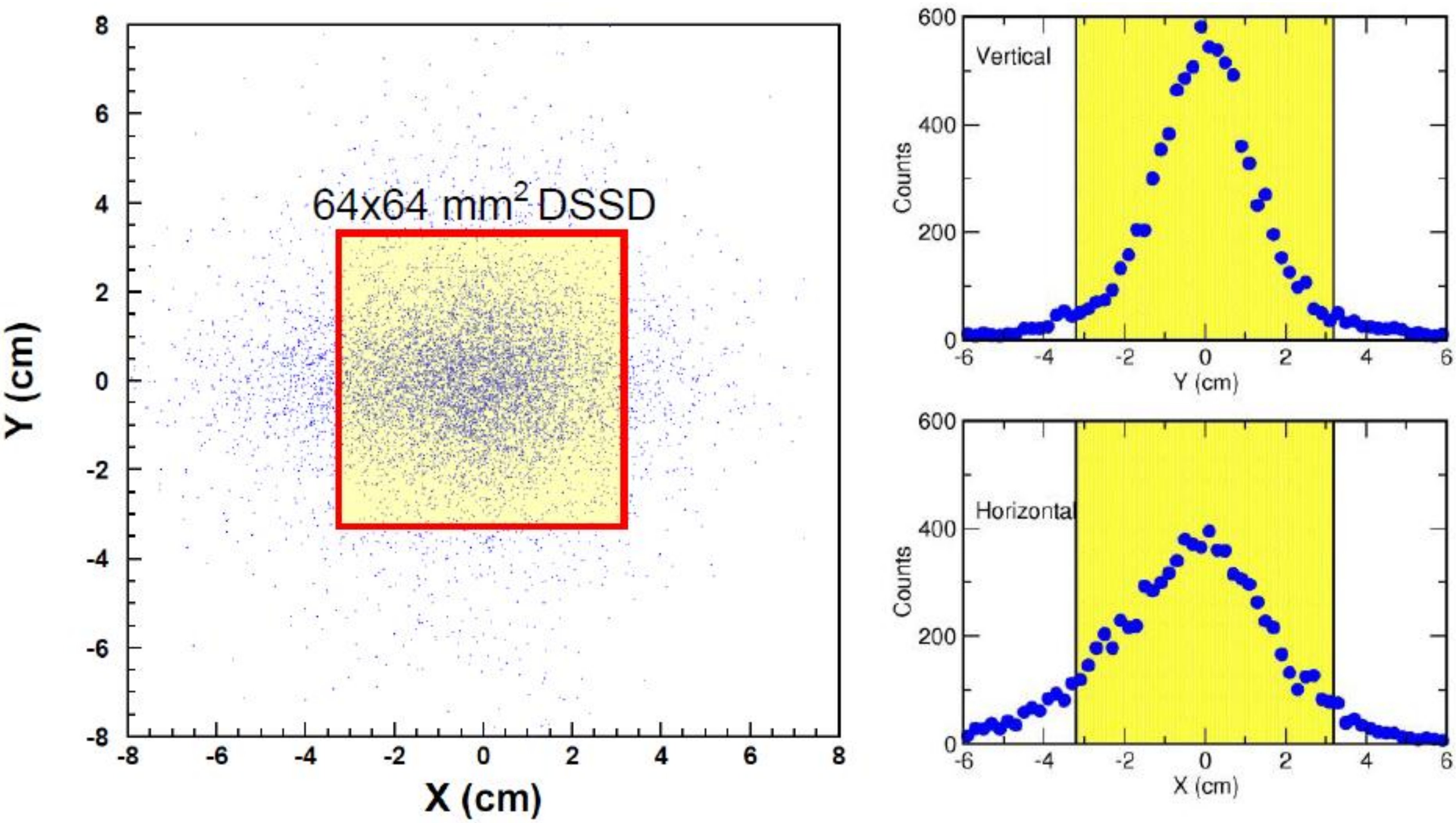
$E_{beam} = 220$ MeV

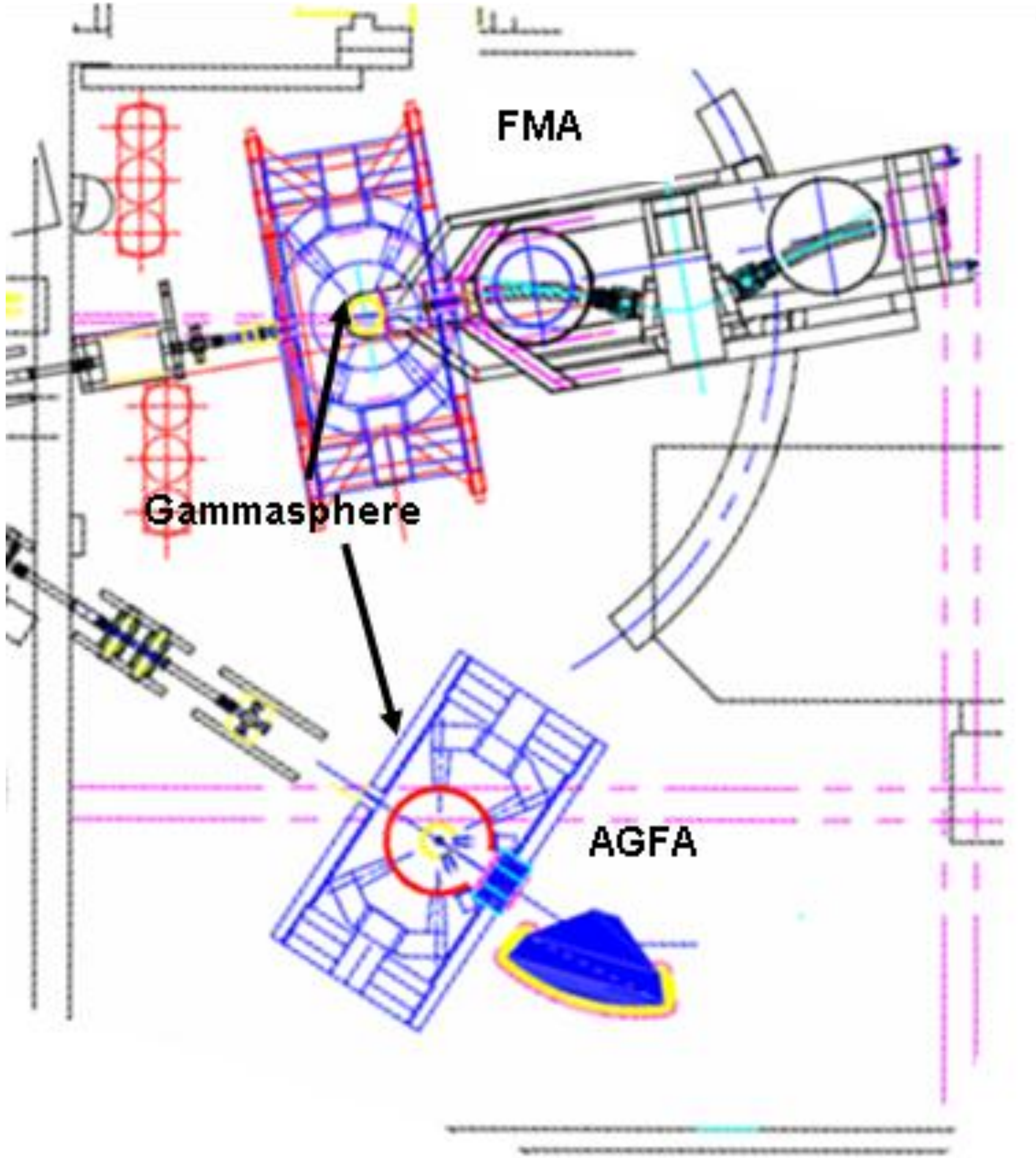
- 1 Torr He, 5 x 2 mm beam spot
- ^{254}No angular distr: Gaussian, $\sigma = 51$ mrad
- ^{48}Ca stripped, (C foil) $q_{bar} = 17.1$
- 89% of ^{254}No transported to focal plane
- 71% fall within a 64 x 64 mm^2 DSSD
- Solid angle to DSSD is 22 msr
- Beam is well separated



Simulations still undergoing

Focal plane distribution

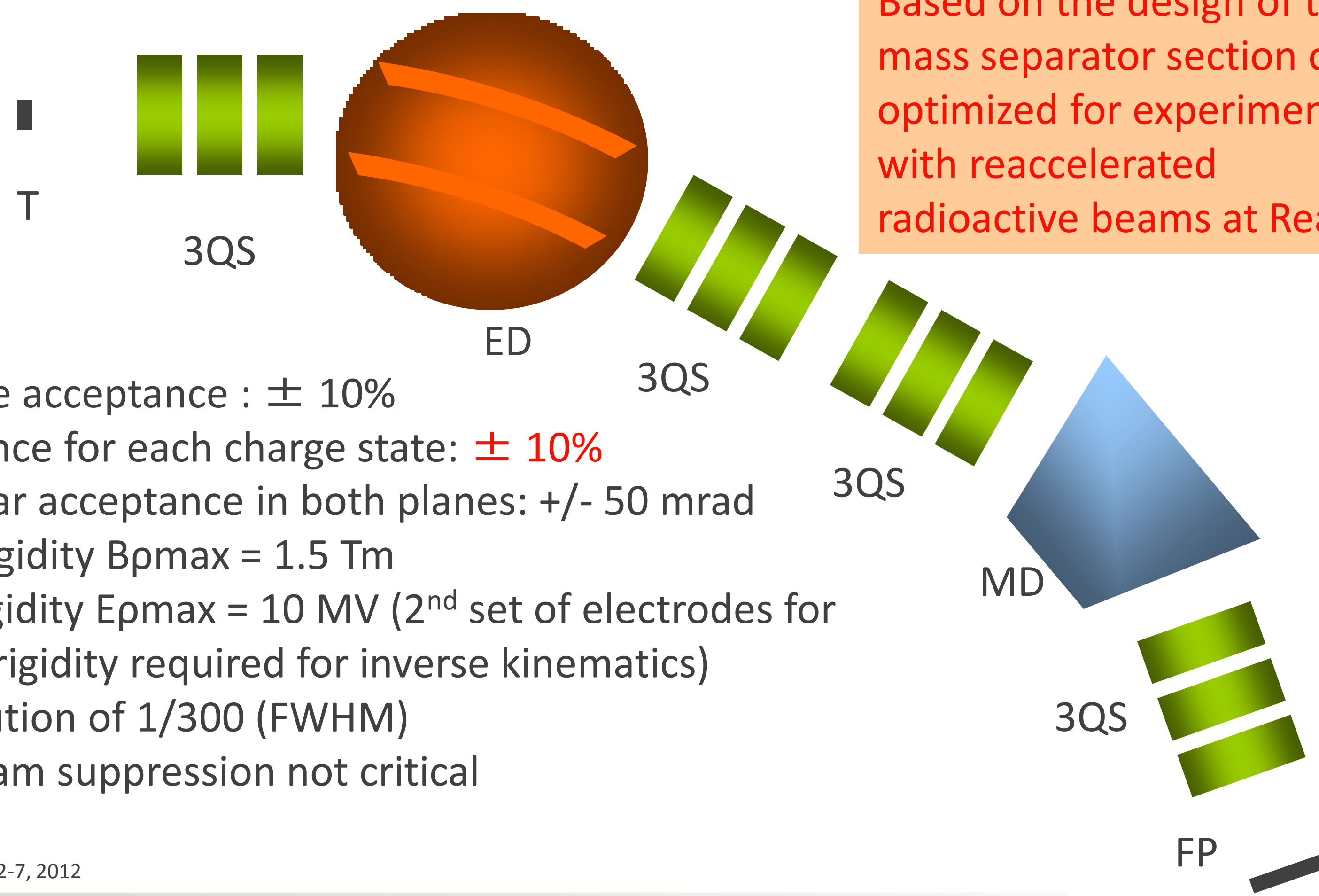



FMA
Gammasphere
AGFA

Separator for Unique Products of Experiments with Radioactive Beams - SUPERB

A.M. Amthor[1], A. Drouart[2], S. Manikonda[3], J. Nolen[3], H. Savajols[4], D. Seweryniak[3]
[1]Bucknell University, [2]CEA-DSM/Irfu/SPhN, [3]Argonne National Laboratory, [4]GANIL

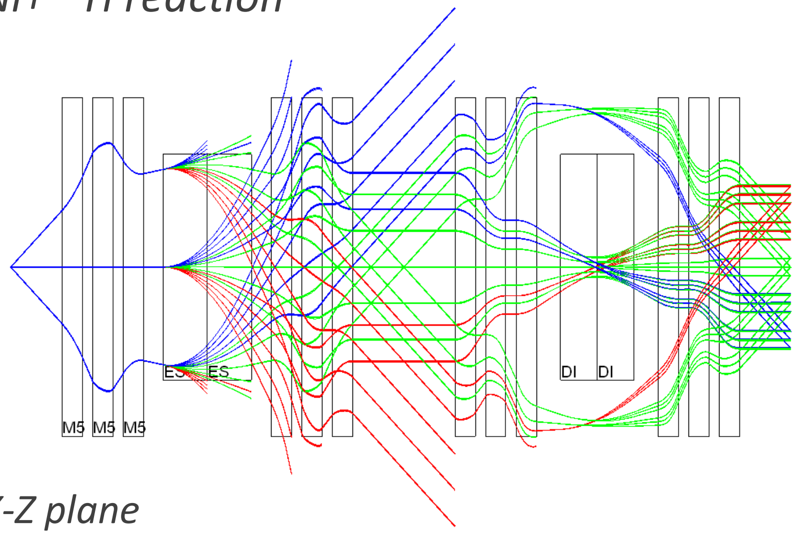
Based on the design of the mass separator section of S^3 optimized for experiments with reaccelerated radioactive beams at Rea12



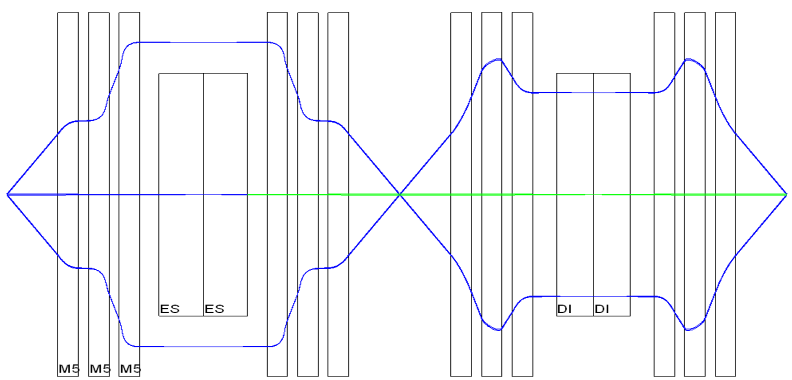
- A charge state acceptance : ± 10%
- A Bρ acceptance for each charge state: ± 10%
- A large angular acceptance in both planes: +/- 50 mrad
- A magnetic rigidity Bρmax = 1.5 Tm
- An electric rigidity Eρmax = 10 MV (2nd set of electrodes for higher electric rigidity required for inverse kinematics)
- A mass resolution of 1/300 (FWHM)
- A primary beam suppression not critical

SUPERB – 1st order calculations

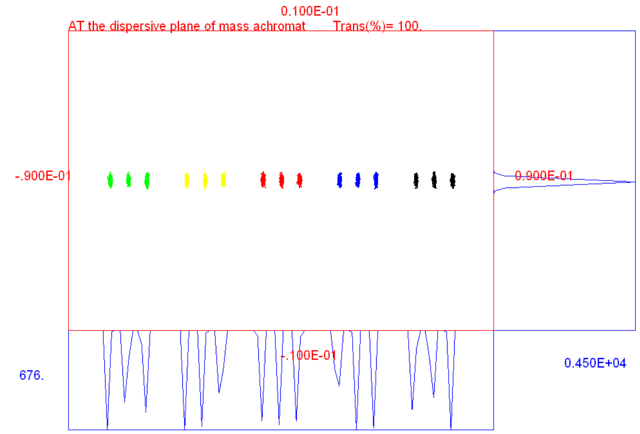
$^{58}Ni+^{46}Ti$ reaction



X-Z plane



Y-Z plane



X-Y distribution at the focal plane for 5 charge states/3 masses

Easier than S^3 because of small beam spot (~1 mm dia)

Conclusions

- FMA is almost ready to accept high-intensity beams from ATLAS
- AGFA will complement FMA for experiments with heavy nuclei
- SUPERB combines advantages of FMA and AGFA for experiments with reaccelerated radioactive beams

Thank you
for your attention!