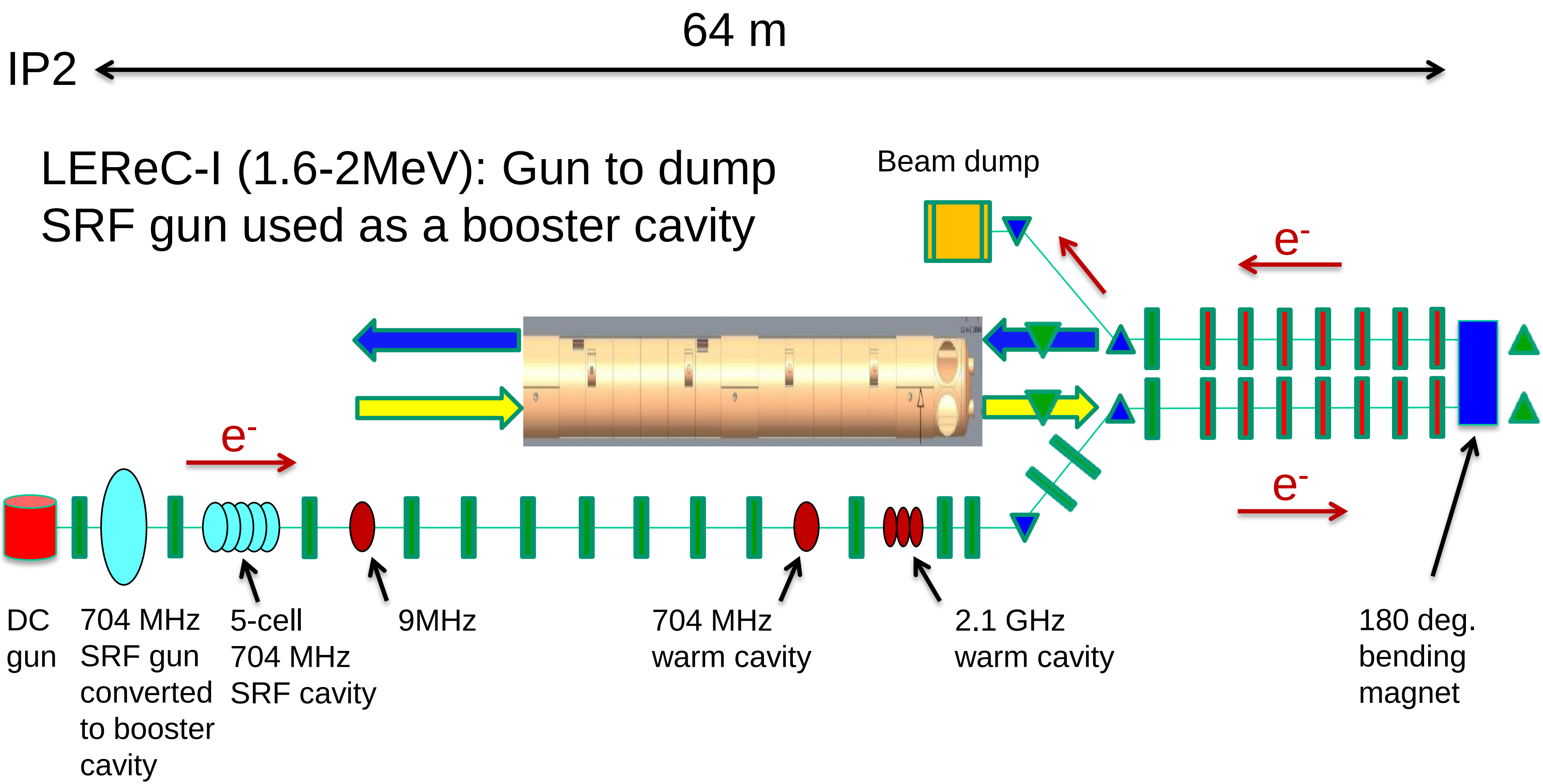
LEReC-I (1.6-2MeV): Gun to dump

SRF gun used as a booster cavity



20 & 180º Dipole

- Prior to ordering magnets, document the design basis for the magnets (Physics design review or defined and doucmented in White Paper).
- Vacuum chamber/bellows designs to be reviewed by Mike Blaskiewicz.
- Design magnet and stand to enable splitting for baking out. (Note: chambers to remain stationary when iron yoke is moved away.)

Beam Line

- Bellows for Recombination Monitor: Due to the low likelihood, proceed with the design of a bellows without adaptations to scintillator elements.
- Vacuum isolation of Cooling Section: 2 large valves near 180° dipole and 2 small valves in transport line entering/exiting section. **Requisition approved.**

Other Instrumentation:

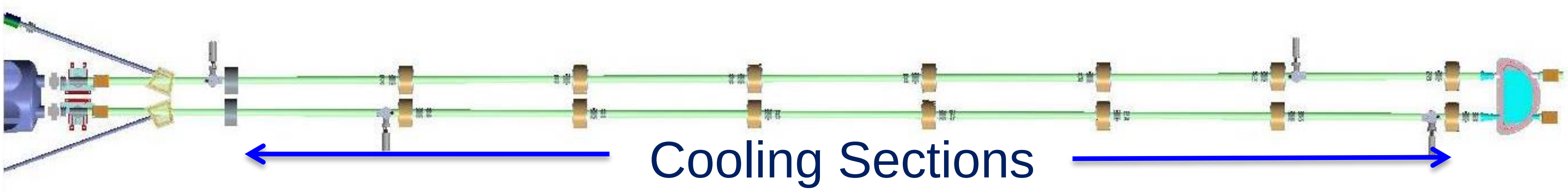
- Toby M. working with Peter T. and Gary W. on concept for slits
- Quotation on BPM from MPF in process (Dave G)

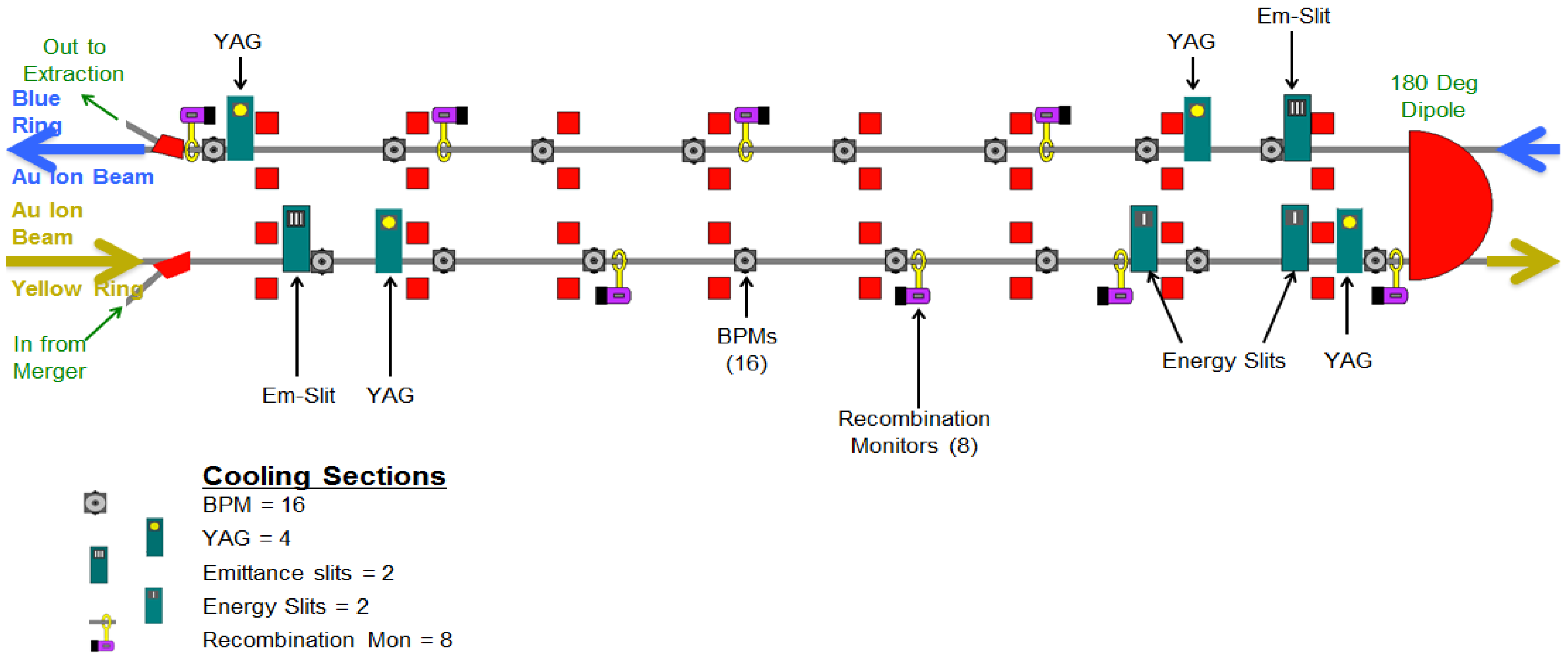
Other:

- Design of the 2.1 GHz cavity underway

Magnet Lattice Physics Review

Beam Instrumentation Meetings on Thursday 3:00 PM

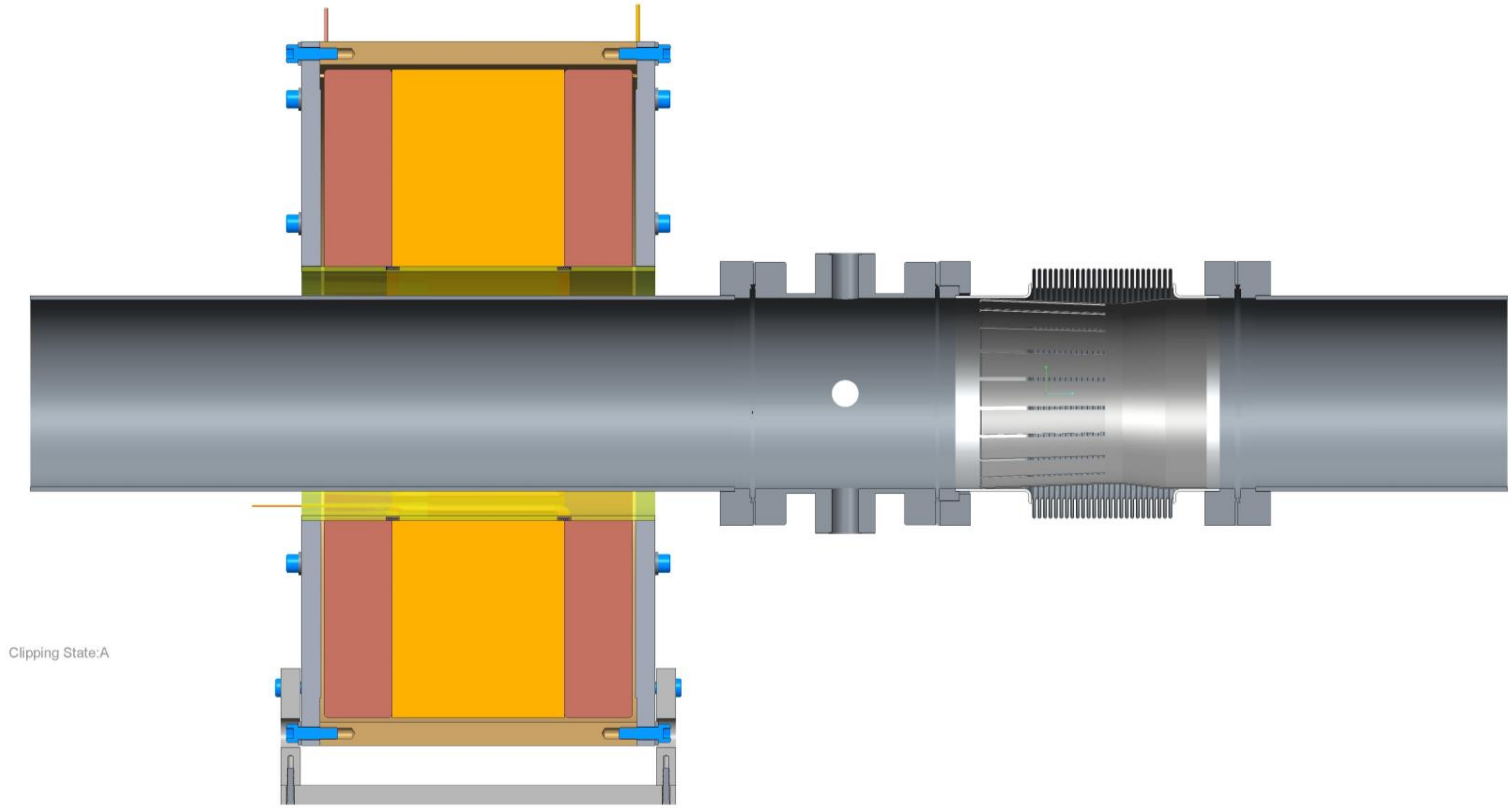




Compensating Solenoids

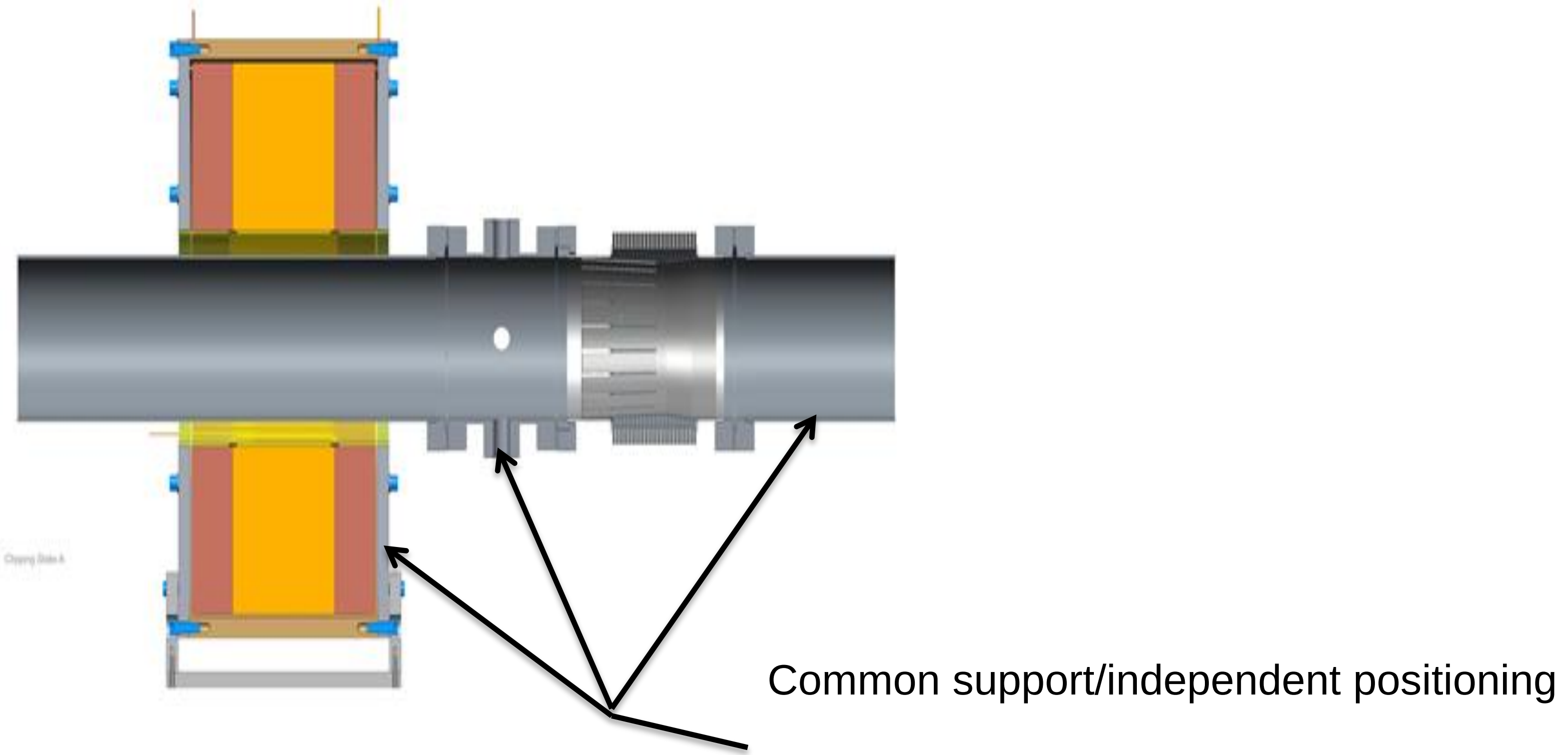
Design Review:

- Field measurements and positioning accuracy specifications.
- Magnetic shielding measurements
- Magnet measurement fixture Plan for mu metal prototype and test fixture.



Beam Line

- LF Solenoid, BPM, and long pipe are to be independently positioned and surveyed (Note: this can be on common stand).



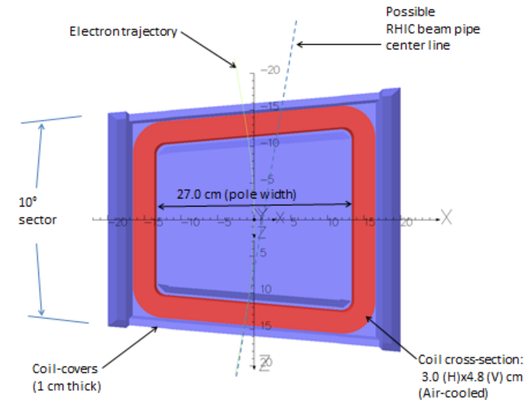
20º Dipole Magnet

Drawings checked – preparing requisition.

Distance Between Pole Faces = 10.4 cm (4.1 in.)

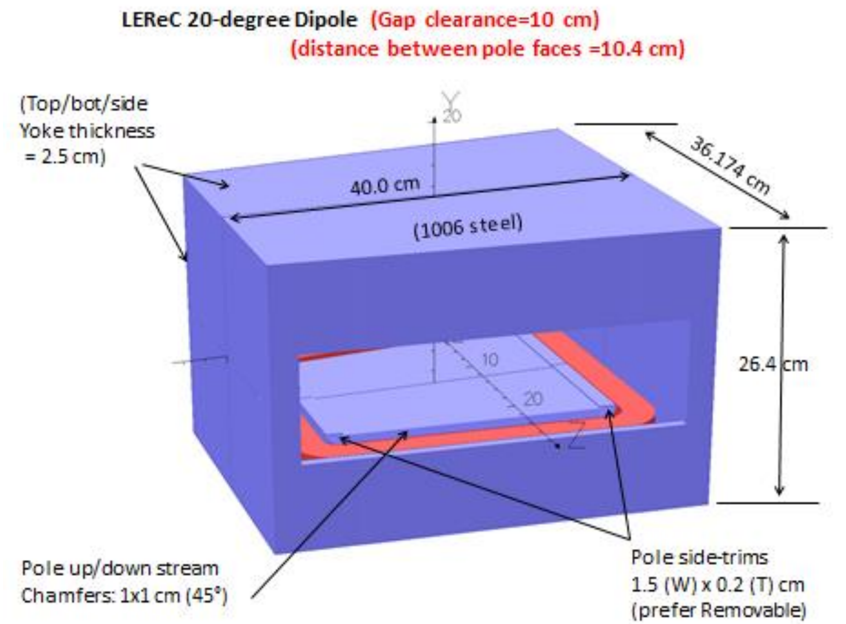
Magnet Vertical Gap = 10 cm

Vacuum Chamber V Aperture = 9.5 cm (3.74 in.)



Electron tracking results and field qualities along trajectory on R=1 cm curved cylinder:

	Ek = 5 MeV	Ek = 1.6 MeV
Current per coil (Amp-turn)	1053.288	393.192
Overall current density (A/mm²) (overall coil cross-section 3.0x4.8 cm)	0.73145	0.27305
Central Gap Field (Gauss)	251.20	93.73
Half b1-integral (dipole) (G-cm)	3.1982E3	1.1930E3
Half b3-integral (6-pole) (G-cm) [Ratio to dipole integral]	1.803E-2 [5.64E-6]	7.019E-3 [5.88E-6]
Half bending angle from tracking tests (required 10°)	10.013°	10.006°



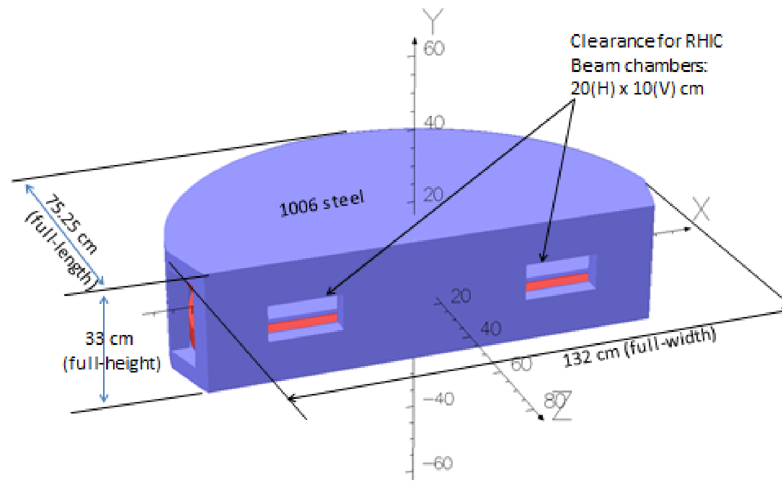
180º Dipole Magnet

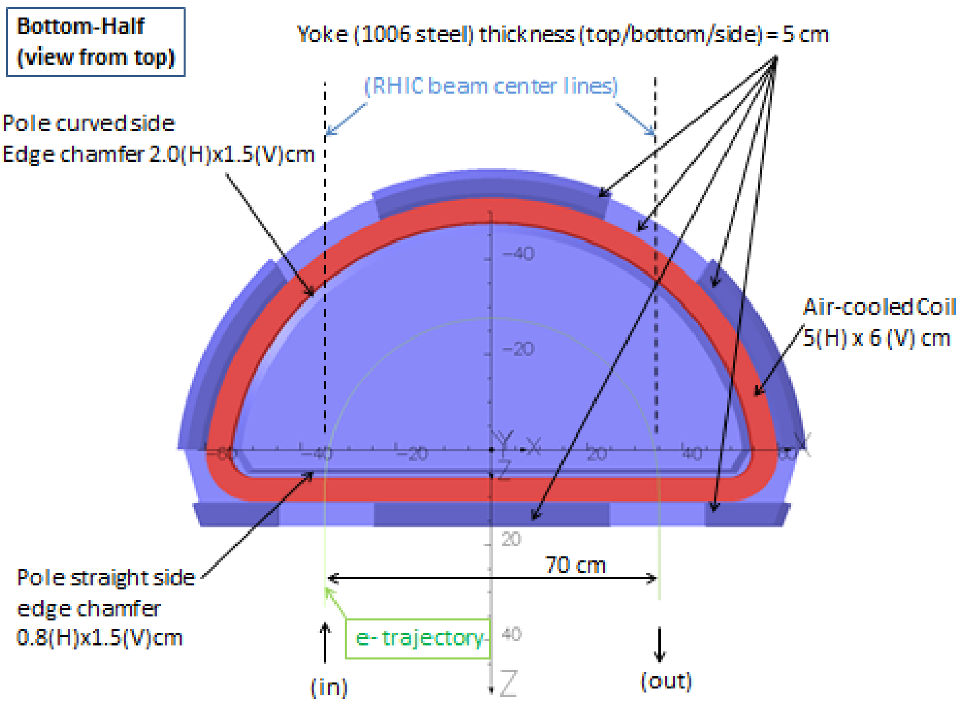
Range of motion for magnet core?

Magnet Vertical Gap = 10.0 cm (3.94 in.)

Vacuum Chamber Aperture = 9.5 cm (3.74 in.)

LEReC 180-degree Dipole : (Gap=10 cm) ----- Envelop





Electron tracking results and field qualities along entire trajectory on R=2 cm curved cylinder:

	Ek = 5 MeV	Ek = 1.6 MeV
Total current per coil (Ampere-turn)	2119.146	791.077
Overall current density (A/mm²) (coil-pack cross-section: 5.0 x 6.0 cm)	0.7064	0.2637
Central Field deep inside magnet (Gauss)	525.21	195.78
Effective Magnetic Length (cm)	109.43	109.57
Full b1-integral (dipole) (G-cm)	5.7471E4	2.1452E4
Full b3-integral (6-pole) (G-cm) [Ratio to dipole integral]	0.132 [2.30E-6]	0.005 [2.44E-7]
Full bending angle as shown in tracking studies (required 180°)	180.002°	180.003°

Core Steel for Dipole Magnets

This magnet will operate at fields between 195.2 Gauss and 523.0 G. (P. Thieberger)

Low fields values affect good field quality nor and field reproducibility in steel dominated magnets.

These limitations are related to significant remanence and to material inhomogeneities.

Steel laminations separated by plastic sheets increase the operating steel magnetization and averaging out local steel inhomogeneities by shuffling the laminations at increased cost.

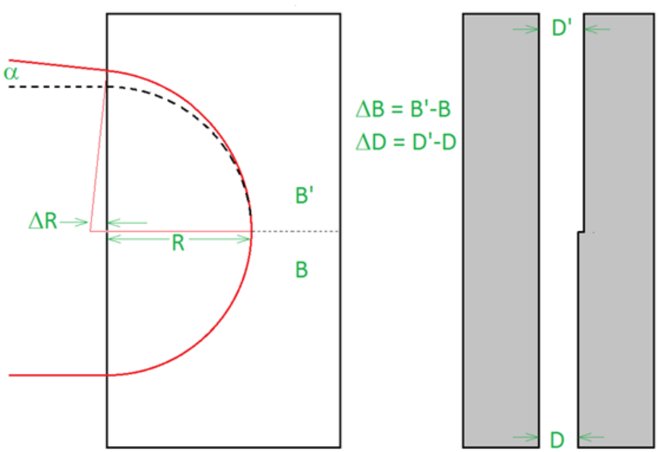
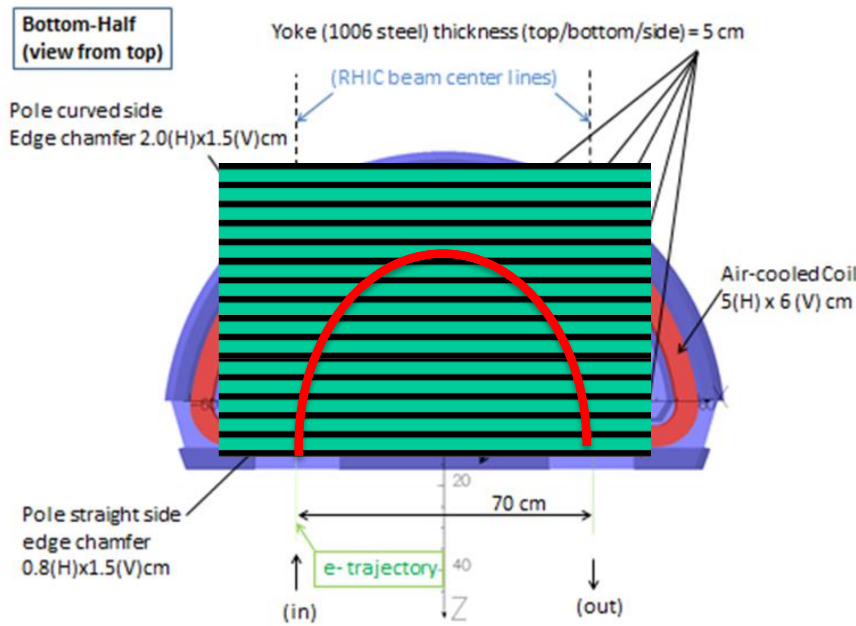


Figure 1 – Exaggerated example to illustrate the effect of a step in the gap-width

$$\alpha \approx \frac{\Delta R}{R} = \frac{-\Delta B}{B} = \frac{\Delta D}{D}$$



Core Steel for Dipole Magnets

Is a highly consistent field required in the dipoles or can the beam be steered/dipole field tuned using the BPM's?

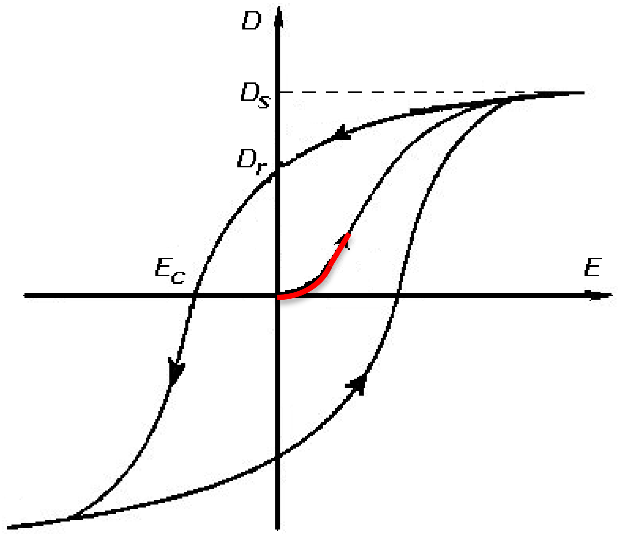
Will the magnet be used for energy spread measurement?

Solid Core Magnets - J. Tanabe Iron Dominated Electromagnets: Design, Fabrication, Assembly and Measurements

Magnets fabricated from solid cores require programming the power supplies for slow reproducible conditioning cycles and current settings. Conditioning cycles require the power supplies to ramp slowly to 110% of the maximum operating current at least 3x before slowly ramping the magnet current to the operating setting to ensure all magnets in the same family operate in the same hysteresis curves.

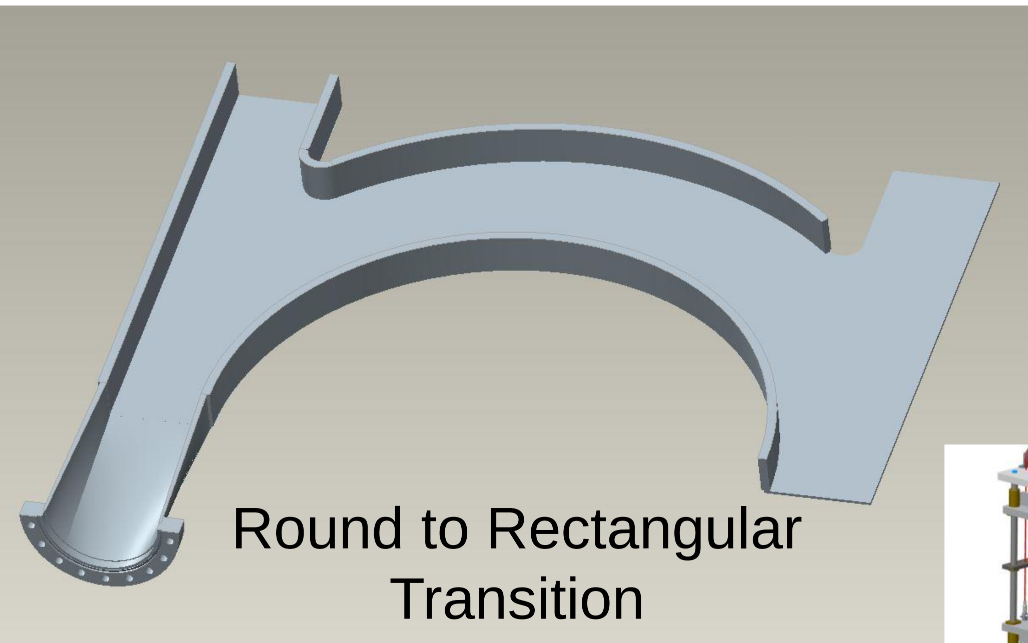
Do we need to cycle to reverse the field?

These magnets will operate in a short region of the hysteresis curve far from saturation, will that reduce the affect?.

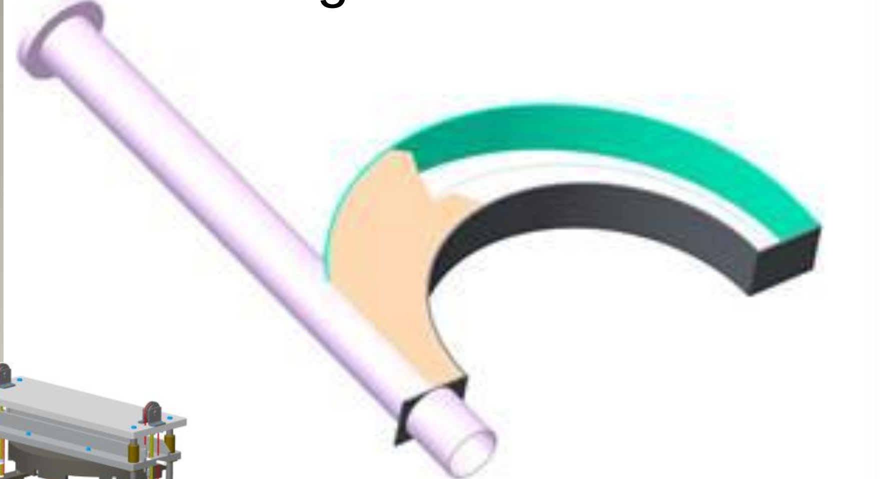


Comment:

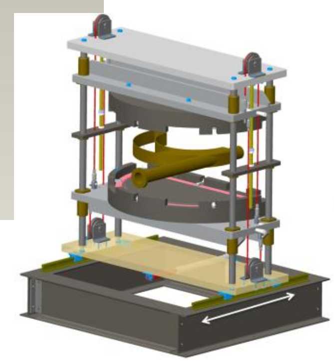
1. Two preliminary 180º dipole vacuum chamber concepts developed.
2. Chamber design discussed with Mike B.
3. Karim developed a magnet stand that can split and slide.



Round to Rectangular Transition

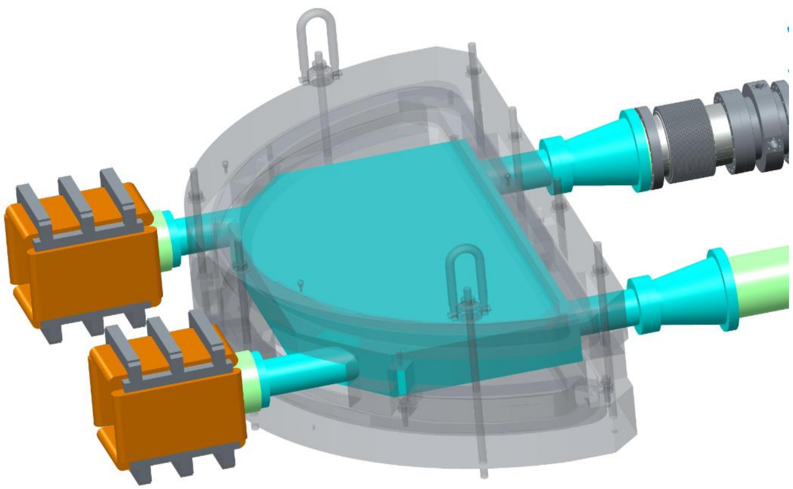


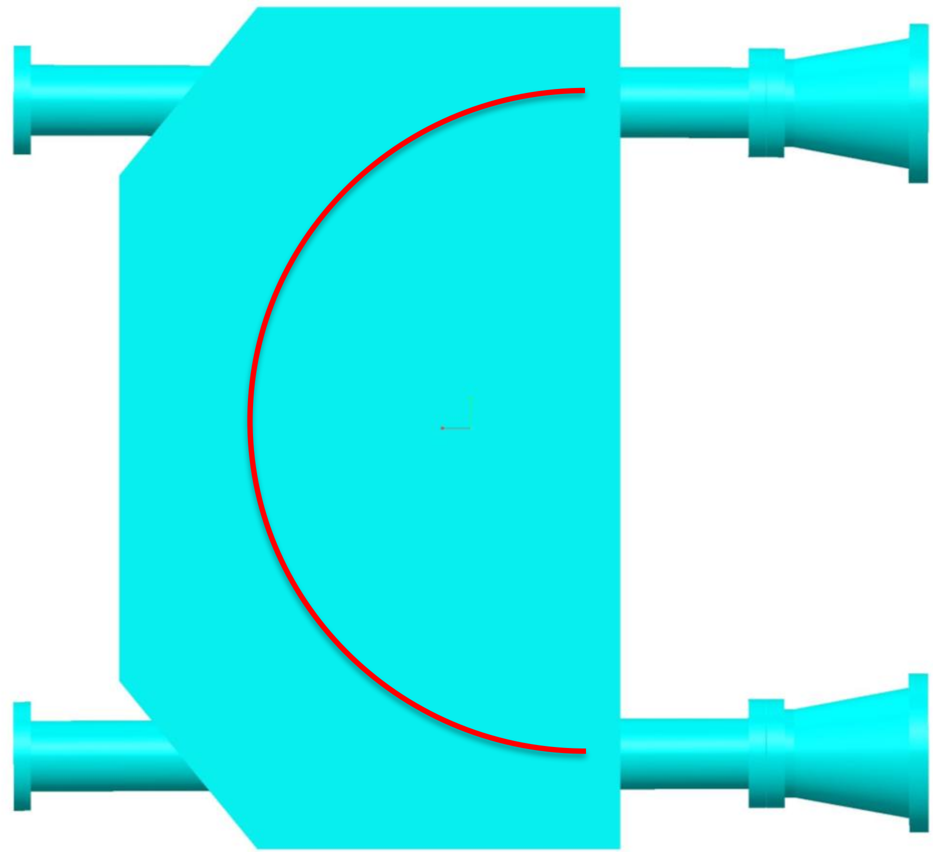
Round RHIC beam tube
Rectangular bend chamber



Vacuum Hardware

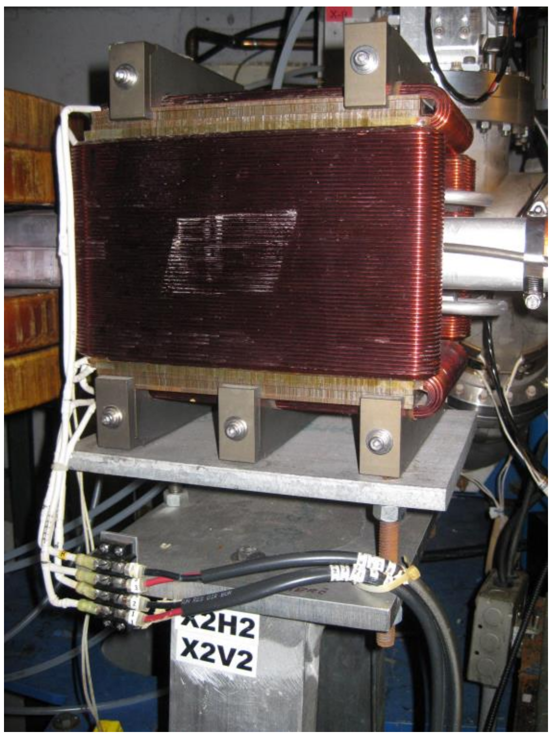
- Large open 180° vacuum chamber and 20° chamber - beam impedance concerns shield the electron beam path.
- Design and order beamline RF shielded bellows. Recombination monitors??
- Order RF shielded valves.

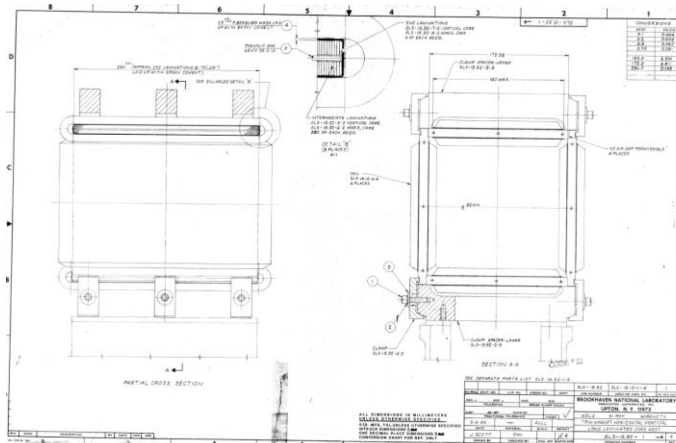


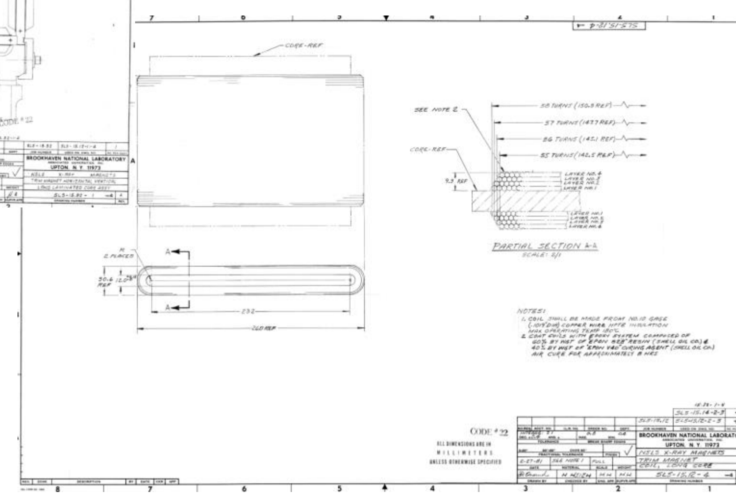


NSLS I Equipment

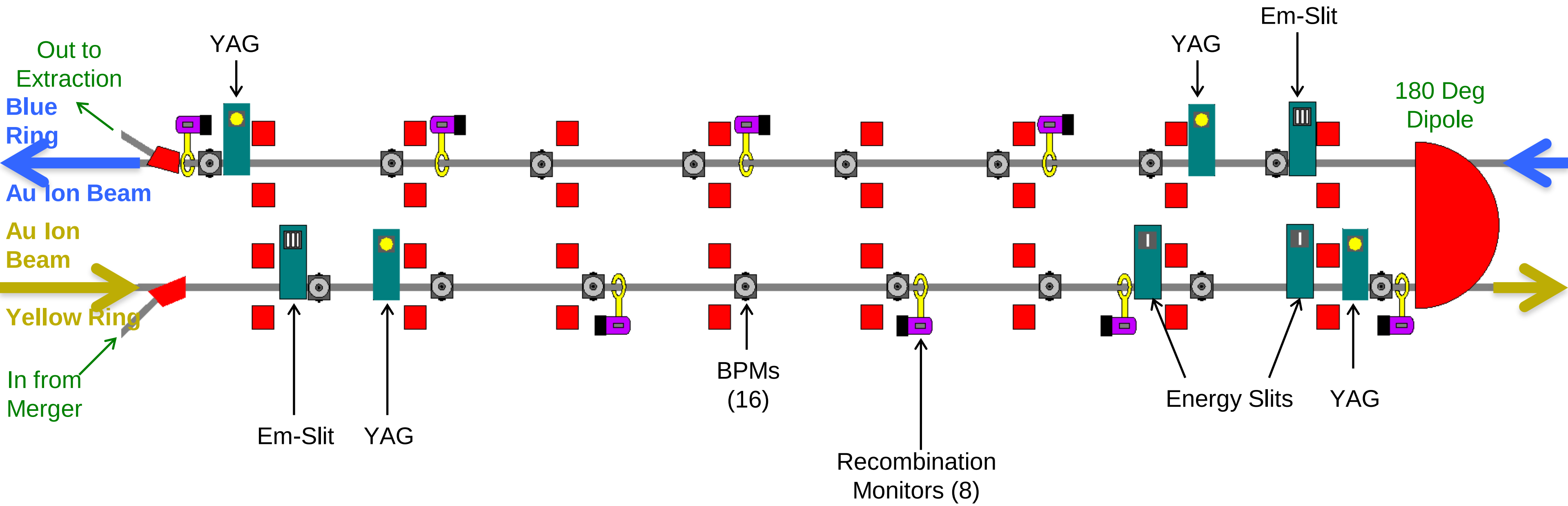
- Compensating dipole for 21º e beam injection/extraction
- 375 Gcm/A
- . . . the list of equipment available from NSLS I. The orientation meeting on the equipment transfer is today, Wednesday, 3 - 4 pm in the 725 seminar room.

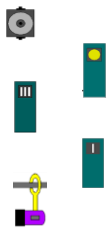






Cooling Section Beam Instrumentation





Cooling Sections

BPM = 16

YAG = 4

Emittance slits = 2

Energy Slits = 2

Recombination Mon = 8

Procurement & Repurpose: High Priority Items

- Cooling Sections elements installed in 2015 shutdown (**July '15 – Jan '16**)

Moderate Priority
High Priority

	Begin Procurement	Procurement	Lead Time	Testing	Installation
Profile Monitors	Feb. 2015	2 mo.	6 mo.	3 wks.	Dec. 2015
Emittance Slits	Feb. 2015	2 mo.	6 mo.	3 wks.	Dec. 2015
Defining Slits	Feb. 2015	2 mo.	6 mo.	3 wks.	Dec. 2015
BPMs	Feb. 2015	2 mo.	4 mo.	6 wks.	Oct. 2015
Recomb. Mon. Chamber	April 2015 (2 mo. Design)	1 mo.	2 mo.	3 wks.	Sept. 2014

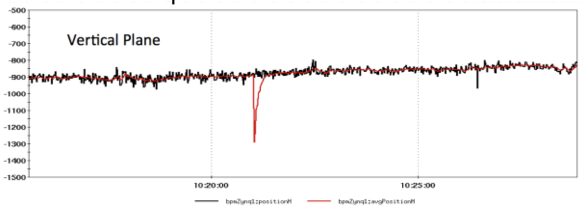
BPMs in Cooling Section (14 Locations)

Shared Pick-Ups:

One dual plan station at each solenoid is shared by two electronics boards, one measuring ions and one measuring electrons.

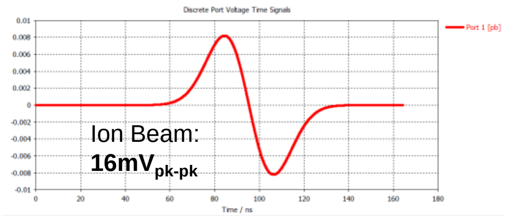
BNL Zync Electronics Design:

- VME Form Factor
  - Use RHIC Controls Infrastructure
- Configurable Front End RF Section
  - **39 MHz** for Ions
  - **700 MHz** for electrons
- 4 x 400MSPS A/D Converters
  - 2 Planes of Measurement / Board
- Integrated Front End Computer
  - FEC & FPGA on Single Chip (Zynq)
- Ethernet Connectivity (x2)
  - Controls Network
  - High Speed Interface for Feedback
- Test results below at the ATF with 9.3mm buttons showed better than 100um accuracy and 10um precision.

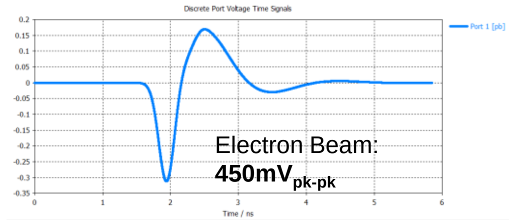


Signal Simulations:

Simulations were made with the short electron bunches and long ion bunches to determine expected signal amplitudes on the buttons.

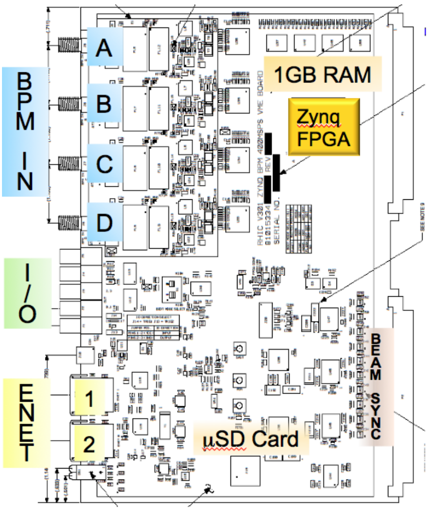


γ= 4.1
Ions/bunch = 7.5E8
Charge/bunch = 9.48E-9 C
RMS length = 3.2 m



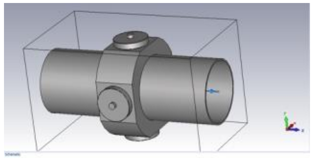
Simulations: Courtesy of Peter Thieberger

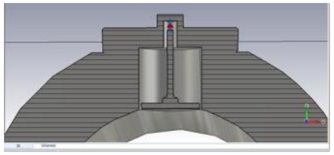
γ= 4.1
Charge/bunch = 100 pC
RMS length = 100 ps
RMS length = 30 mm



New Pickup Design:

- Large Dia. BPM Housings
- 28mm buttons
- N-Type feedthrough
- MPF Q7031-1





Profile Monitors – New designs for Cooling Section

Low Power profile measurement
- 4 or 6 stations
- Two Position plunger (similar to ERL Design)
- 100um thick YAG crystal
- Impedance matching cage
- Large cube for 5” beam pipe
- Same optics as ERL design

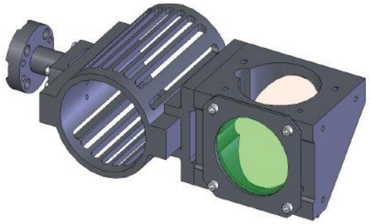


Photo courtesy of Radiabeam

High Power profile measurement
- 2 stations
- Compact offset cam design
- 9 μm carbon fiber passes beam only once @ 20 m/s
- accelerate/coast/decelerate in two rotations
- PMT detects X-rays generated by the scattered electrons

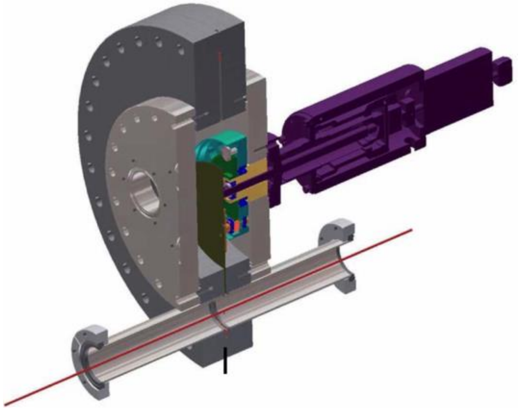
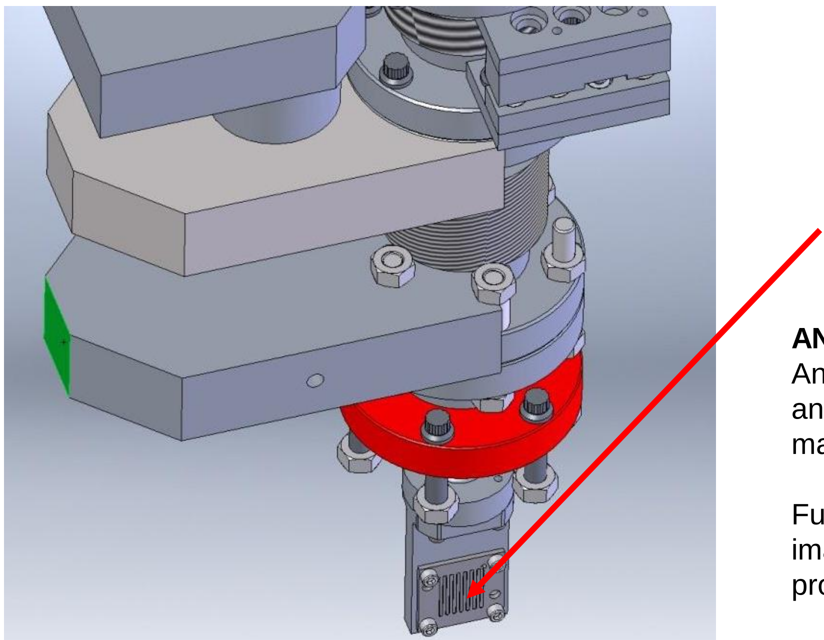


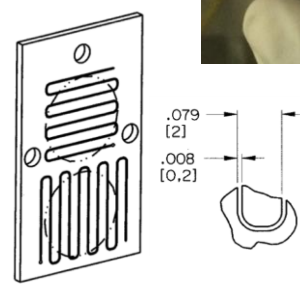
Photo courtesy of B. Dunham, Cornell

Emittance Slit Measurement

- Low Power Operations Only
- New Dual axis design for Horizontal & Vertical measurements.
- Positioned 0.16 – 1 m upstream of profile monitor
  - Final spacing TBD…
- Tungsten Slit mask, optimized for beam parameters
  - Mask 1.5mm thick… # slits & TBD…

Dual Station Actuator retrofitted for new dual axis mask.





ANALYSIS:
An algorithm was developed for analyzing the image from a multi-slit mask for emittance measurement.

Future plans are to automate the image analysis for on-line processing and data logging.

Intensity Distribution at mask

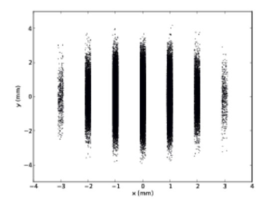
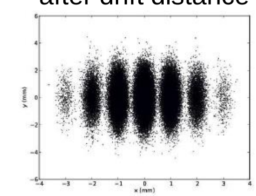
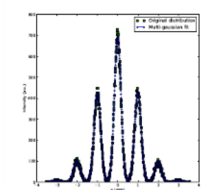


Image on profile monitor after drift distance

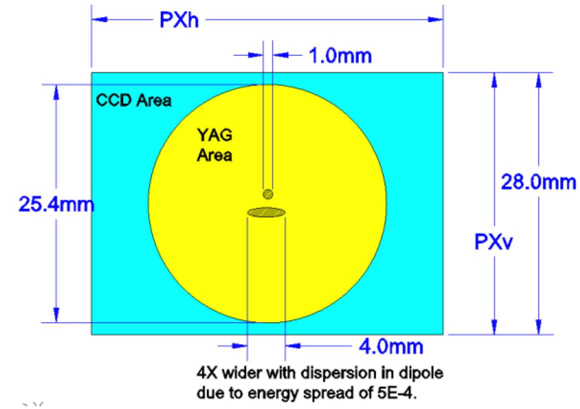




Energy Spread Measurements – 2 Locations

- Max. Energy Spread: $\Delta p/p = <5e\text{-}4$
- Beam Size (d): 1mm (dia.)
- Double Slit before dipole & drift to YAG
- May use **Quad** to increase resolution between cooling sections
- *Considering alternatives:*
  - *Dedicated energy spectrometer beam line*
  - *Cornell's method of using deflecting cavity*

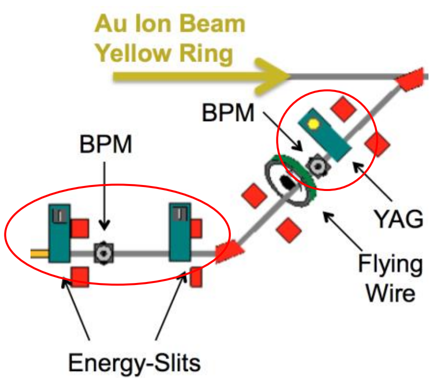
Image of YAG as projected onto CCD



Before Cooling Sections

- σ_δ = 750μm
- Resolution = σ_δ / $Pitch_{YAG}$
- 750μm / 29μm/px = 25 px

➔ 4% Resolution

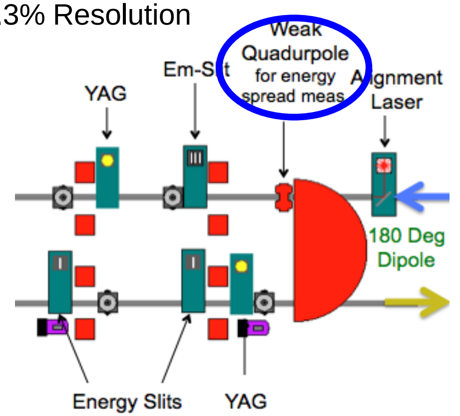


$\sigma_\delta = \eta\delta = 1.5m(5x10^{-4}) = 750\mu m$

Between Cooling Sections

- σ_δ = 350μm
- Resolution = σ_δ / $Pitch_{YAG}$
- 350μm / 29μm/px = 25 px

➔ 8.3% Resolution



$\sigma_\delta = 2R\delta = 2(0.35m)(5x10^{-4}) = 350\mu m$

- 2MP CCD: 1292_h X 964_v px
- $Pitch_{YAG} = proj\text{-}H_{CCD}/px_v$
  = 29μm/px

Recombination Monitor: Ion Collection

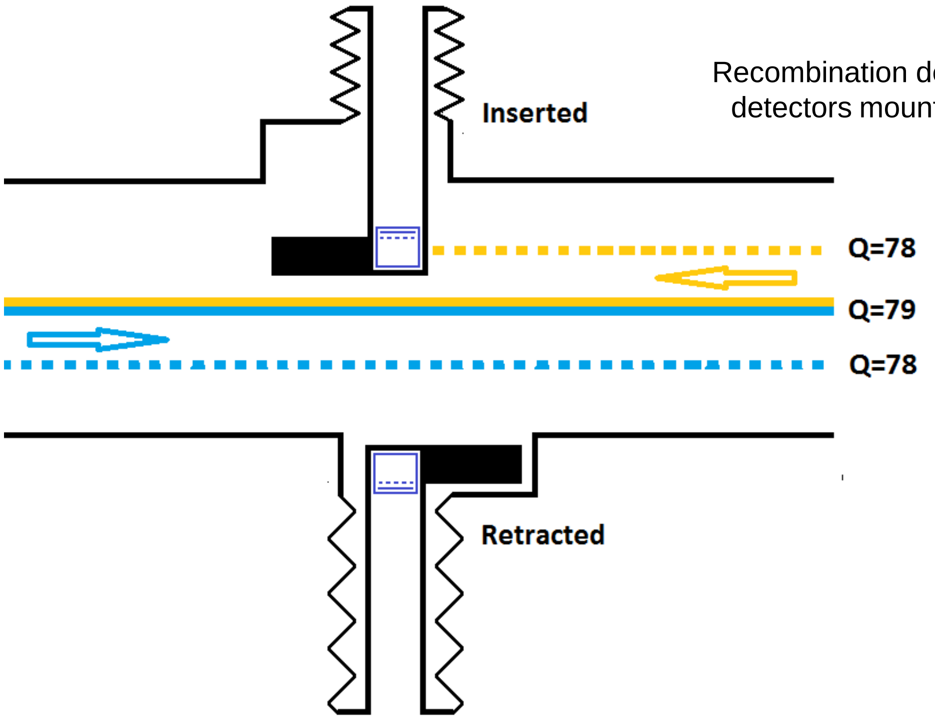
E-Ion RECOMBINATION:

- Au^{+79} ➔ Au^{+78}, Expected rate ~5e6 per second
- Creates ions of wrong charge
- Generates X-rays in cooling section
- loss rate ≈ alignment

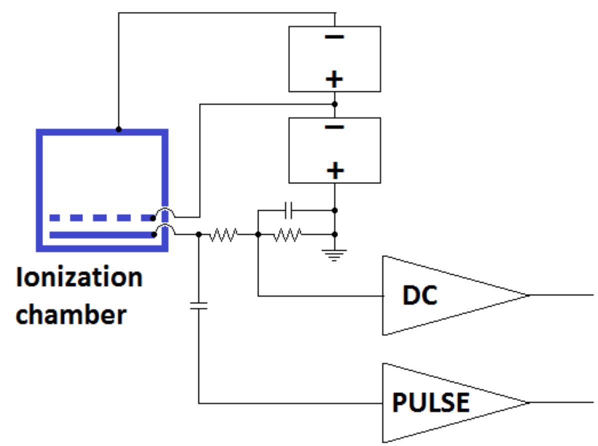
ION (wrong charge) **COLLECTION:**

- Lost at predictable location (collimators)?
- Detector: PMT + Counter
- ! Lattice simulation predicts lattice aperture acceptance of Au^{+78} ions !

  => **Work underway to develop a lattice with dispersive section.**



Recombination detector concept showing two ionization detectors mounted in retractable roman pot systems.

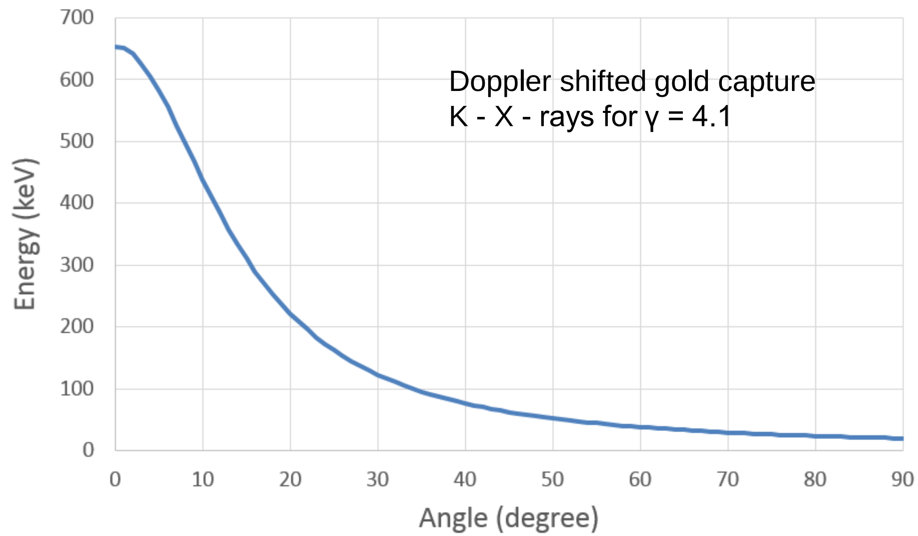


Courtesy of Peter Thieberger

Recombination Monitor: Radiative Detector

RADIATIVE RECOMBINATION DETECTION:

- Recombination radiation
  - 10-80keV x rays emitted a shallow forward angle
  - Scintillators located at in COOLING SECTION
- Detector
  - Scintillator + PMT + Counter
  - => loss rate ≈ alignment



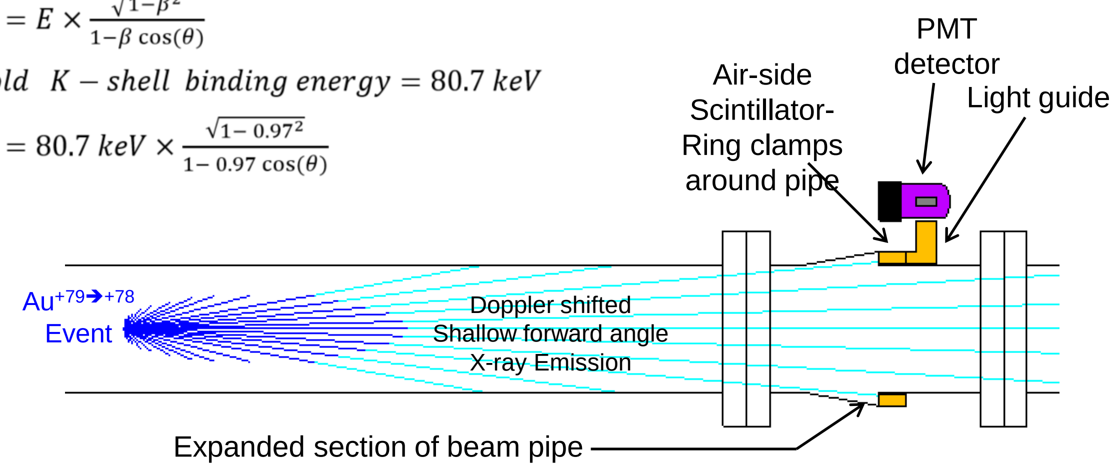
$$for\ \gamma = 4.1$$

$$\beta = \sqrt{1 - \frac{1}{\gamma^2}} = 0.970$$

$$E' = E \times \frac{\sqrt{1-\beta^2}}{1-\beta\cos(\theta)}$$

$$Gold\ \ K - shell\ \ binding\ energy = 80.7\ keV$$

$$E' = 80.7\ keV \times \frac{\sqrt{1-0.97^2}}{1-0.97\cos(\theta)}$$



Courtesy of Peter Thieberger

LEReC ERL schematic layout

Outside Issues: location of the 5 cell cavity and egun.

Beam line distance or distance as the crow flies?

Tolerance for the 5 cell location?