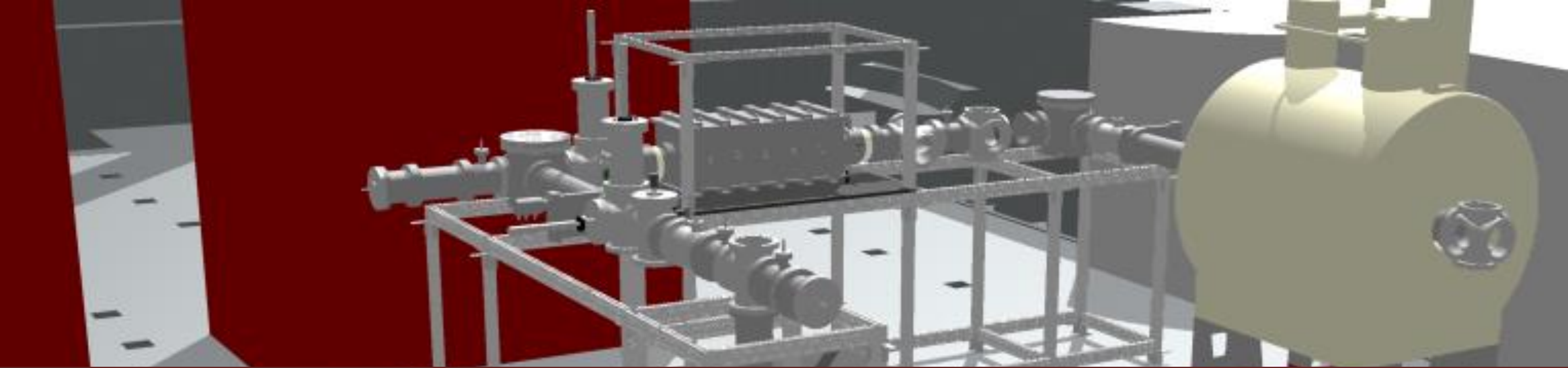


Current Status of the TAMUTRAP Facility

Michael Mehlman / DGM Group

TCP 2014, Takamatsu Japan - December 1, 2014

Outline

- Motivation
- **D**
- **C**
- F

•**Bring TAMUTRAP to attention of trapping community**

•**Consider other possible uses for facility**

•**Receive feedback and advice**

TAMUTRAP

- Texas A&M University Penning Trap Facility
- A new precision measurement facility for studying the weak interaction
  - $a_{\beta\nu}$, b, *ft* values
- Plus
  - Mass measurements
  - Spectroscopy
  - General purpose decay station: ultra pure, low energy, spatially well-defined source

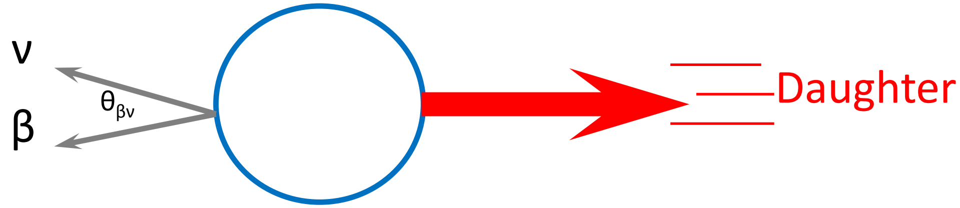
Dan Melconian
Friday @ 10:25

CYCLOTRON INSTITUTE
TEXAS A&M UNIVERSITY

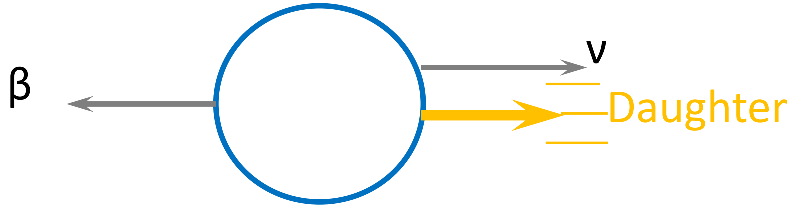
Motivation

$$\frac{d^5\Gamma}{dE_e d\Omega_e d\Omega_\nu} \propto 1 + \frac{p_e}{E_e} a_{\beta\nu} cos\theta_{\beta\nu} + b\frac{m_e}{E_e}$$

$a_{\beta\nu}$ related to angle between beta and neutrino

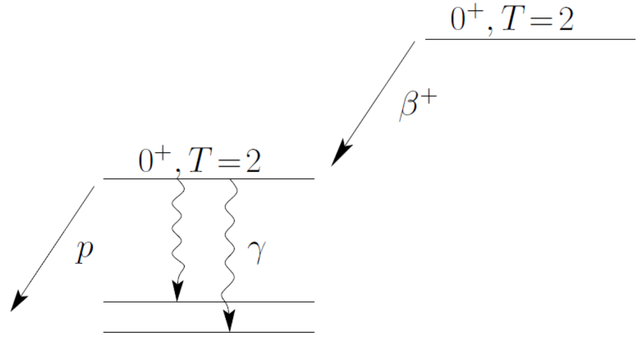


-versus-



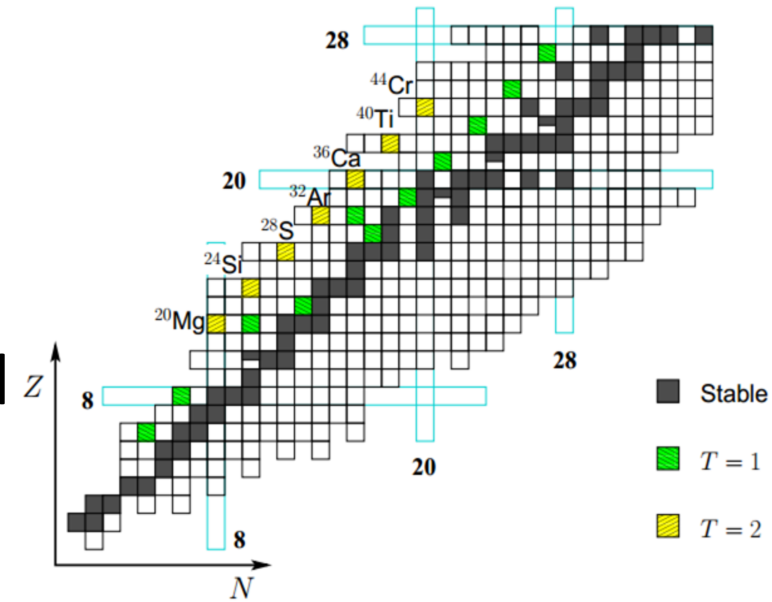
T=2, $0^+ \rightarrow 0^+$ β-delayed Proton Emitters

- Protons easy to contain/measure
- $M_{GT} = 0$
- ^{32}Ar = good initial test (Adelberger et. al)
- Series can be produced at Cyclotron Institute



RIB	$t_{1/2}$ [ms]	Production Rate (particles/s)
^{40}Ti	53	~ 7×10^4
^{36}Ca	102	~ 2.5×10^5
^{32}Ar	98	~ 1.4×10^5
^{28}S	125	~ 1.5×10^5
^{24}Si	140	~ 6.5×10^4
^{20}Mg	90	~ 1.4×10^5

P.D. Shidling



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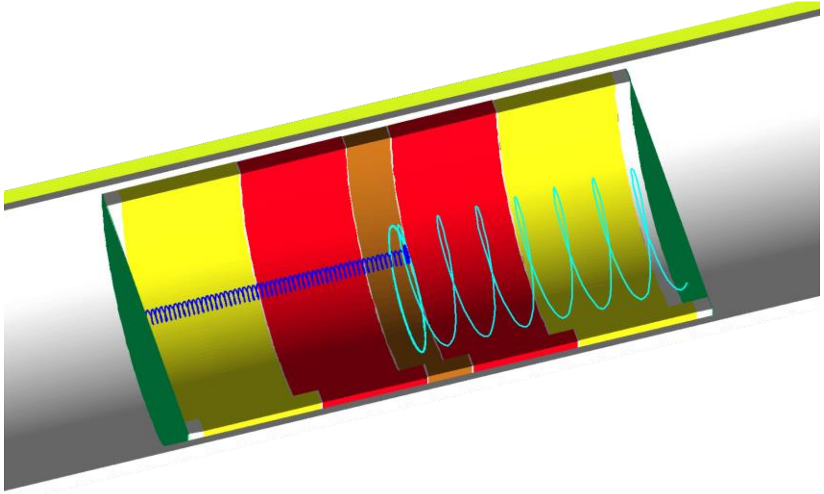
Penning Trap

In 7T field:

Teal: Proton, 4.28 MeV, ≤ 42.7mm radius
Blue: Beta, 10 MeV, ≤ 5mm radius



GEANT 4 simulation – P.D. Shidling

- Spatially confined source
- Minimal effect on proton energy
- Contains/collects protons
- Contains/collects βs
- Reduced systematics

Nuclide	Lifetime (ms)	E_p (MeV)	R_L (mm)
^{20}Mg	137.05	4.28	42.7
^{24}Si	147.15	3.91	40.8
^{28}S	180.33	3.70	39.7
^{32}Ar	141.38	3.36	37.8
^{36}Ca	141.15	2.55	33.0
^{40}Ti	72.13	3.73	39.9
^{48}Fe	63.48	1.23	22.9

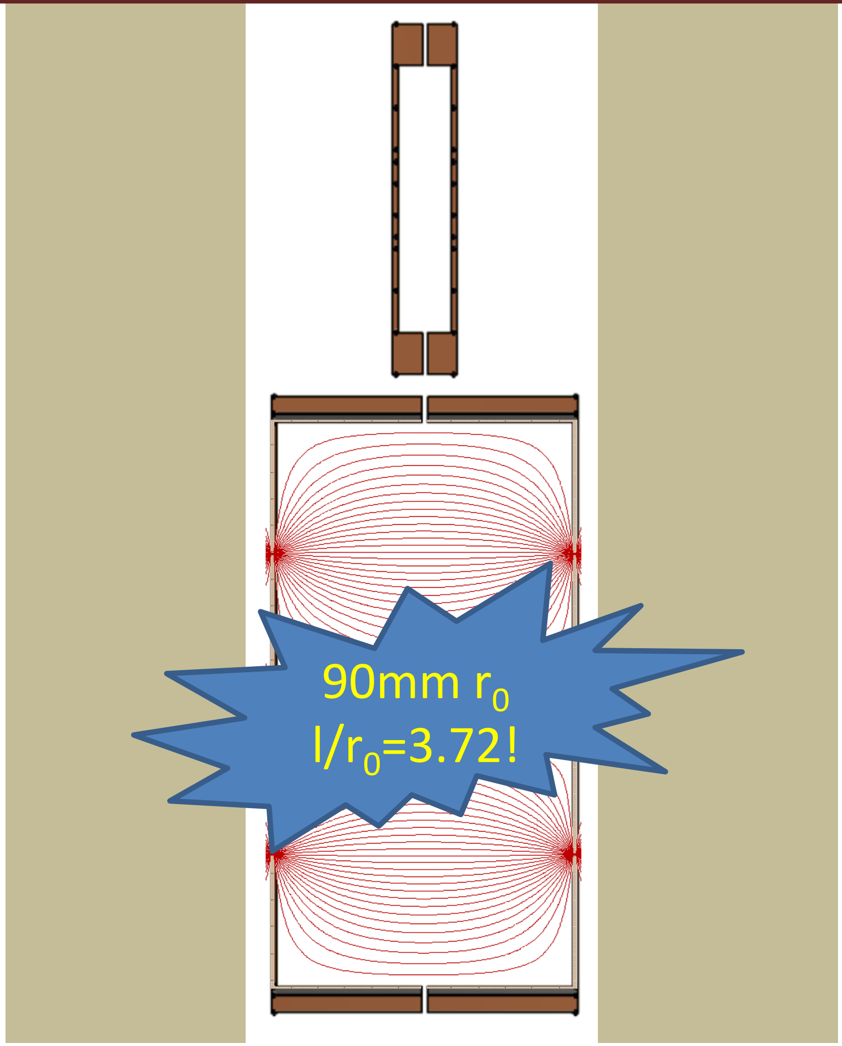
All radii for 7T magnetic field

Penning Trap

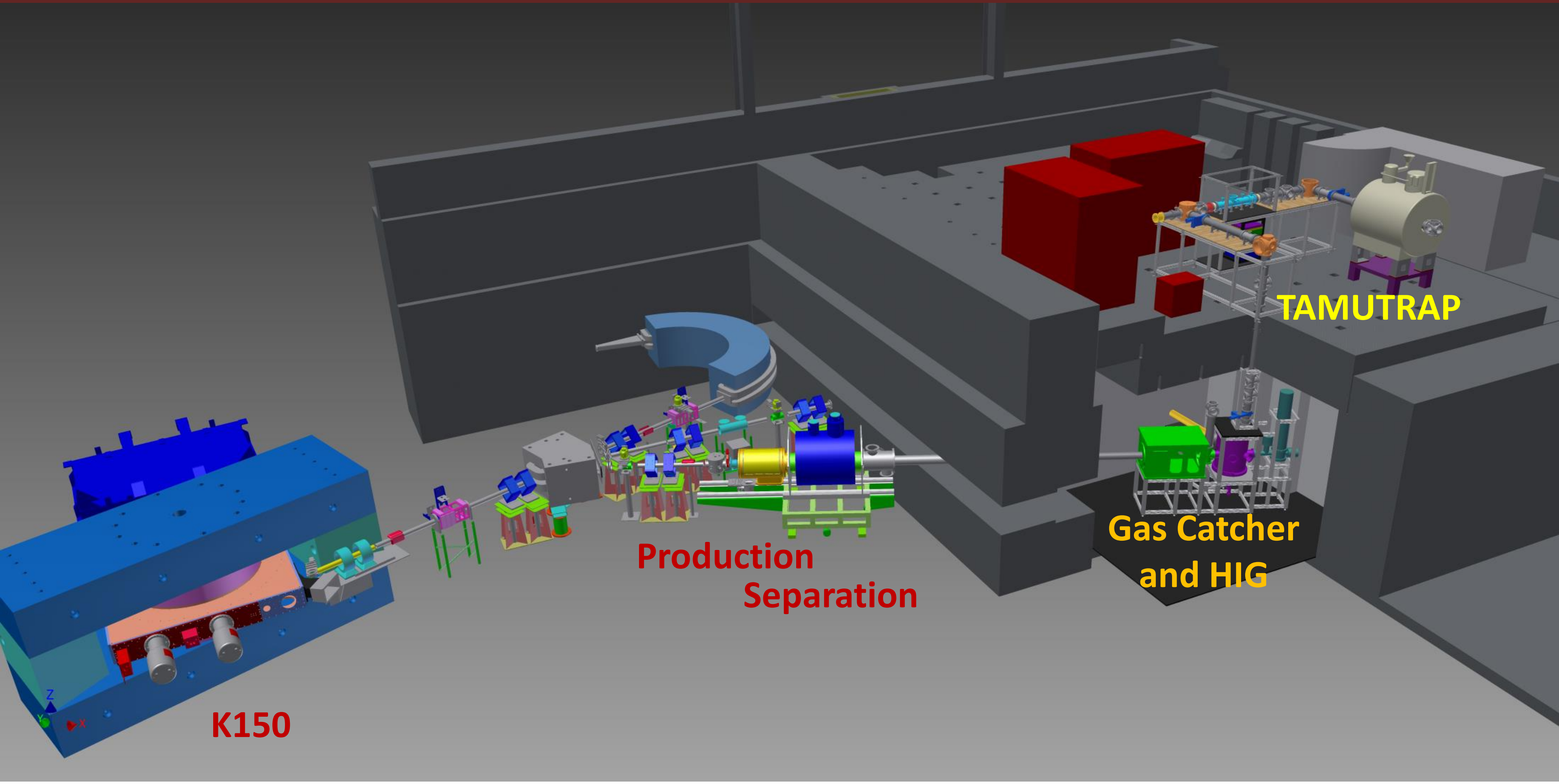
2 traps within Agilent 7T, 210 mm bore magnet:

- Purification trap (ISOLTRAP)
- Measurement trap: **new** design:
  - Large bore to contain decay products
  - Harmonic, “tunable”, “orthogonalized” for precision mass measurements

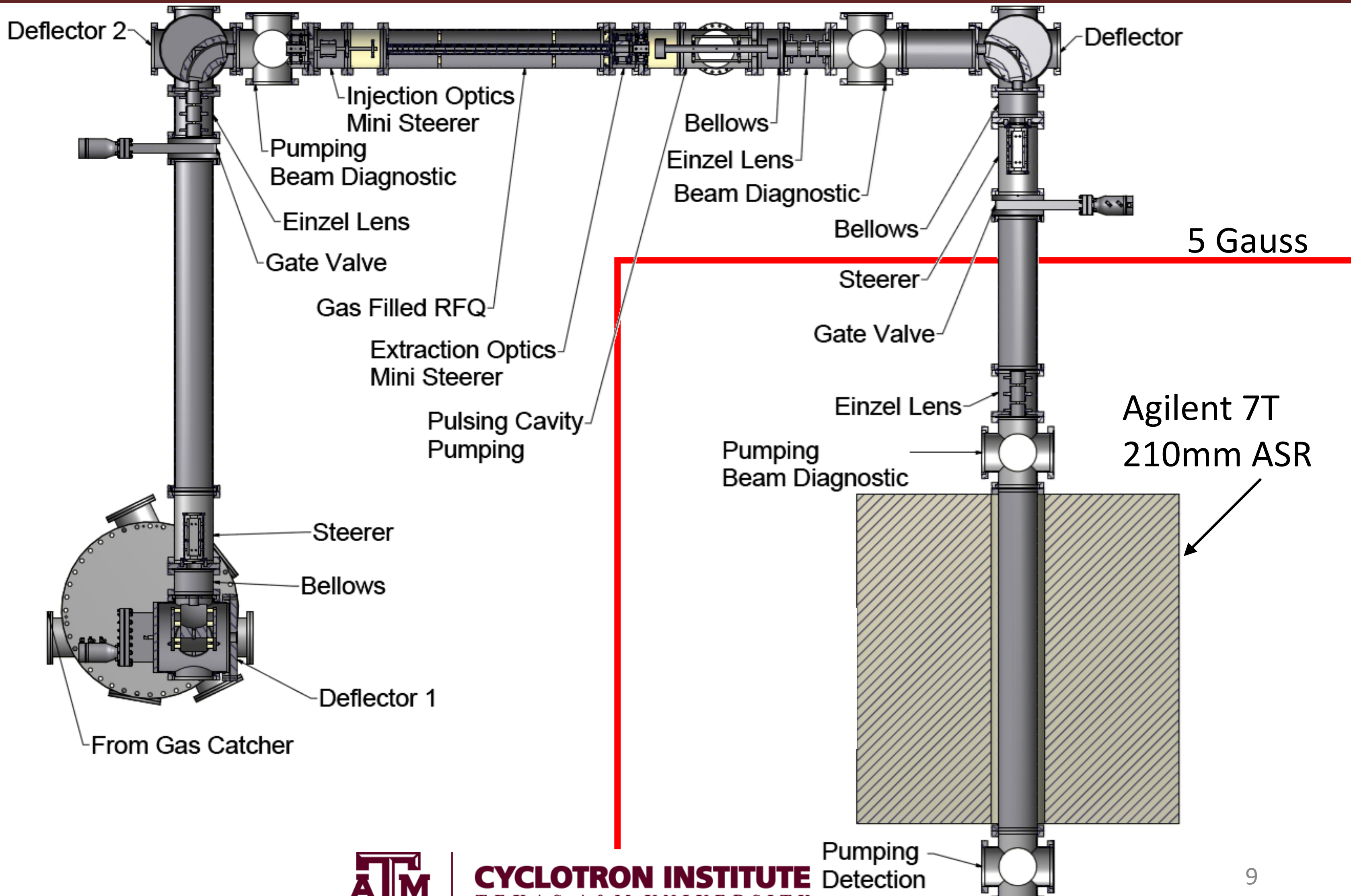
Mehlman, et al. NIM A 712, 0168-9002 (2013)



Cyclotron Institute



TAMUTRAP Beam Line



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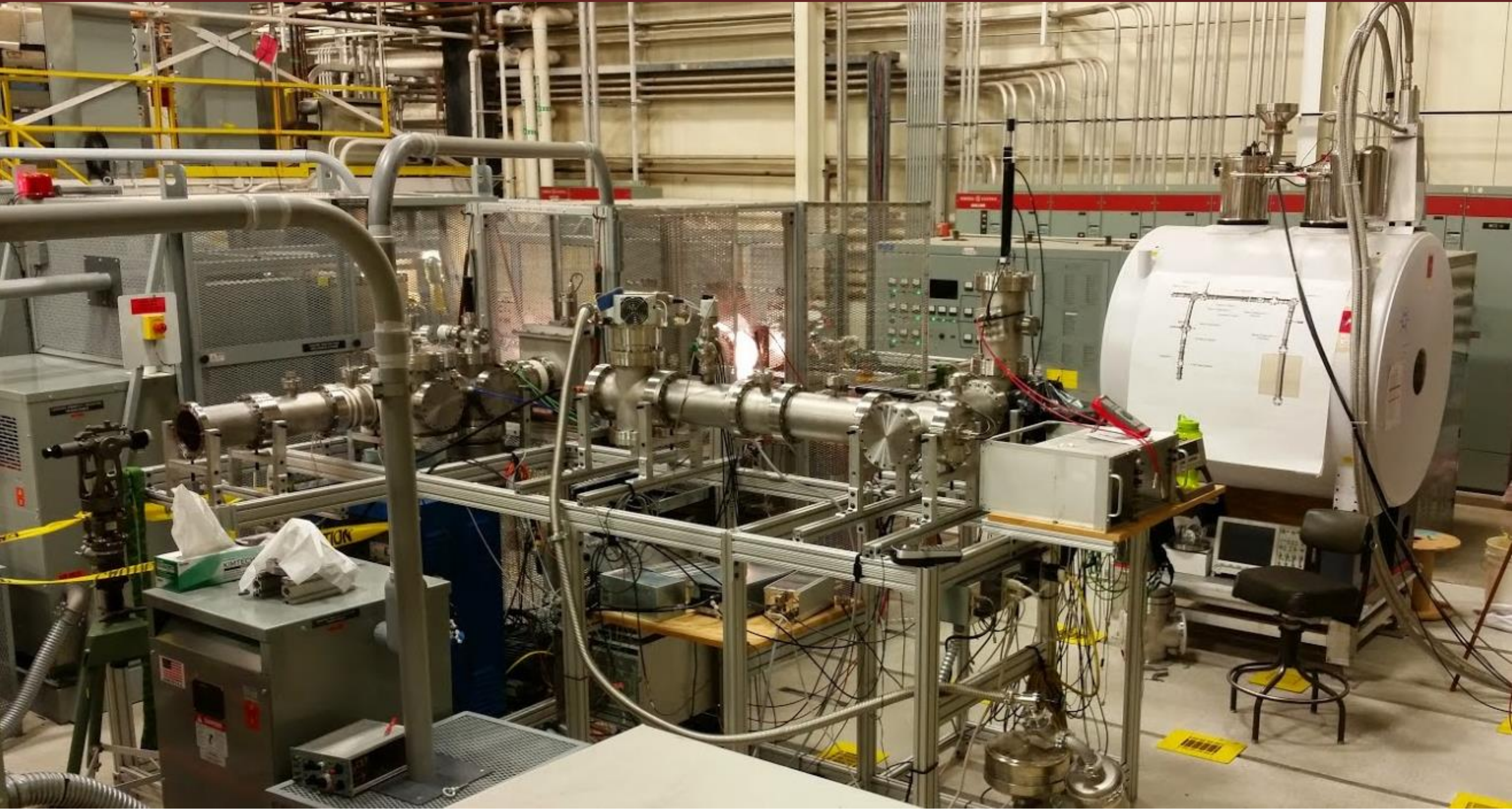
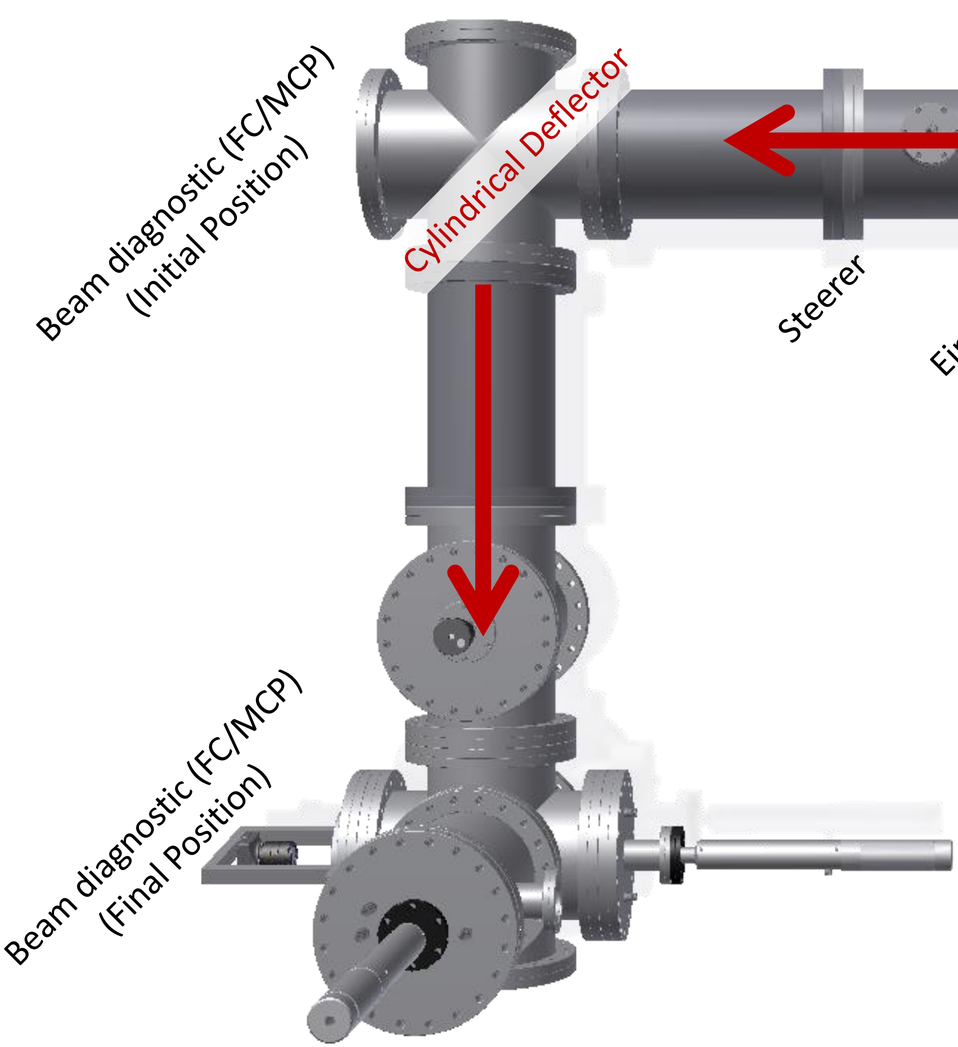
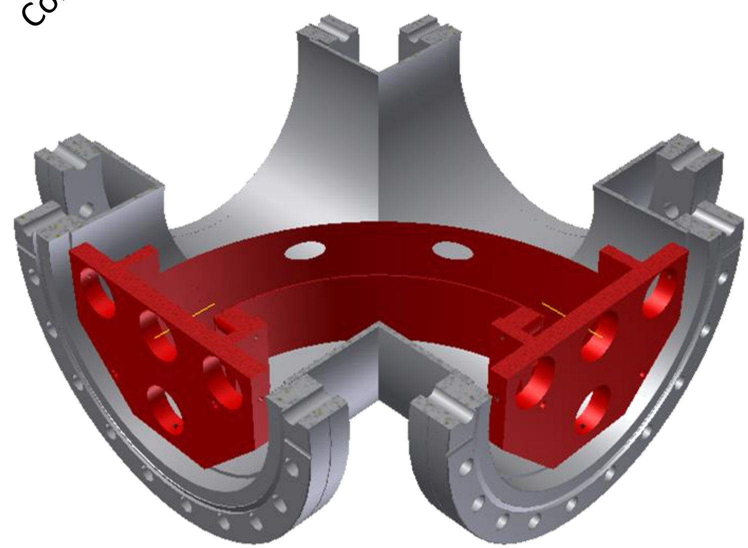
TAMUTRAP Beam Line



Cylindrical Deflectors





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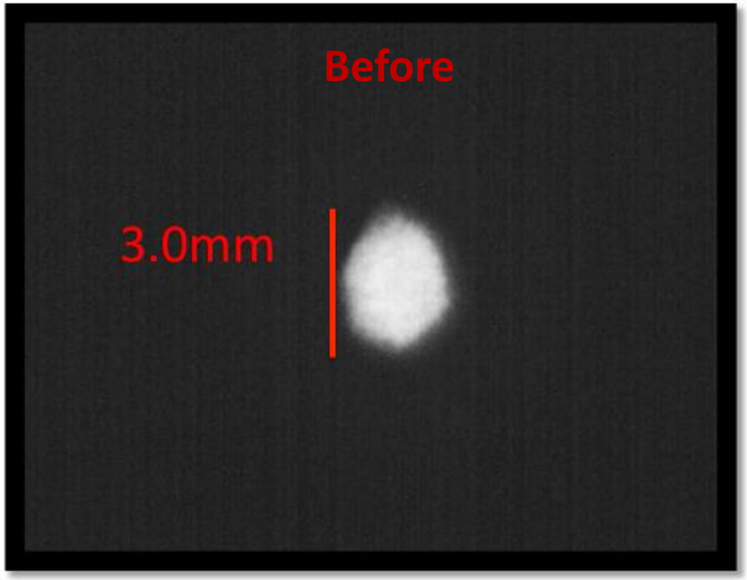
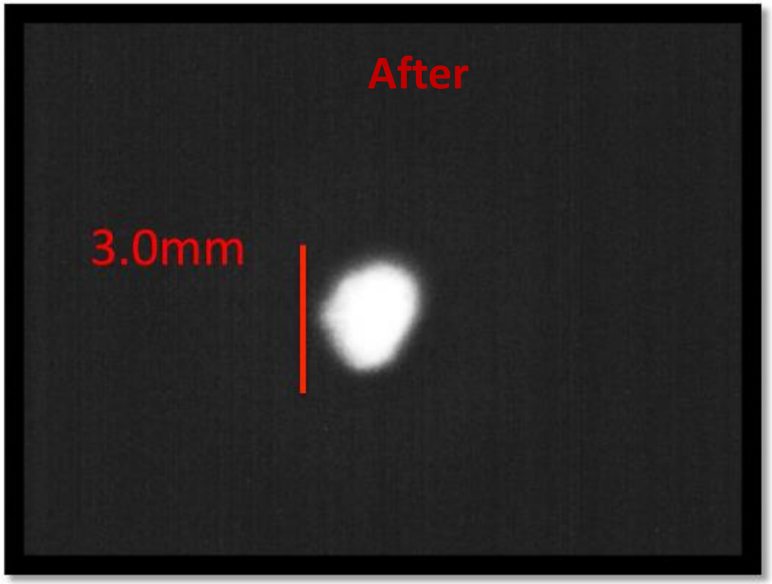
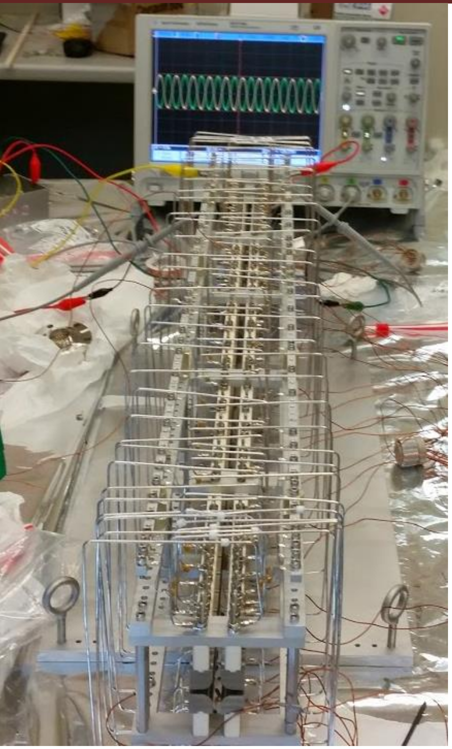
Inspired by Kreckel et al 2010

Cylindrical Deflectors

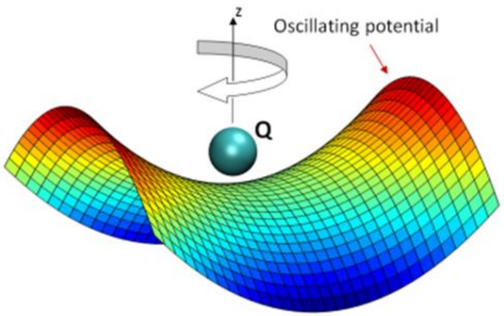


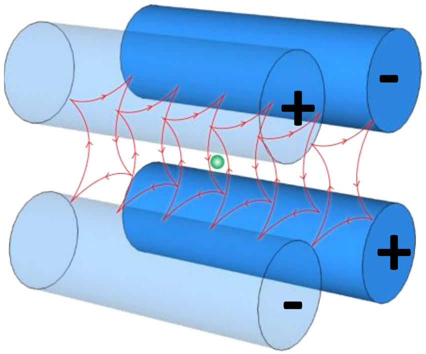


RFQ Cooler/Buncher



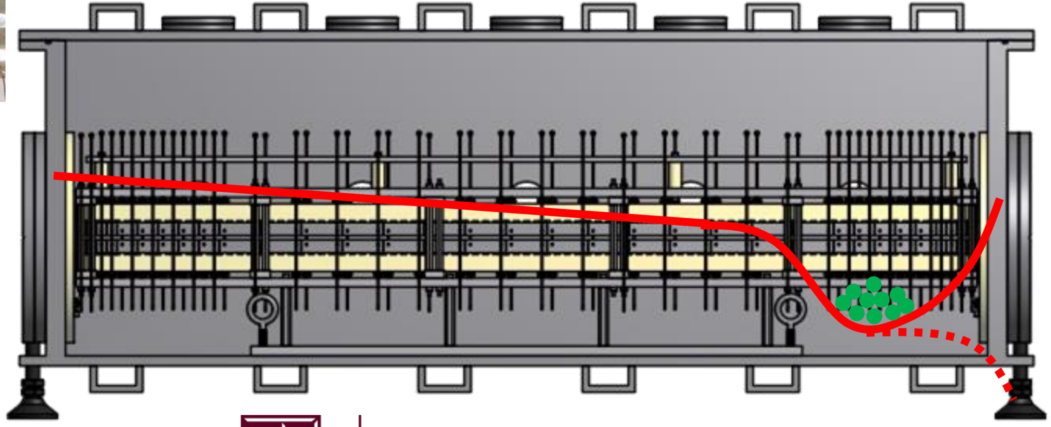
Up to 120V P-P RF
0.5-1.4 MHz frequency
(analog electronics)





10^{-2}-10^{-4}mbar 99.999% He
2-10 ms cooling time

33 Segments
Variable drag
(0-100V DC)



$\Delta E_f \approx 5$ eV
$\Delta t_f \approx 1.2 \mu s$

RFQ 2.0 Design

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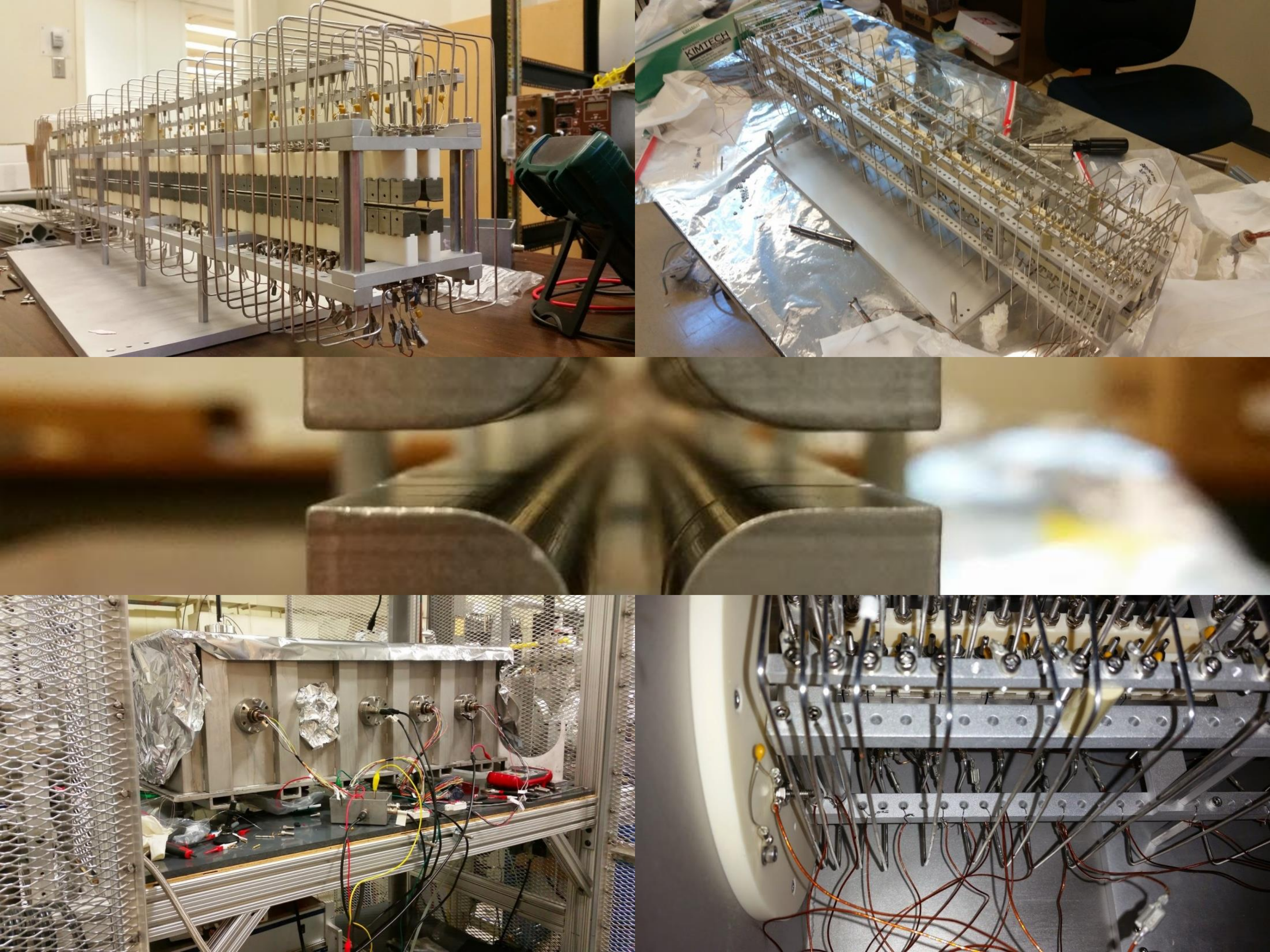
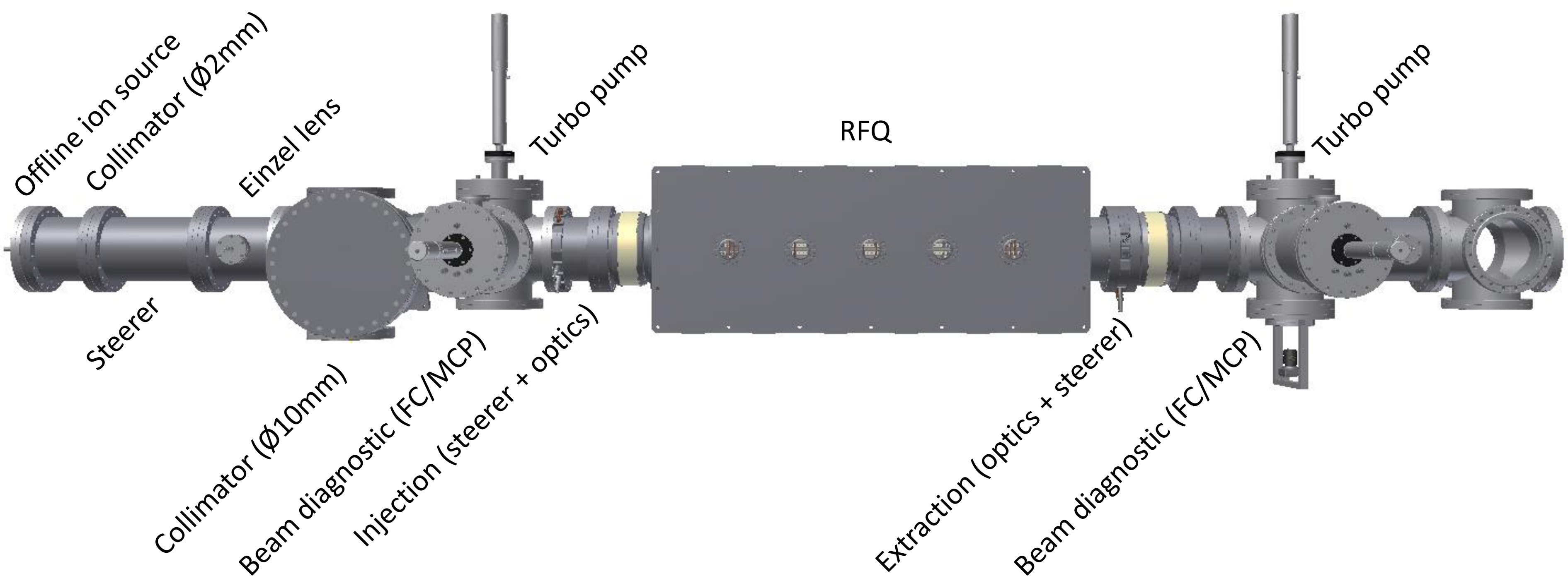
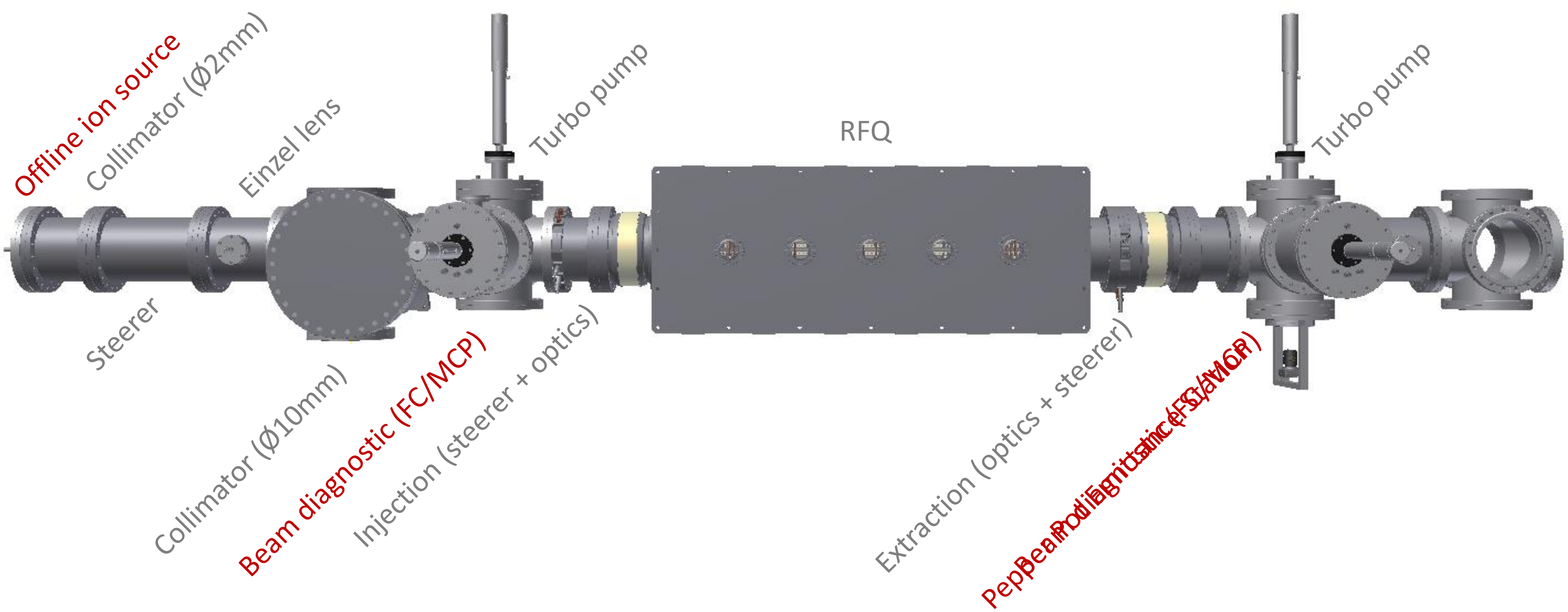

KIMTECH

Beam Line Install

Aligned optically to about ≤1mm from beam axis at any element



Beam Line Characterization/Optimization



Preliminary Results

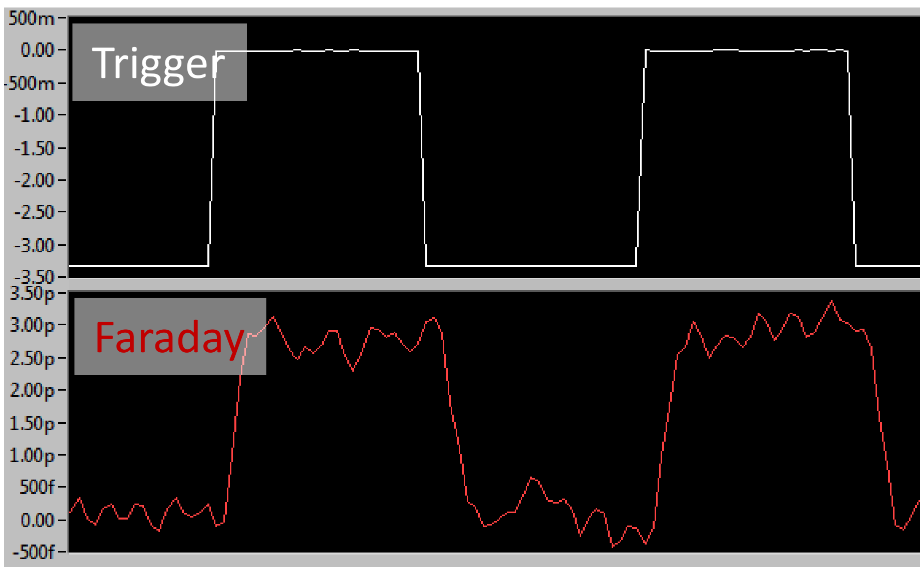
- Continuous Mode Efficiency
  - (RFQ + Injection + Extraction)
    - No gas, 112V_{pp}, 1.1MHz, 180eV Beam Energy
      - Greater than 74%
    - No gas, 112V_{pp}, 1.1MHz, 100eV Beam Energy
      - Greater than 64%

Extraction still needs to be optimized!

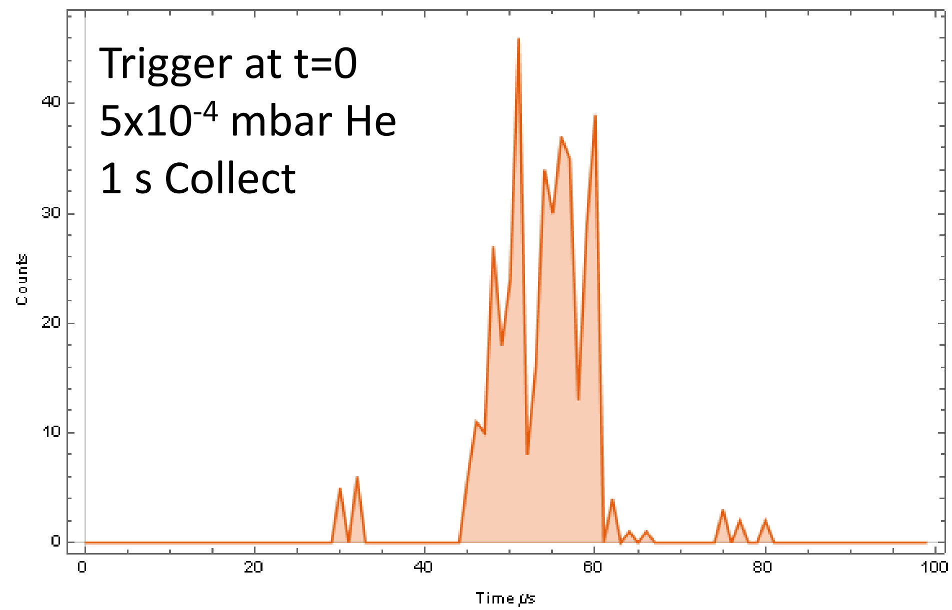
First transmission **October 2014!**

Preliminary Results

- Bunching
  - Preliminary, but clear signal over continuous mode



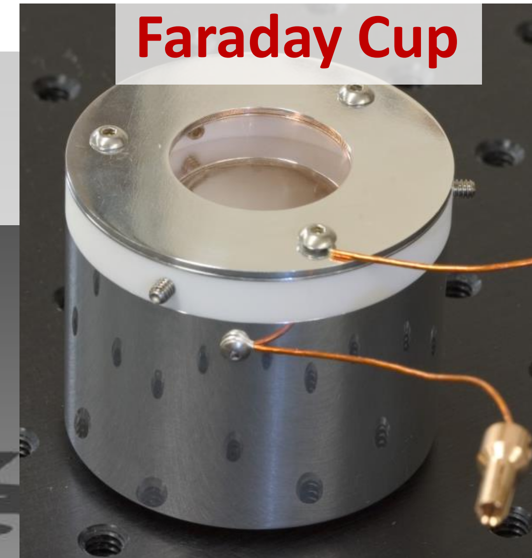
Nov. 11, 2014

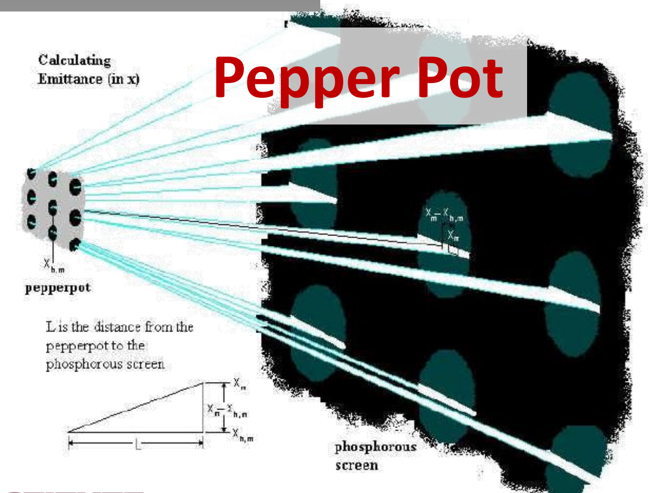


Nov. 19, 2014

Future Plans

- Continue beam characterization / optimization
  - Emittance (MCP + pepper pot)
- Simulation of traps, detectors, etc. (GEANT) (P.D. Shidling)
- Mechanical design of traps, detectors, etc.
- Data acquisition, etc.
- ???
- TRAP / SCIENCE!





Acknowledgements

- DGM Group (Dan Melconian, Praveen Shidling, Spencer Behling, Ben Fenker, Eames Bennett, Me!)

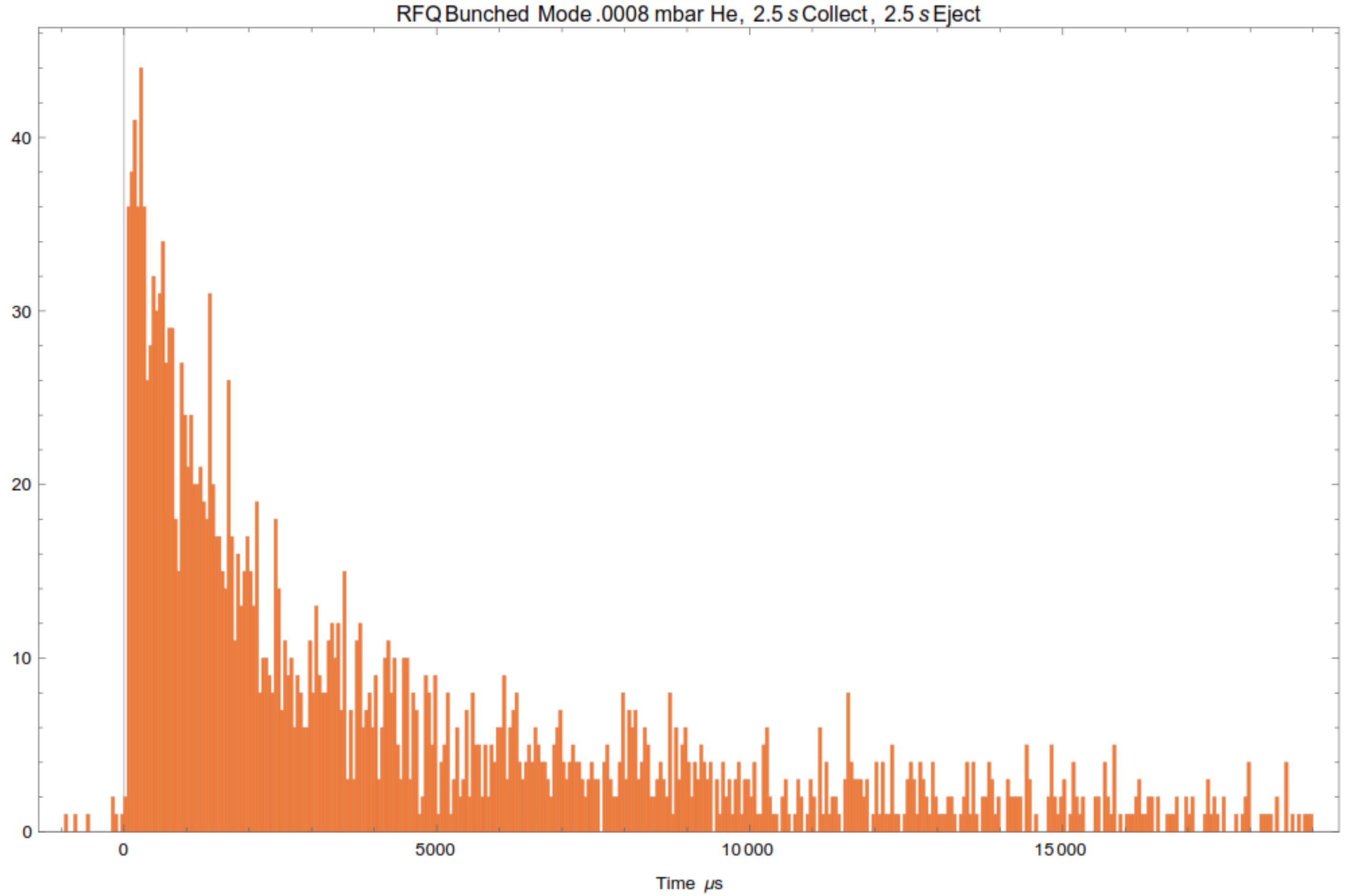
- The CPT group at ANL and the TITAN group at TRIUMF

- Cyclotron Institute employees and researchers

- Supported by the U.S. Department of Energy under grants ER41747 and ER40773

Backup Slides

Bunched Over Continuous

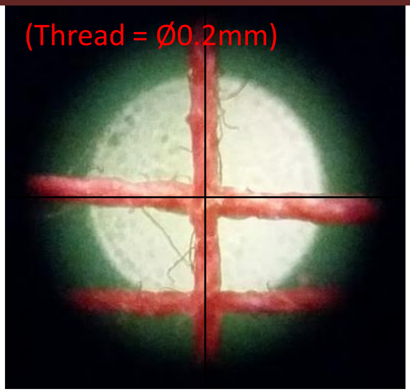


Beamline Losses / Feasibility

Calculating 32Ar requirements

Element	Efficiency (%)	Rate After Element (p/s)	Current (pA)
Measurement trap	100	5.00E+02	0.00008
Beamline	95	5.00E+02	0.00008
Purification	50	5.26E+02	0.00008416
Beamline	95	1.05E+03	0.00016832
RFQ (bunched mode)	50	1.11E+03	0.00017712
Beamline	95	2.21E+03	0.00035424
Magnet (coarse selection)	100	2.33E+03	0.00037296
Multi-RFQ	80	2.33E+03	0.00037296
Gas catcher	10	2.91E+03	0.00046624
Big Sol	30	2.91E+04	0.0046624
Production	100	9.71E+04	0.01554128

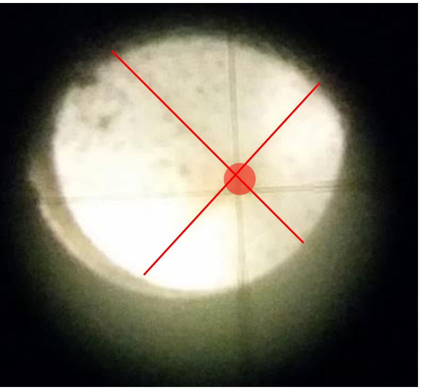
Beam Line Alignment



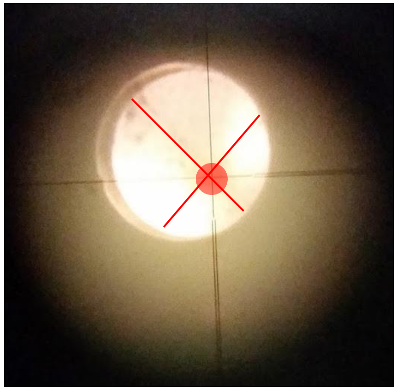
Ion Source Flange

1st Collimator (Ø2mm)

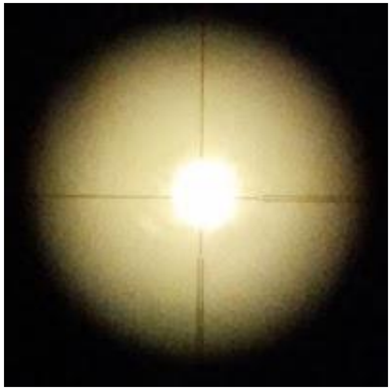
2nd Collimator (Ø10mm)



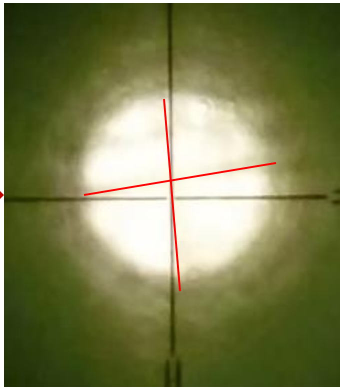
Injection 1 (Ø2mm)



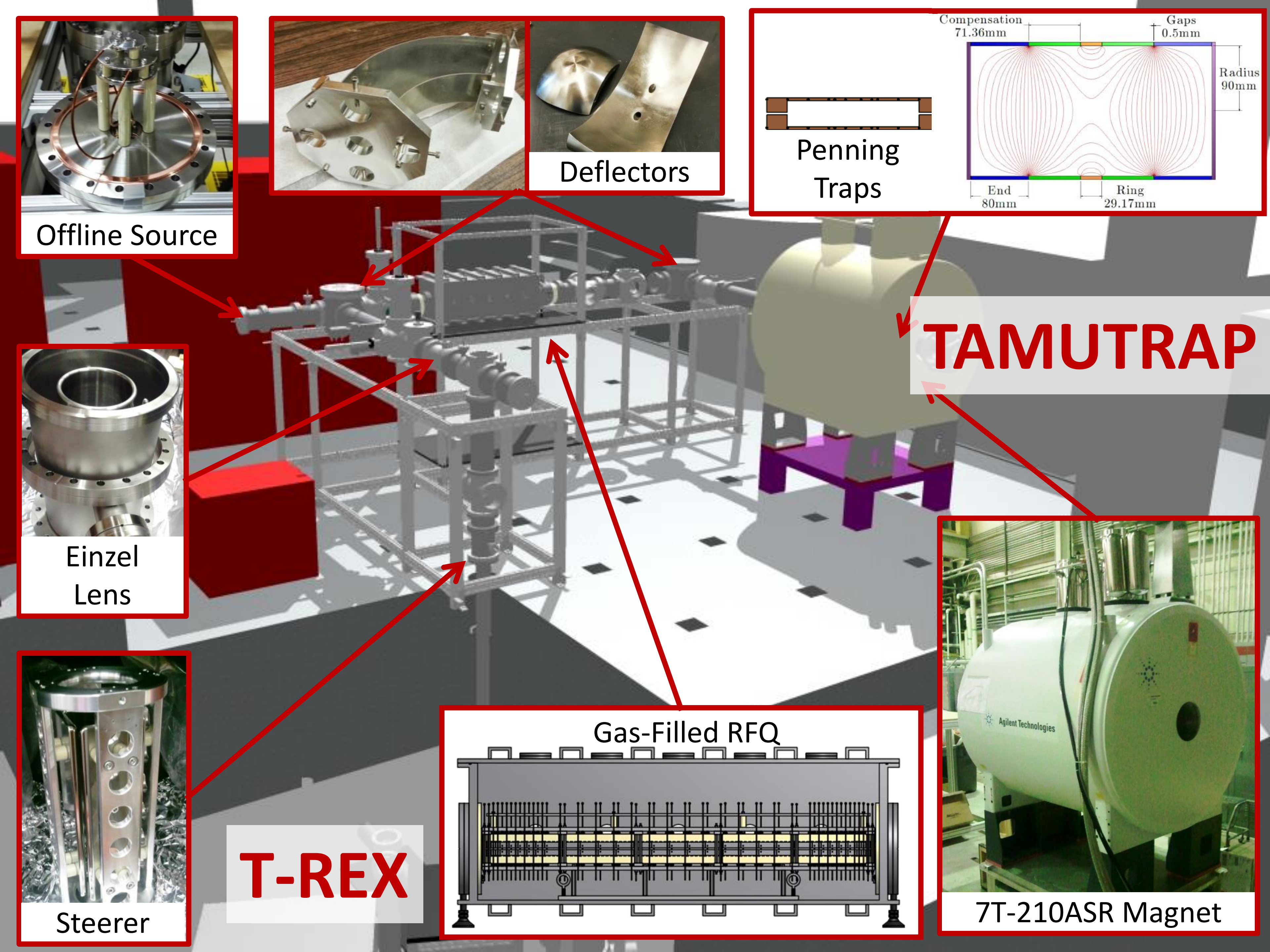
Injection 2 (Ø2mm)



RFQ Entrance (Ø6mm)



Extraction (Ø6mm)



Offline Source
Deflectors
Penning
Traps
Compensation
71.36mm
Gaps
0.5mm
Radius
90mm
End
80mm
Ring
29.17mm
TAMUTRAP
Einzel
Lens
Steerer
T-REX
Gas-Filled RFQ
Agilent Technologies
7T-210ASR Magnet

Measurement Trap

Electric field can be expanded as:

$$V = \frac{1}{2}V_0 \sum_{\substack{k=0 \\ k \text{ even}}}^{\infty} C_k \left(\frac{r}{d}\right)^k P_k(\cos\theta)$$

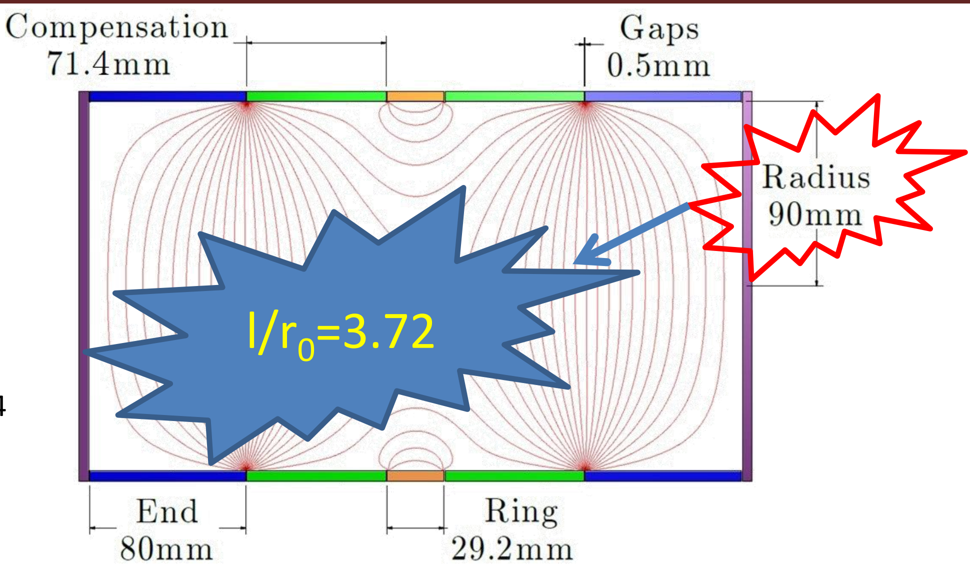
C_4 and higher order are anharmonic terms

Adding compensation electrodes allows for C_4 to be "tuned" out

A geometry exists where adjusting compensation does not affect C_2 ("orthogonal")

$$D_2 = 0 = \sum_{n=0}^{\infty} \frac{2\left\{\frac{\sin(k_n(z_0-z_{c2}))-\sin(k_n(z_0-z_c))}{\pi J_0(ik_n\rho_0)}\right\} d^k {k_n}^k (-1)^{k/2}}{k!}$$

Also minimize higher order terms ($C_{>4}$), most importantly C_6



C_i	TAMU Analytic	TAMU Simulated	TITAN Analytic	LEBIT Simulated
C_0	-5×10^{-1}	-5×10^{-1}	-	8×10^{-1}
C_2	5×10^{-1}	6×10^{-1}		1
C_4	-7×10^{-6}	9×10^{-4}	-7×10^{-6}	2×10^{-3}
C_6	6×10^{-6}	-3×10^{-3}	5×10^{-5}	-4×10^{-3}
C_8	-4×10^{-2}	-4×10^{-2}	-	3×10^{-3}

Calculated tuning (C_4=0) condition: V_c/V_o = -0.371
Maximum machining precision ~0.03mm
SIMION Precision limited to ~3×10^{-3}

M. Mehlman et al.,NIM A 712, 0168-9002 (2013)

Beam Properties

Production	Big Sol	Gas catcher	Pre RFQ	RFQ	Post RFQ
• t=0	• In flight	• Few ms	• Few µs	• 2-10ms	• Few µs

Gas catcher	Pre RFQ	RFQ	Post RFQ	Trap system
• 200-250 mbar	• 10^{-6} mbar	• $10^{-2} – 10^{-4}$ mbar	• 10^{-8} mbar	• <10^{-9} mbar

Gas Catcher	Beam Line	Einzel	Steerer	Deflector	RFQ	Pulsing Cavity	Traps
• 10kV	• 0V	• 0-7kV	• 0-200V	• 4-5kV	• 10kV	• 10kV->2.5kV • 2.5kV->10V	• 0-100V

Production	Gas catcher	Beam Line	RFQ	Beam Line	Traps
•Tens of MeV	•Thermal (~.08 eV + KE)	•10 keV	•Thermal (~.08 eV + KE)	•10keV→2.5keV→10eV	•Tens of eV or less