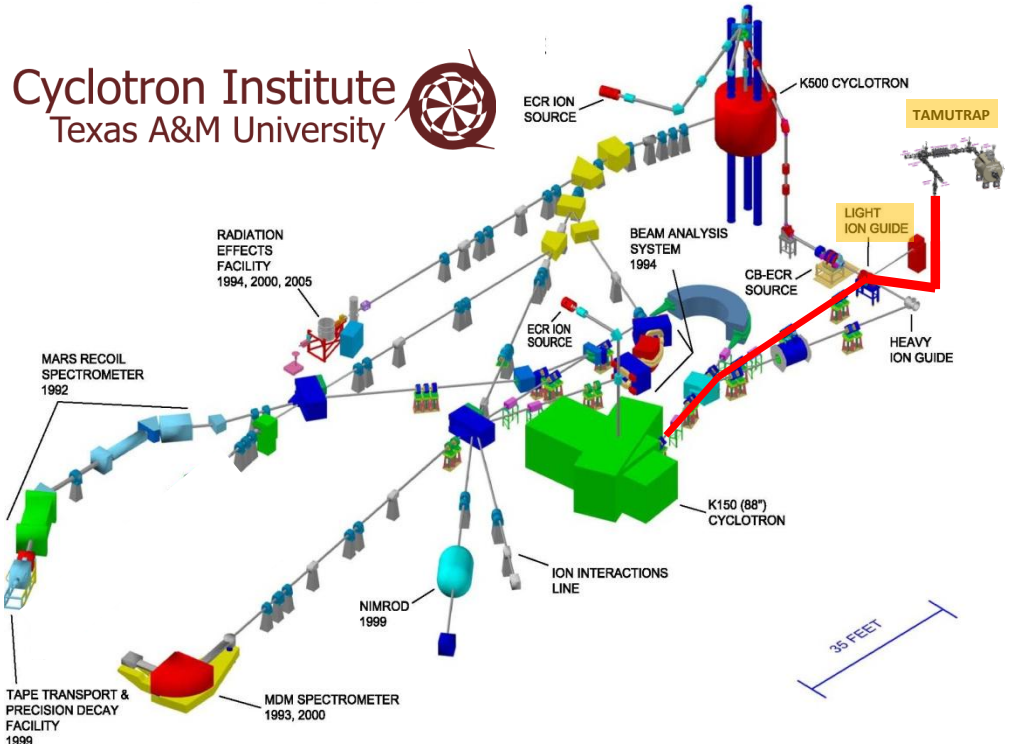
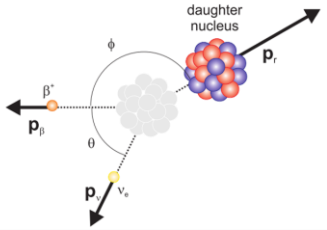
TAMUTRAP facility:
Penning trap facility for weak interaction studies

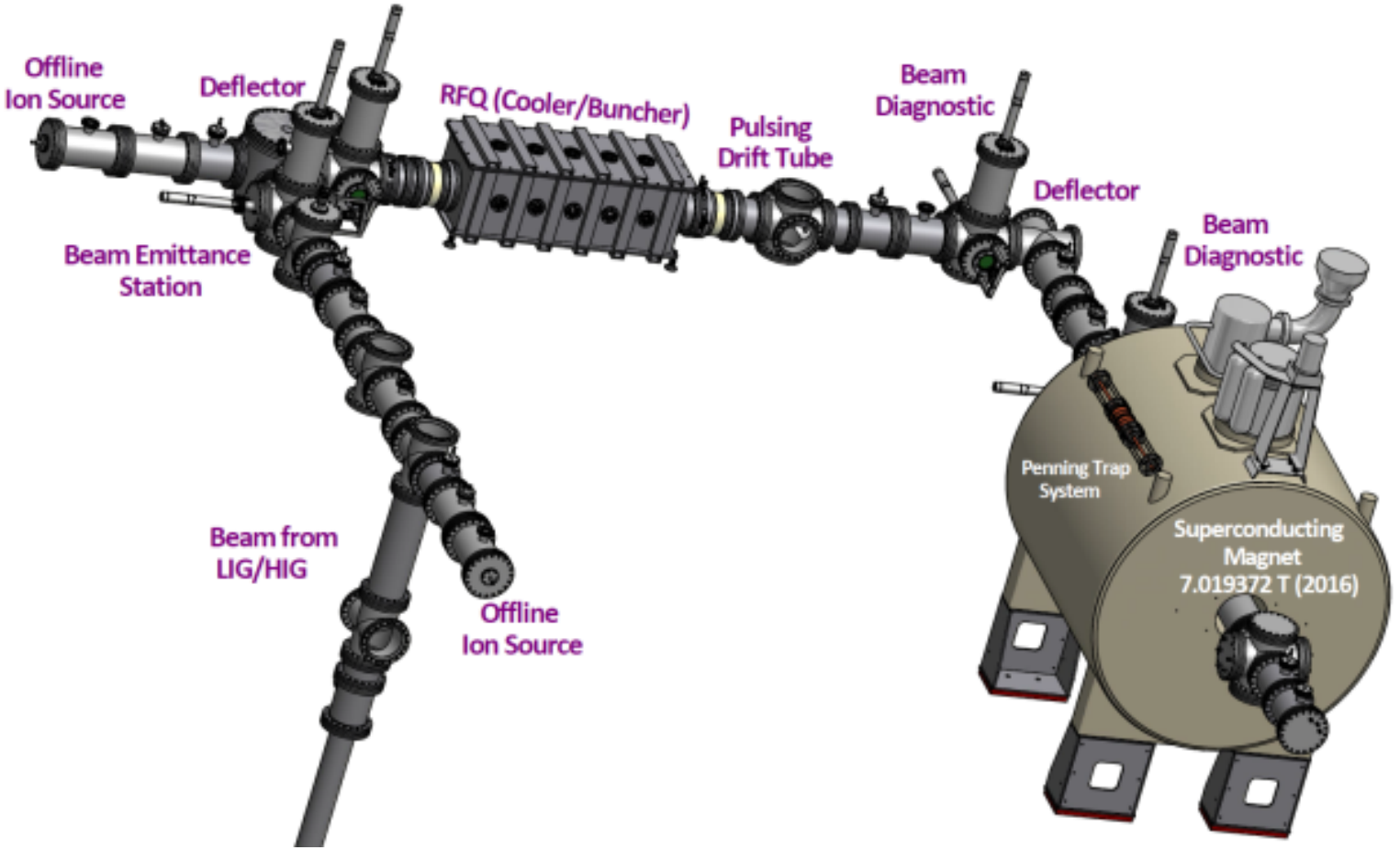




P.D. Shidling
Cyclotron Institute,
Texas A&M University, USA

Planned Physics program @ TAMUTRAP Facility

- Angular correlation parameter.
- Measurement of *ft* value.
- Mass measurement, Decay station….



Angular correlation parameter $(a_{\beta\nu})$

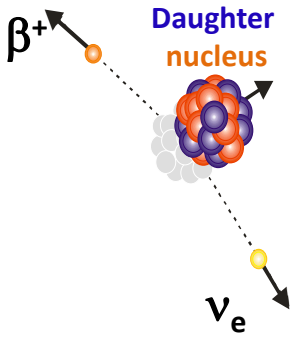
Nuclear β-decay = Governed by Weak force

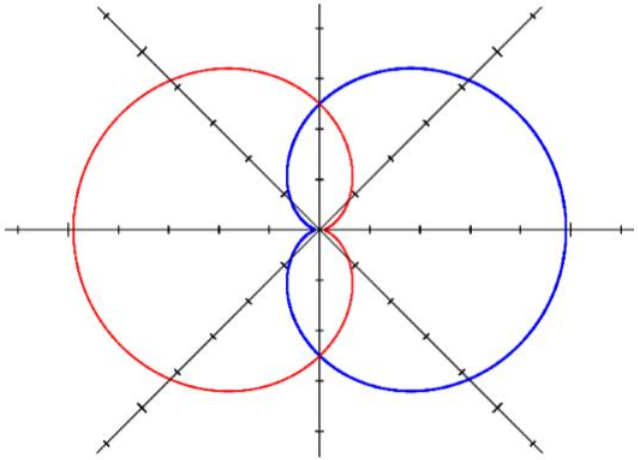
$$W(E_e, \Omega_e, \Omega_\nu) \propto \frac{F(\pm Z, E_e)}{(2\pi)^5} p_e E_e (A_o - E_e)^2 dE_e d\Omega_e d\Omega_\nu \xi \left(1 + a_{\beta\nu} \frac{\boldsymbol{p_e} \cdot \boldsymbol{p_\nu}}{E_e E_\nu} + b \frac{m_e}{E_e} + \dots\right)$$

Pure Fermi Transition:

Beyond Standard Model

$$a_{\beta\nu} = \frac{-|C_S|^2 - |C'_S|^2}{|C_S|^2 + |C'_S|^2}$$

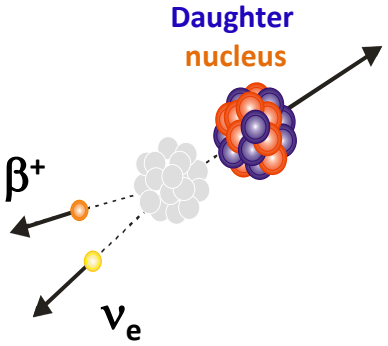




$$a_{\beta\nu} \stackrel{?}{=} 1$$

Standard Model

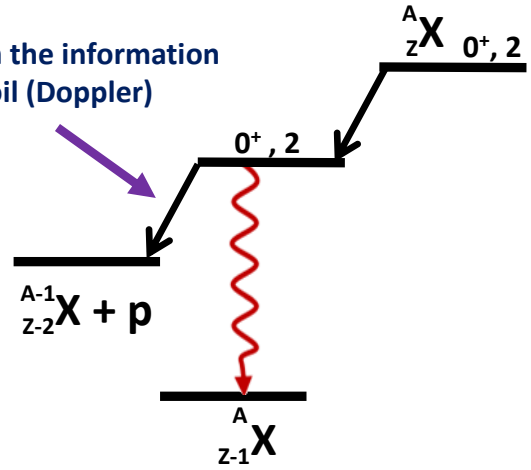
$$a_{\beta\nu} = \frac{|C_V|^2 + |C'_V|^2}{|C_V|^2 + |C'_V|^2}$$

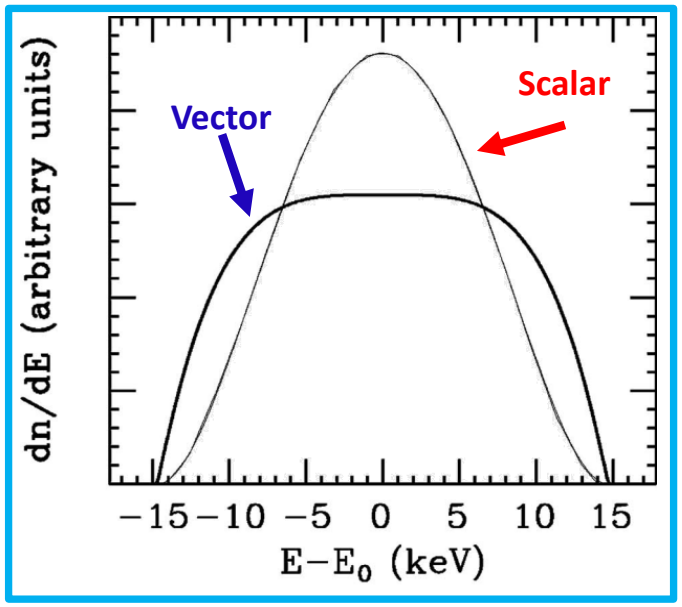


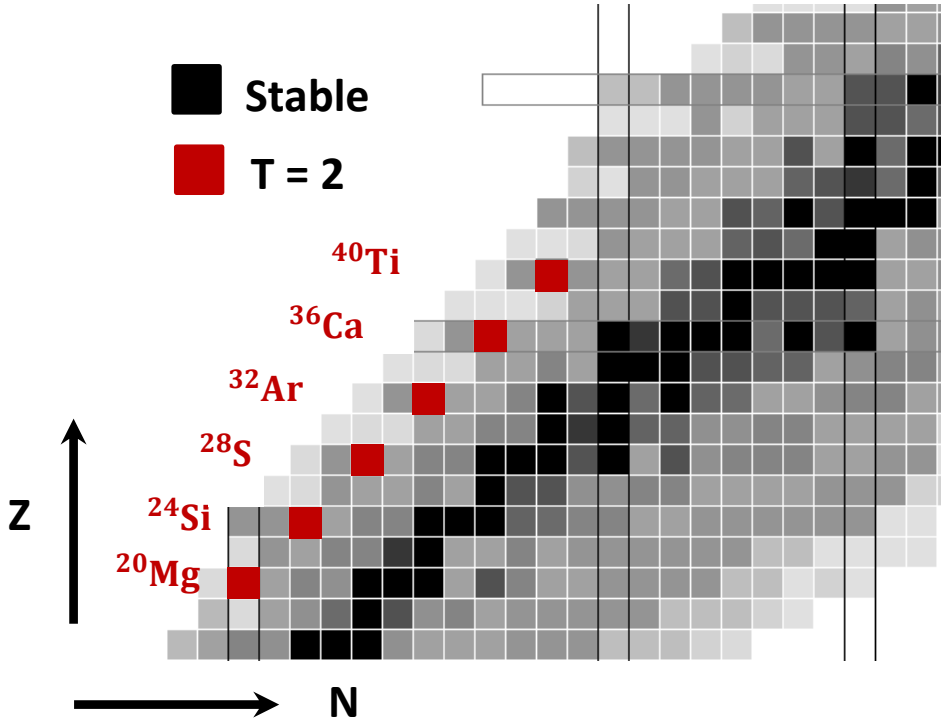
Superallowed pure Fermi Transition

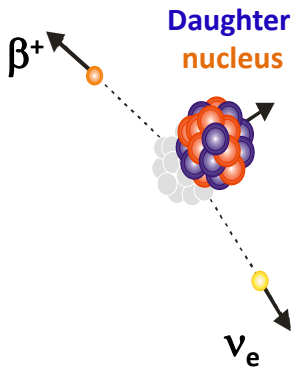
Beta delayed proton decay

Proton contain the information about ^{32}Cl recoil (Doppler)

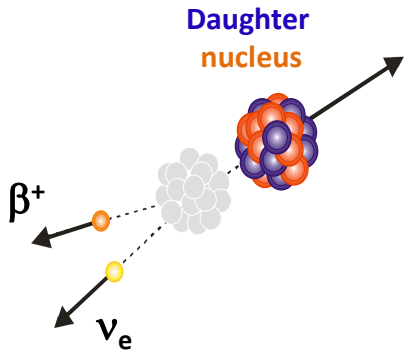








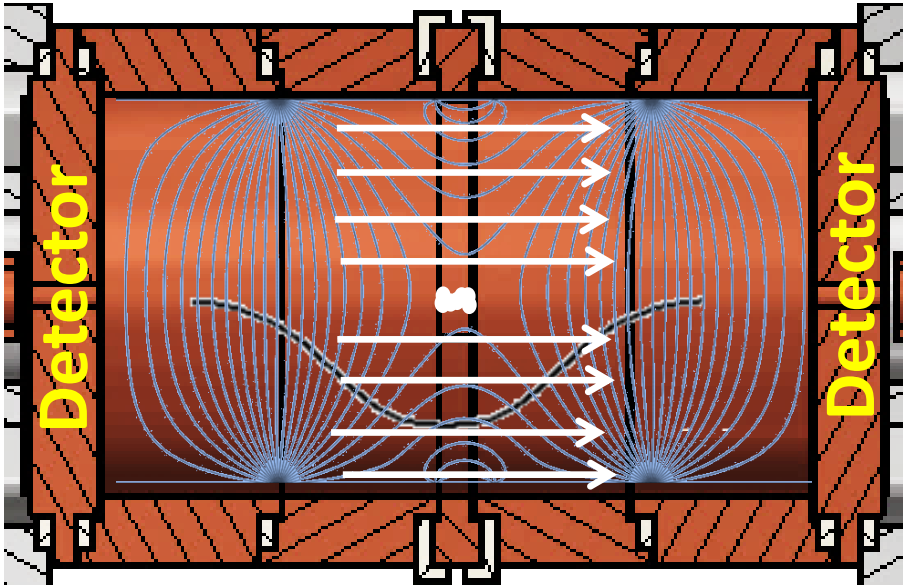
Scalar



Vector

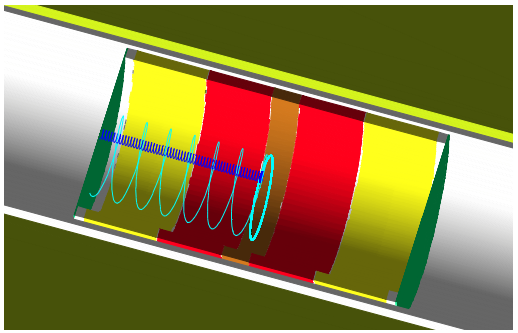
Adelberger E.G. et al. Phys. Rev. Lett. 1299 ***83*** *(1999)*

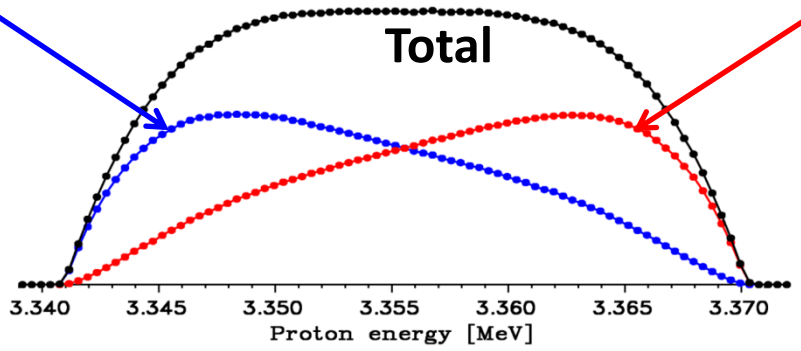
Penning trap for $\beta - \nu$ correlation parameter



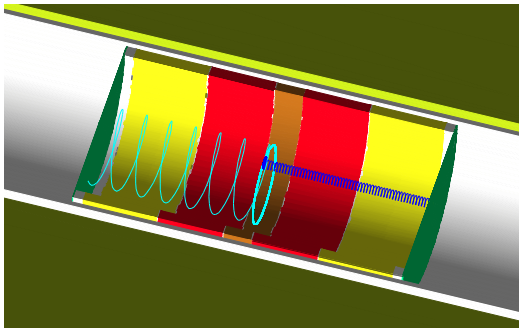
- Increase solid angle.
- Increase sensitivity.
- Allows to detect e along with p

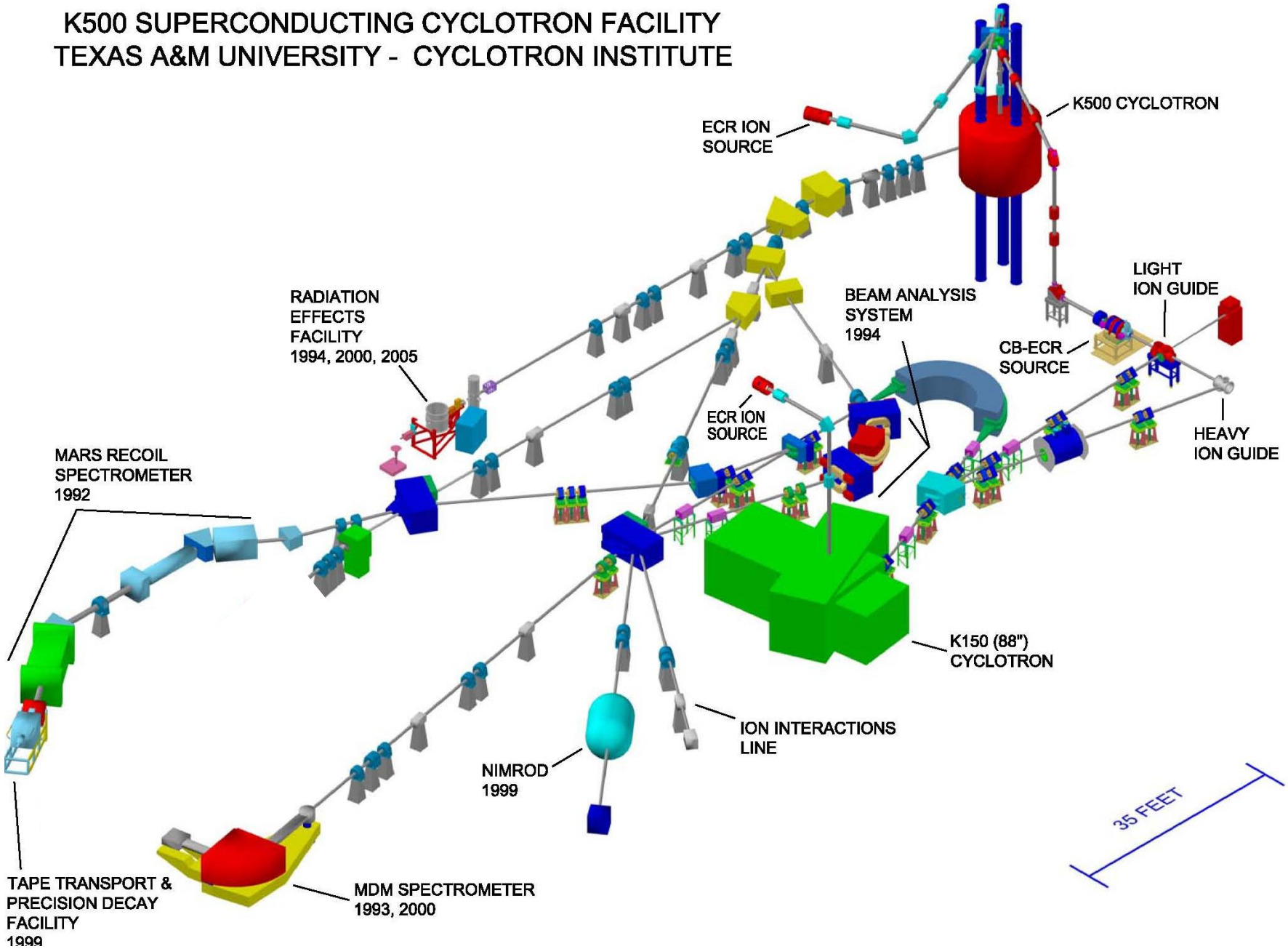
Beta & Proton in same hemisphere





Beta & Proton in different hemisphere

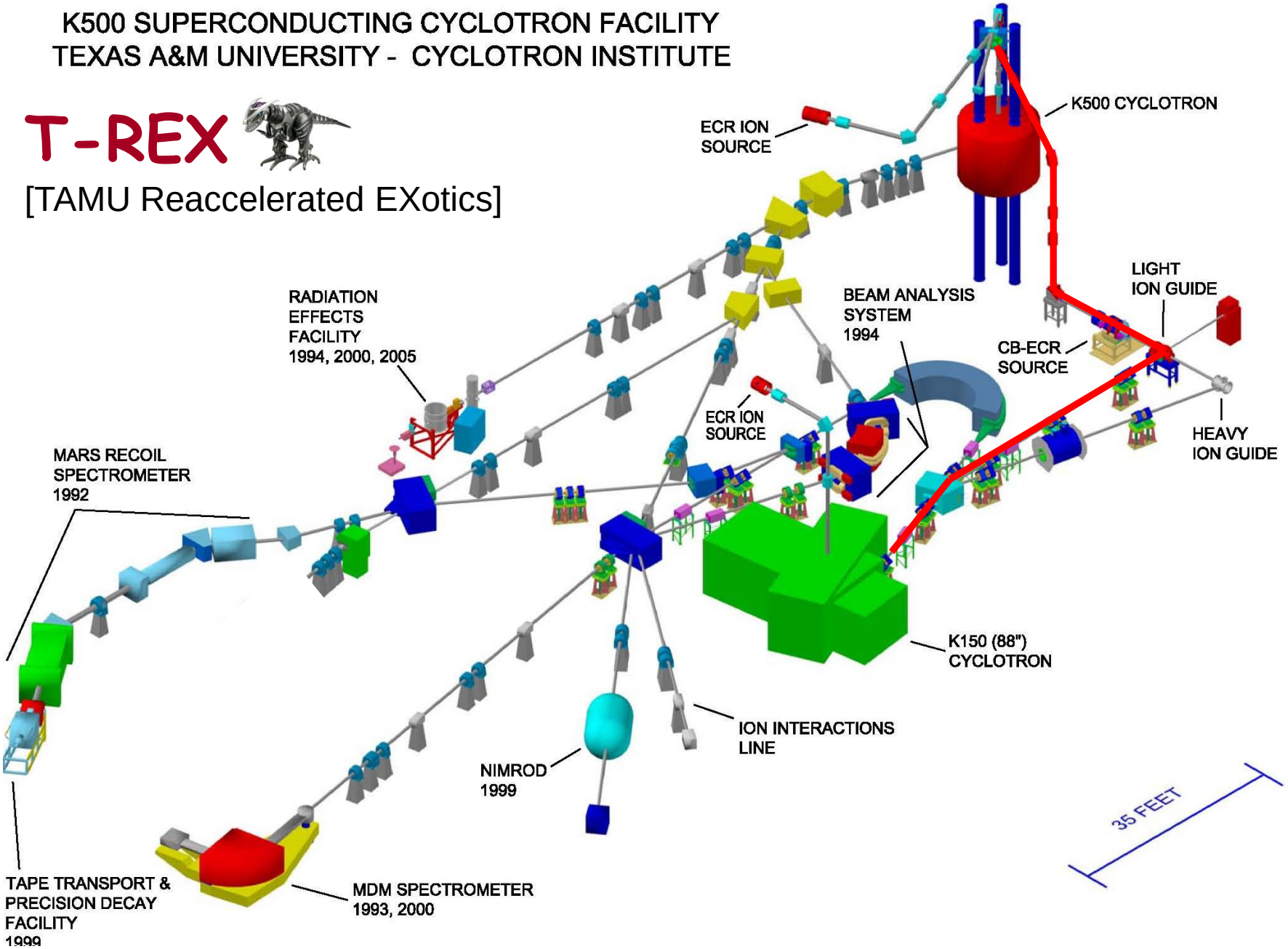


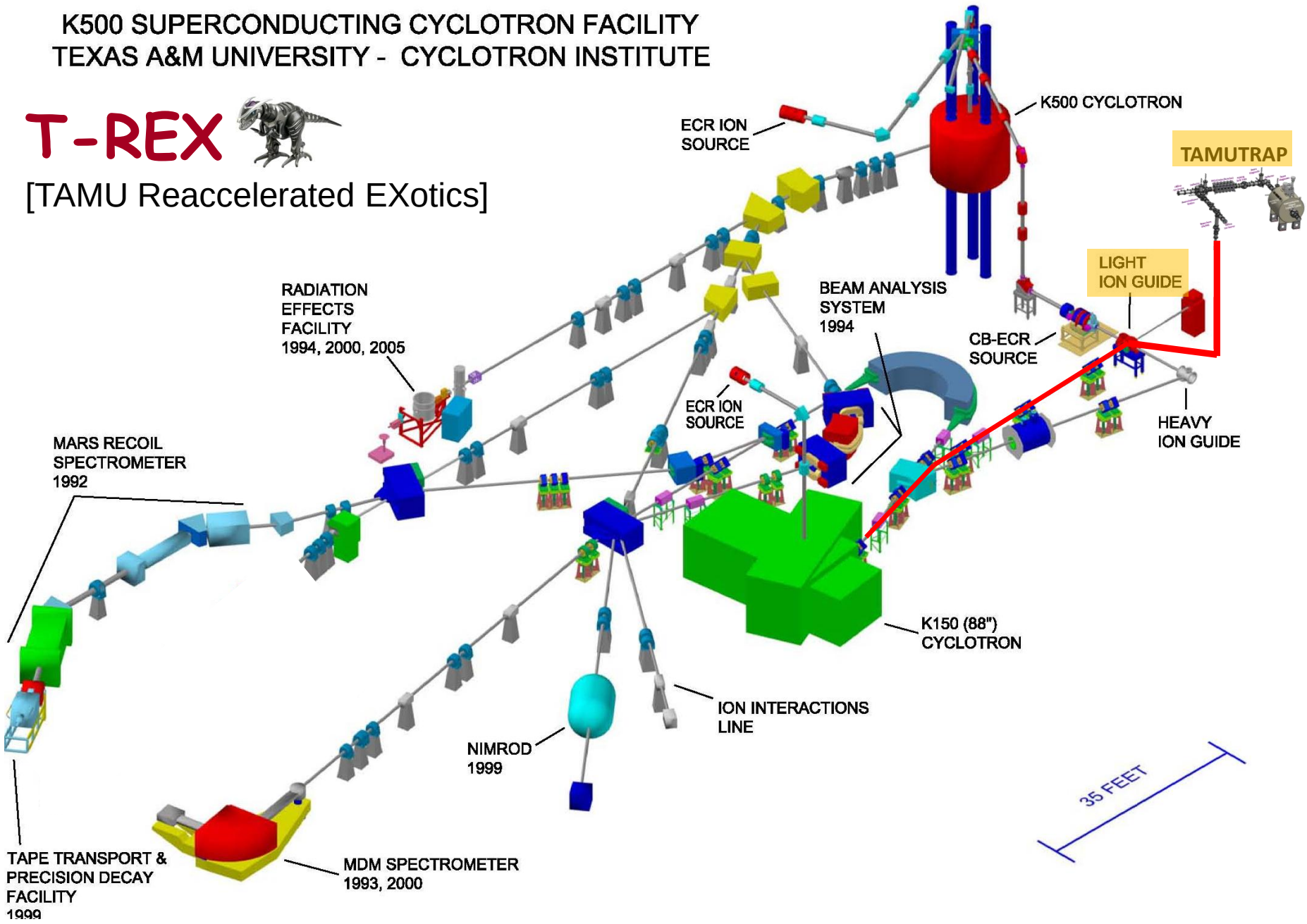

K500 SUPERCONDUCTING CYCLOTRON FACILITY
TEXAS A&M UNIVERSITY - CYCLOTRON INSTITUTE
ECR ION SOURCE
K500 CYCLOTRON
RADIATION EFFECTS FACILITY 1994, 2000, 2005
BEAM ANALYSIS SYSTEM 1994
LIGHT ION GUIDE
CB-ECR SOURCE
ECR ION SOURCE
HEAVY ION GUIDE
MARS RECOIL SPECTROMETER 1992
K150 (88") CYCLOTRON
ION INTERACTIONS LINE
NIMROD 1999
35 FEET
TAPE TRANSPORT & PRECISION DECAY FACILITY 1999
MDM SPECTROMETER 1993, 2000

K500 SUPERCONDUCTING CYCLOTRON FACILITY
TEXAS A&M UNIVERSITY - CYCLOTRON INSTITUTE

T-REX

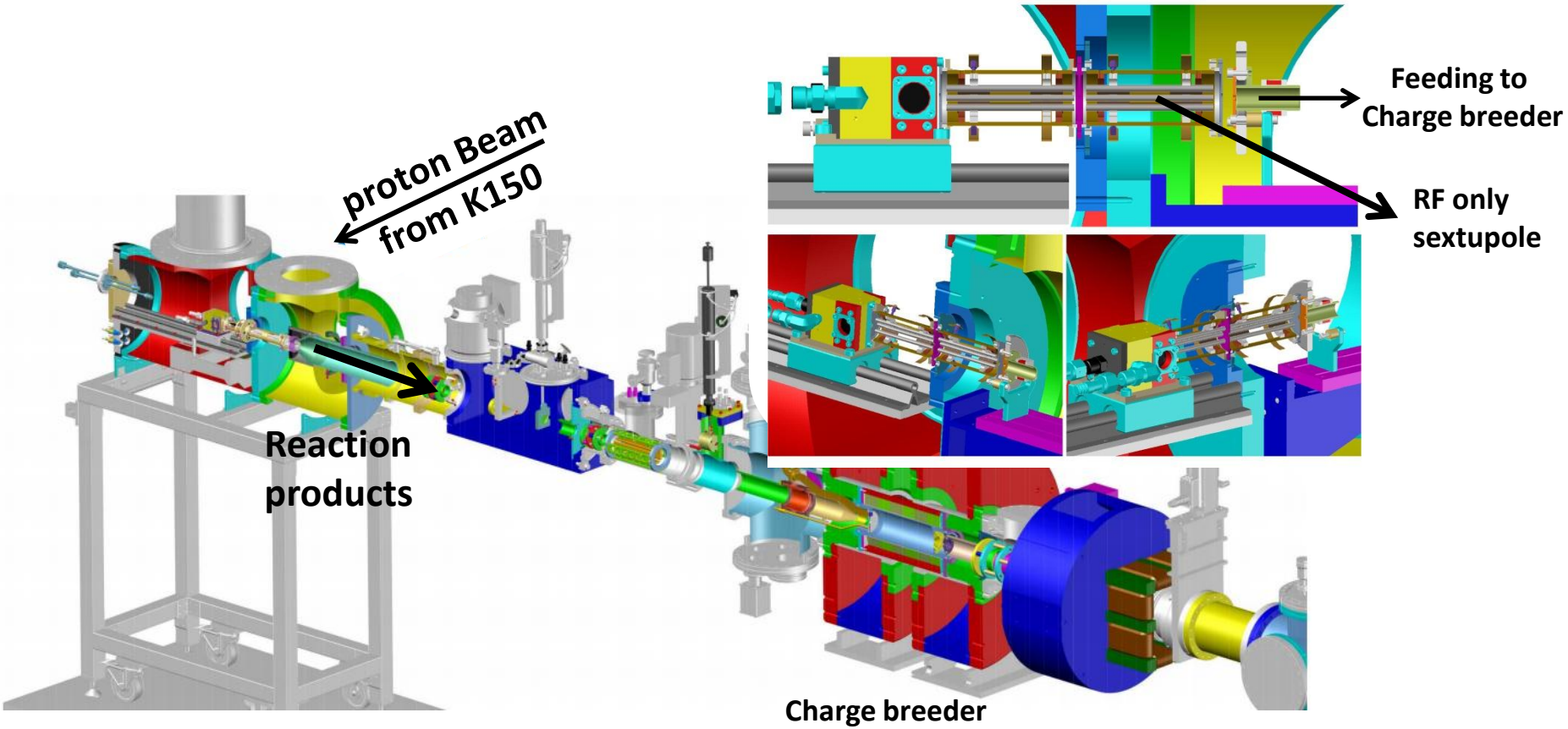
[TAMU Reaccelerated EXotics]



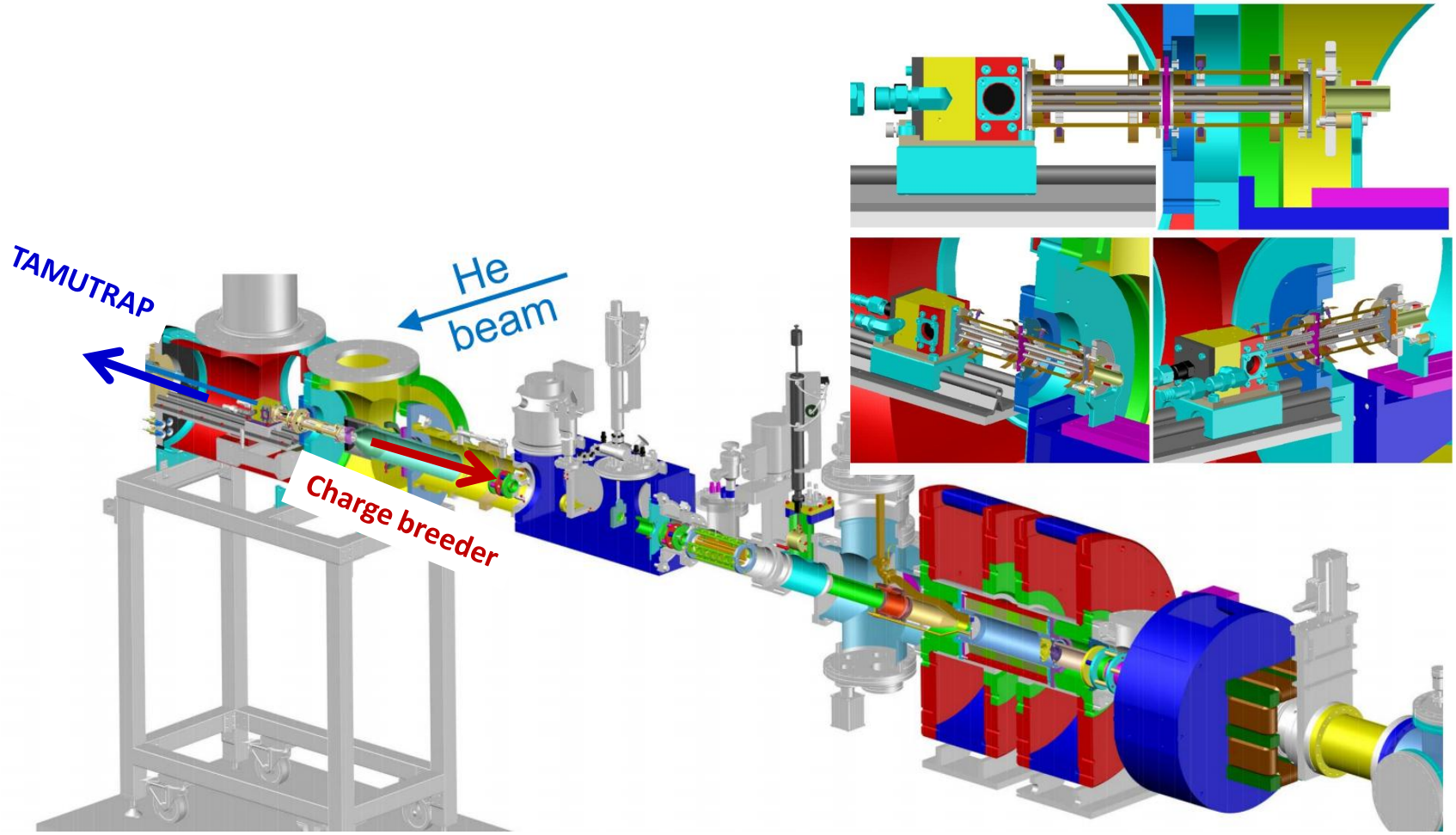

K500 SUPERCONDUCTING CYCLOTRON FACILITY
TEXAS A&M UNIVERSITY - CYCLOTRON INSTITUTE
T-REX
[TAMU Reaccelerated EXotics]
ECR ION SOURCE
K500 CYCLOTRON
TAMUTRAP
LIGHT ION GUIDE
RADIATION EFFECTS FACILITY 1994, 2000, 2005
BEAM ANALYSIS SYSTEM 1994
CB-ECR SOURCE
ECR ION SOURCE
HEAVY ION GUIDE
MARS RECOIL SPECTROMETER 1992
K150 (88") CYCLOTRON
ION INTERACTIONS LINE
NIMROD 1999
35 FEET
TAPE TRANSPORT & PRECISION DECAY FACILITY 1999
MDM SPECTROMETER 1993, 2000

Approach: Light Ion Guide

- (p,n), (d,p) and (He,n) reaction.
- Light ion induced fission.
- Current operating pressure 100-130 mbar.

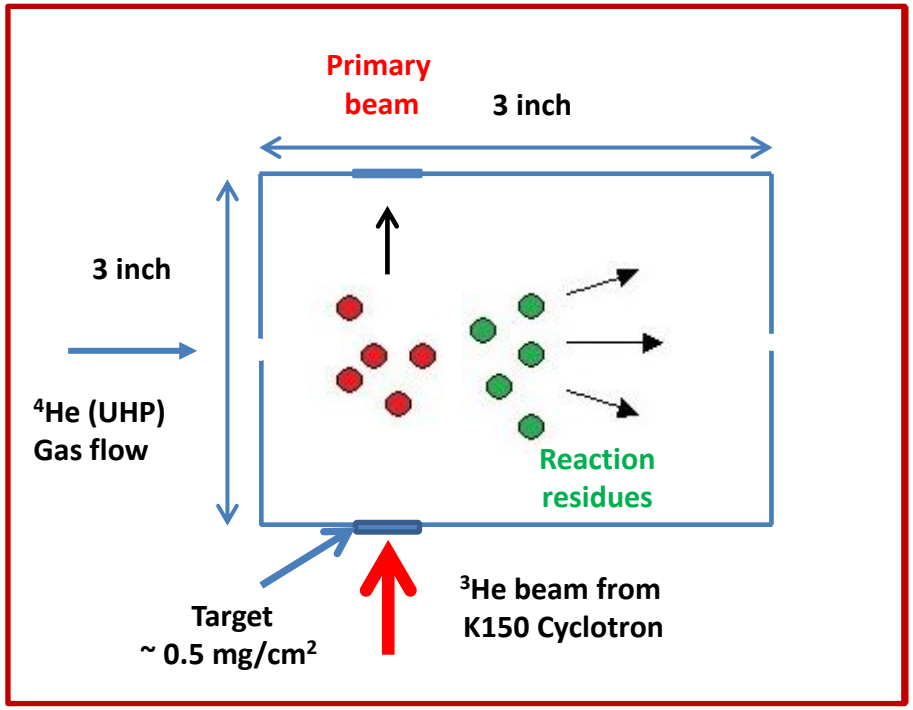


LIG for producing proton rich nuclei



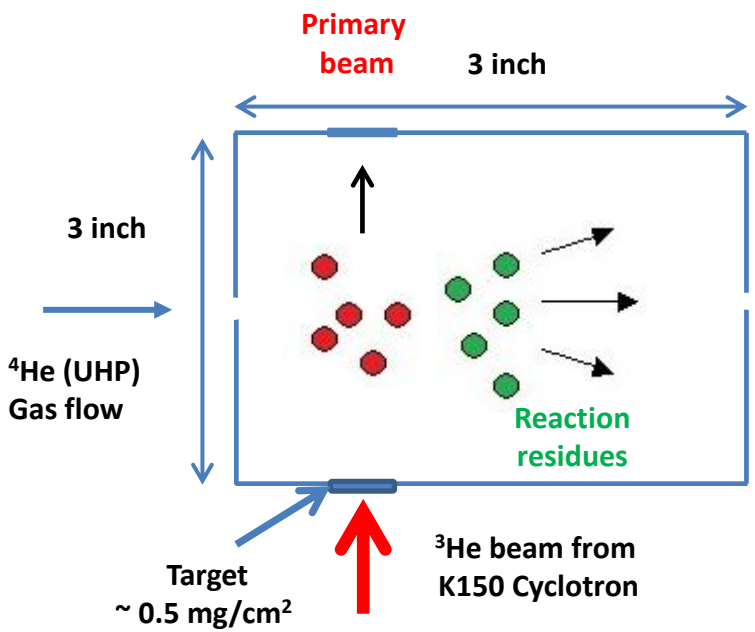
LIG for producing proton rich nuclei

New gas cell suitable for ^{3}He induced reactions.

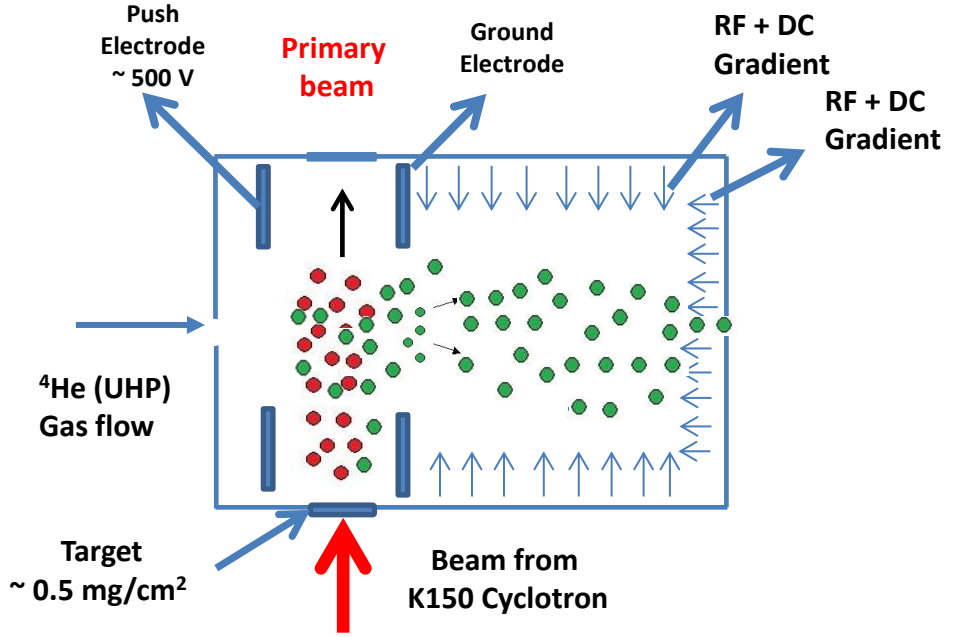


LIG for producing proton rich nuclei

New gas cell suitable for ^{3}He induced reactions.

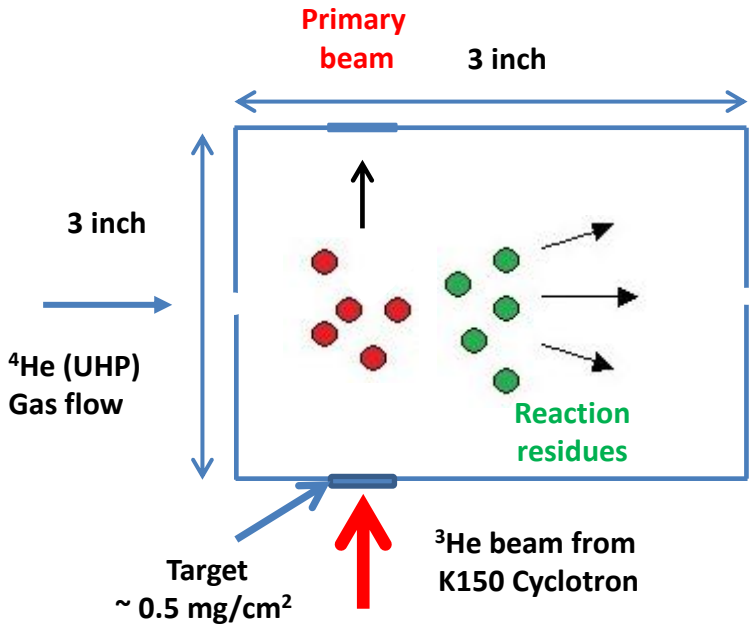


New gas cell suitable for ^{3}He induced reactions with RF Voltage.

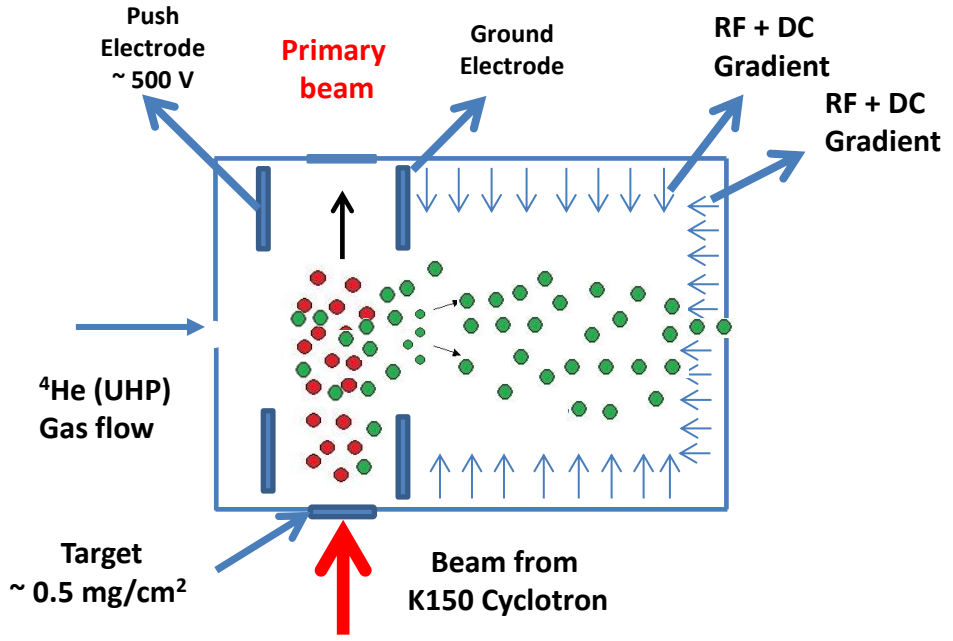


LIG for producing proton rich nuclei

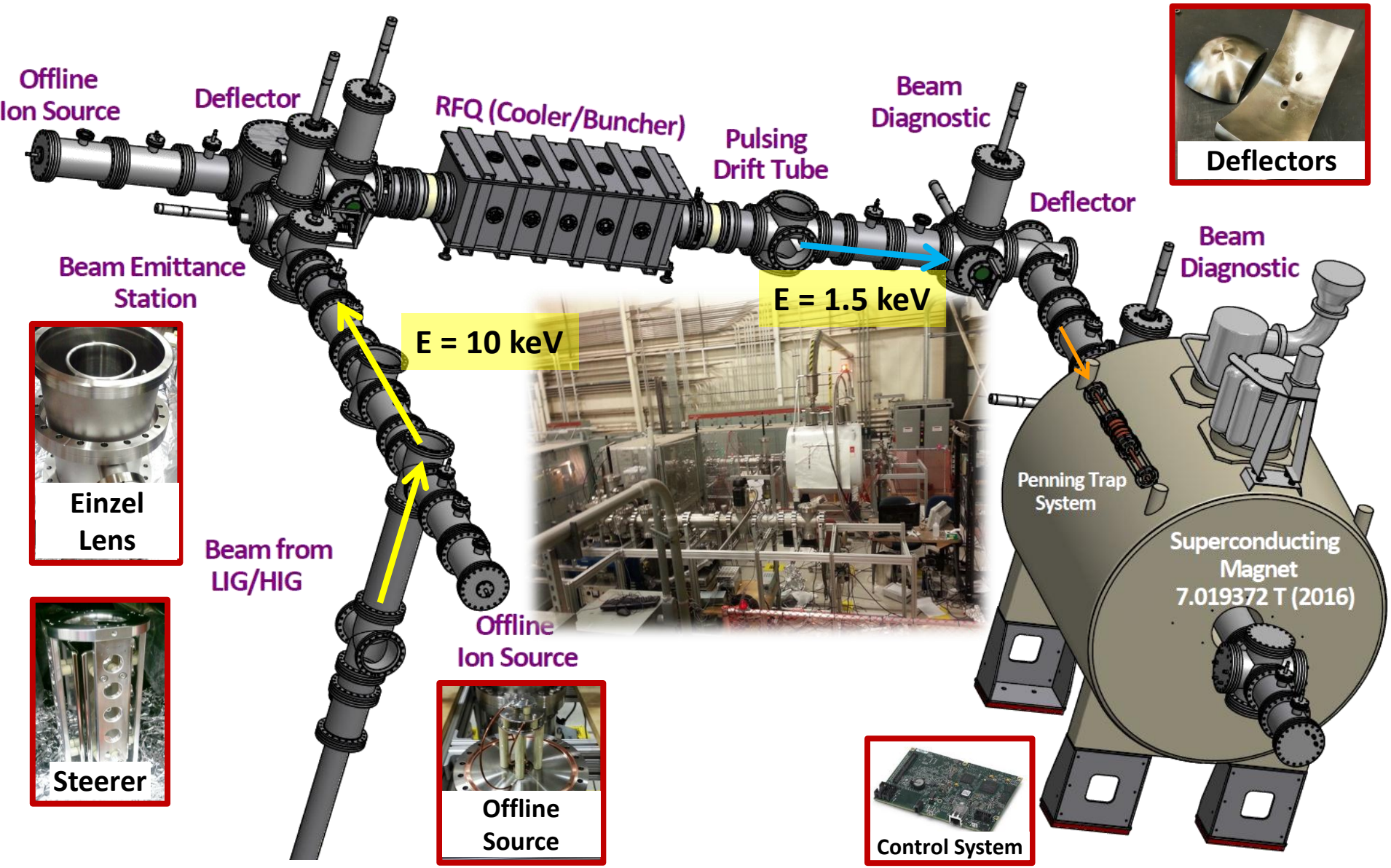
New gas cell suitable for ^{3}He induced reactions.



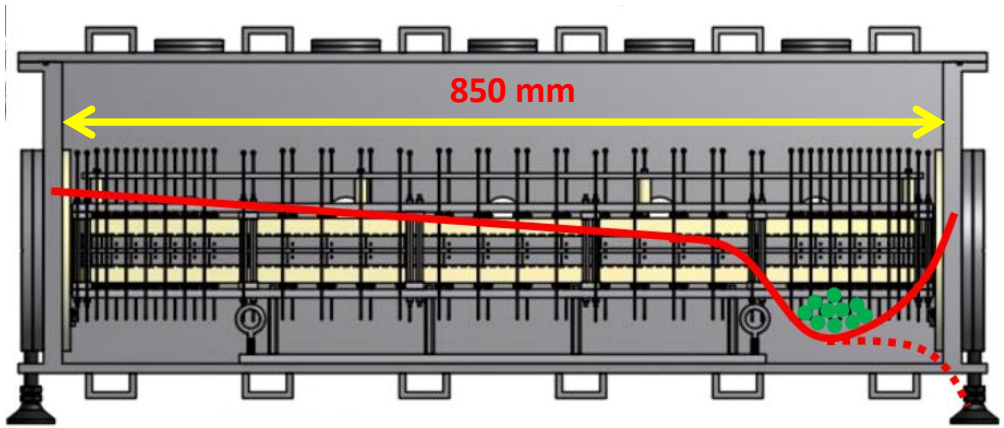
New gas cell suitable for ^{3}He induced reactions with RF Voltage.

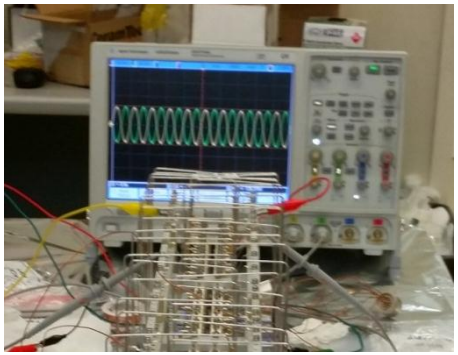


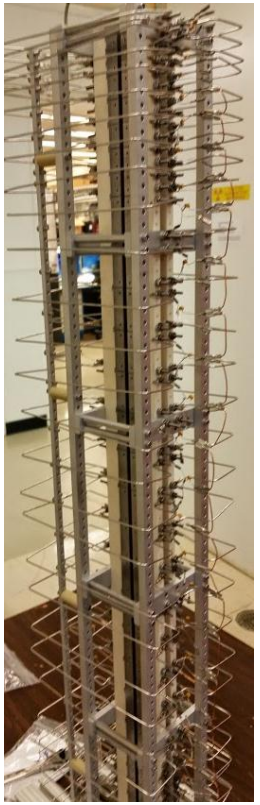
TAMUTRAP facility



TAMUTRAP facility: Cooler/Buncher

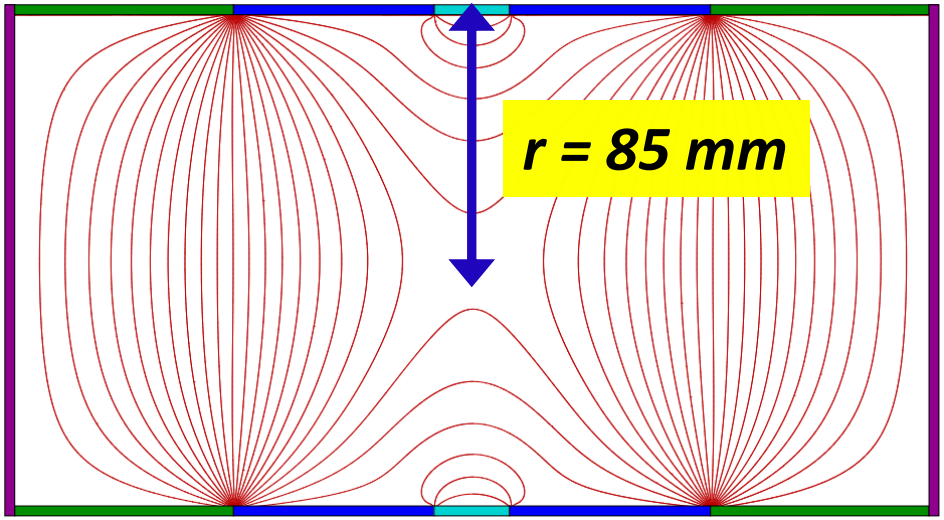






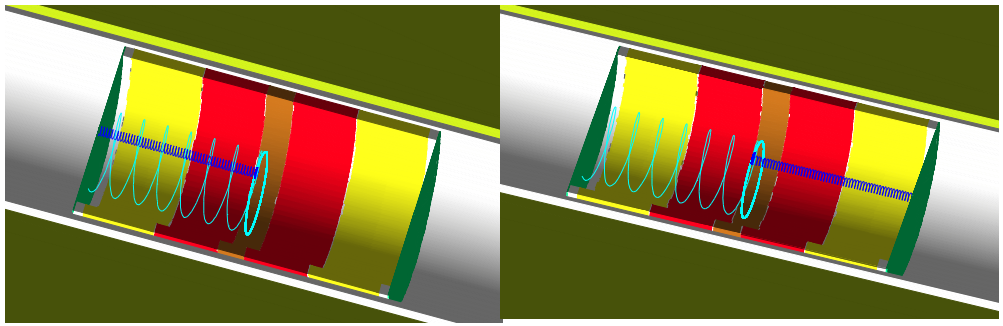
Operating Pressure : 10^{-2} – 10^{-4} mbar.
Cooling time : 2 – 20 ms.
FWHM: 1 to 1.5 μ s.

TAMUTRAP: Penning Trap



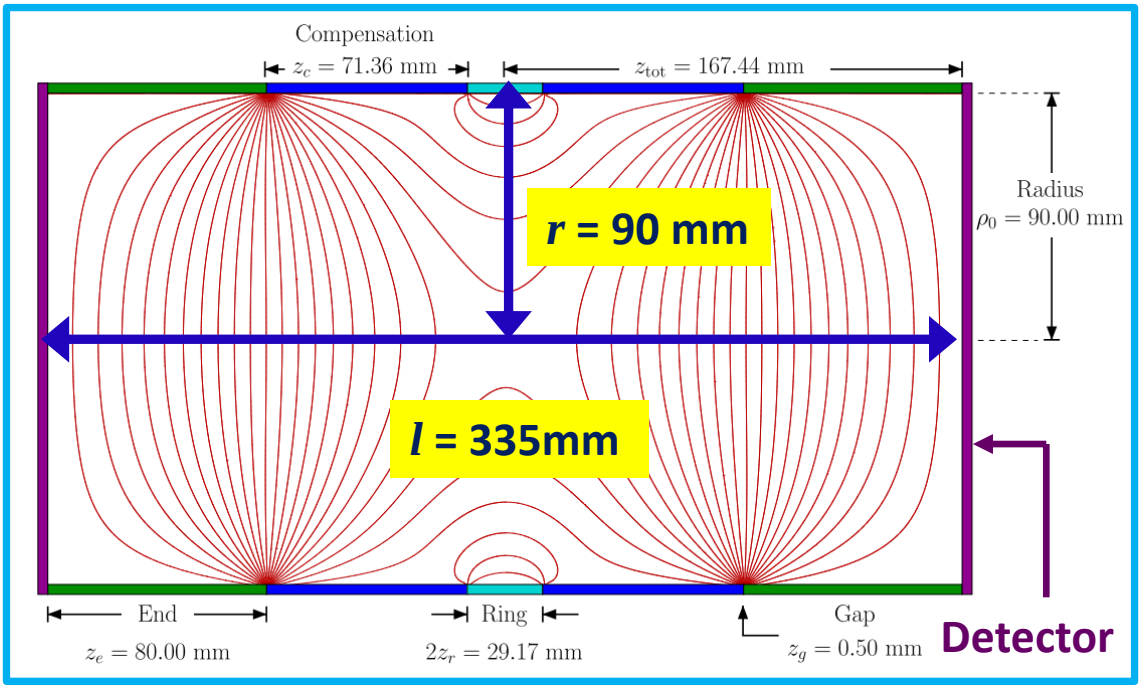
Inner diameter of the trap to contain decay products (protons, electrons):

Diameter = 170 mm.

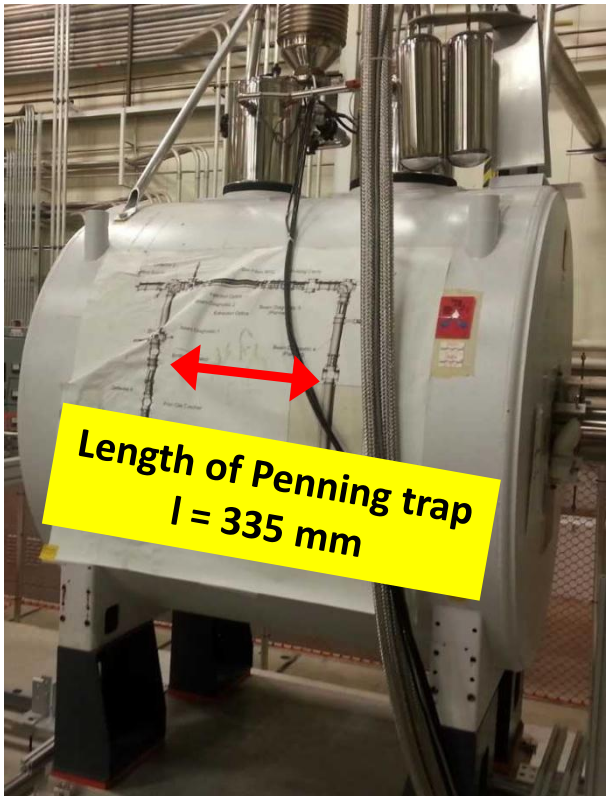


Nuclide	Proton Energy (MeV)	Larmour radii (mm)
^{20}Mg	4.28	42.7
^{24}Si	3.91	40.8
^{28}S	3.70	39.7
^{32}Ar	3.36	37.8
^{36}Ca	2.55	33.0
^{40}Ti	3.73	39.9
^{48}Fe	1.23	22.9

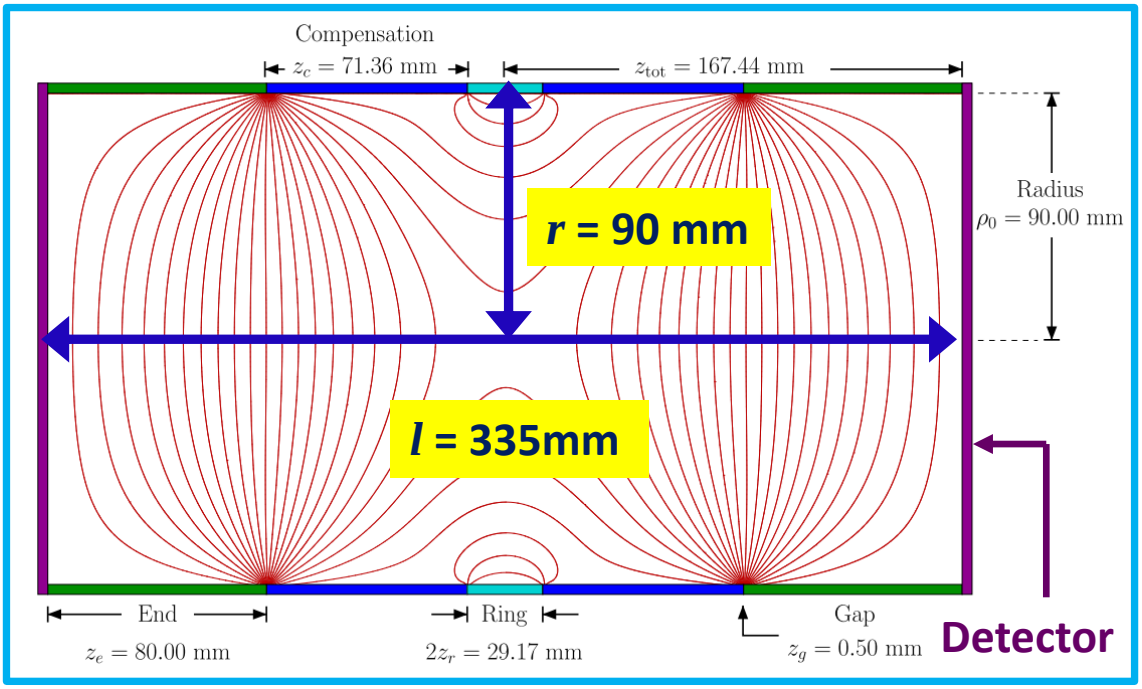
TAMUTRAP: Penning Trap (*l* /*r* = 3.72)



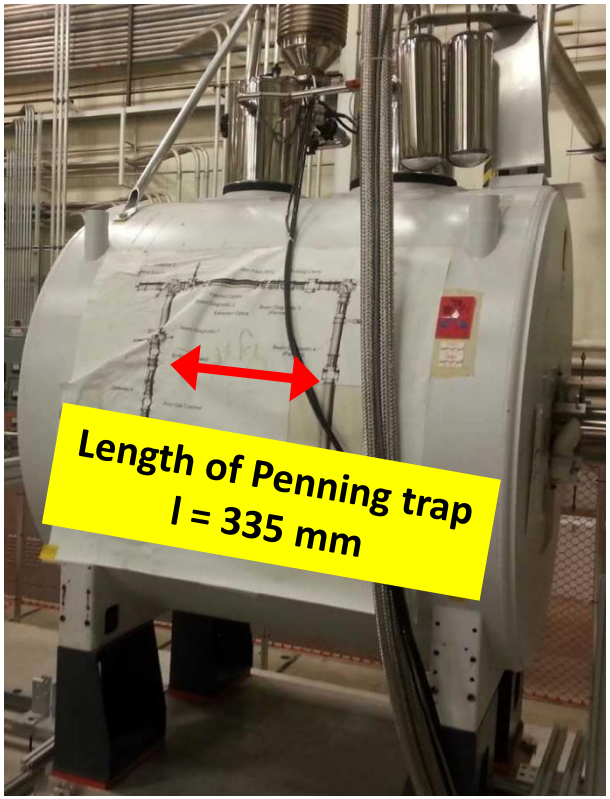
*M. Mehlman et al. NIMA **712** (2013) 9*



TAMUTRAP: Penning Trap (*l* /*r* = 3.72)



*M. Mehlman et al. NIMA **712** (2013) 9*



C_i	TAMU Analytic	TAMU Simulated	TITAN Analytic	PENTATRAP Analytic	LEBIT Simulated
C_0	−5e−1	−5e−1	–	–	8e−1
C_2	+5e−1	+6e−1	–	−2e−2	1e0
C_4	−7e−6	+9e−4	−7e−6	4e−6	2e−3
C_6	+6e−6	−3e−3	+5e−5	2e−7	−4e−3
C_8	−4e−2	−4e−2	–	−1e−1	3e−3

Dimension optimized to perform high precision mass measurement.

Commissioning of TAMUTRAP facility

Mass measurement of ^{23}Na

Time-of-flight cyclotron resonance technique:

- Dipole excitation for 10 ms.
- Quadrupole excitation for 100 ms.
- Reference mass : ^{39}K

20 ms excitation (solid points, red curve)

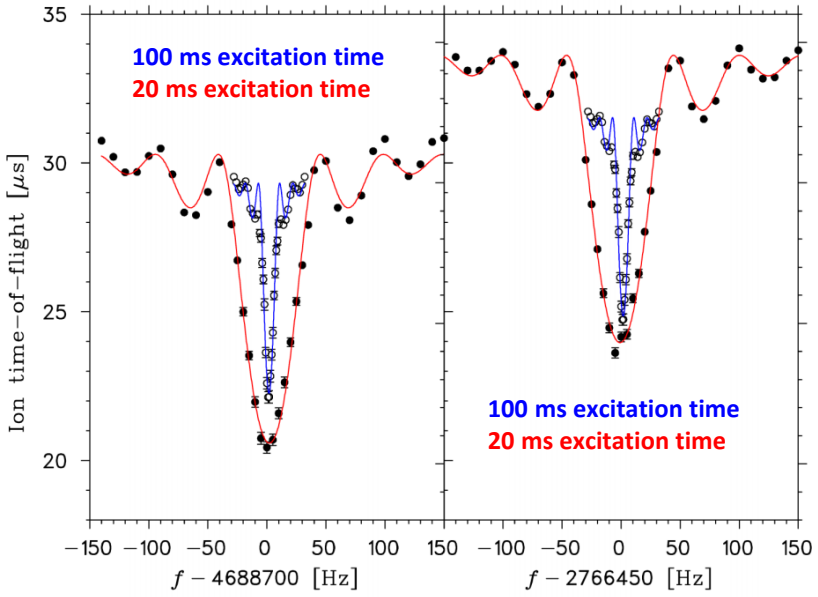
$M_{diff} = calc - AME$

$= 2.8 \pm 2.5$ keV (0.13 ppm measurement)

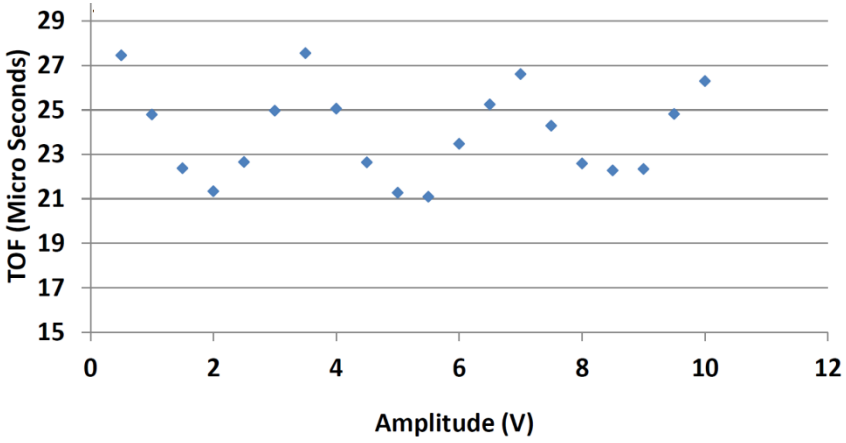
100 ms (open points, blue curve)

$M_{diff} = calc - AME$

$= -0.3 \pm 1.3$ keV (0.06 ppm measurement)



Amplitude scan @ 100 ms excitation time



Prototype Penning Trap
With l/r = 3.72 ; ID: 45 mm

Commissioning of TAMUTRAP facility

Mass measurement of ^{23}Na

Time-of-flight cyclotron resonance technique:

- Dipole excitation for 10 ms.
- Quadrupole excitation for 100 ms.
- Reference mass : ^{39}K

20 ms excitation (solid points, red curve)

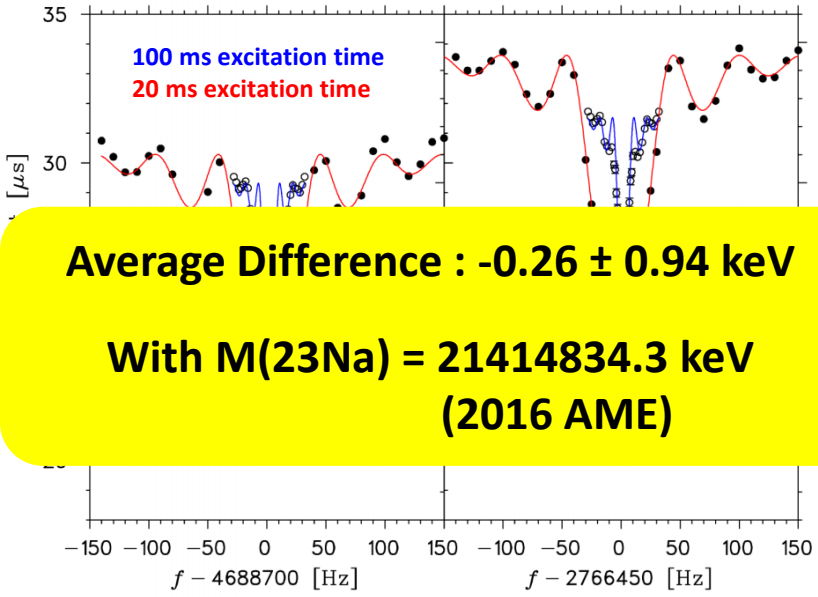
$M_{diff} = calc - AME$

$= 2.8 \pm 2.5$ keV (0.13 ppm measurement)

100 ms (open points, blue curve)

$M_{diff} = calc - AME$

$= -0.3 \pm 1.3$ keV (0.06 ppm measurement)

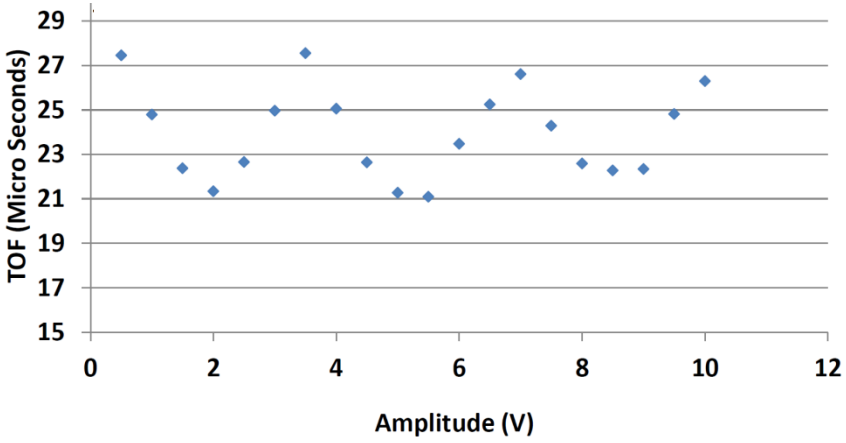


Average Difference : -0.26 ± 0.94 keV

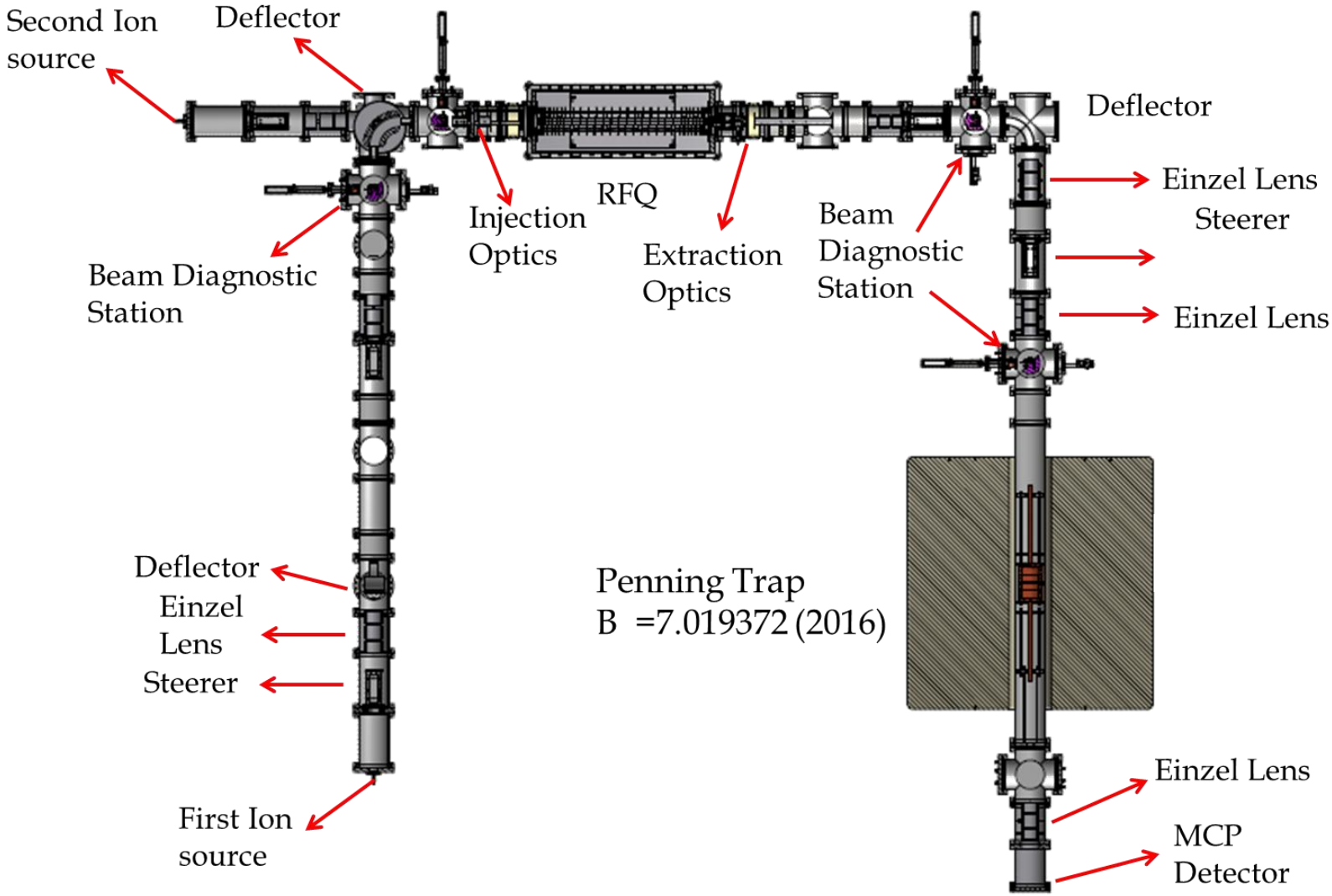
With M(23Na) = 21414834.3 keV (2016 AME)

Prototype Penning Trap
With l/r = 3.72 ; ID: 45 mm

Amplitude scan@ 100 ms excitation time

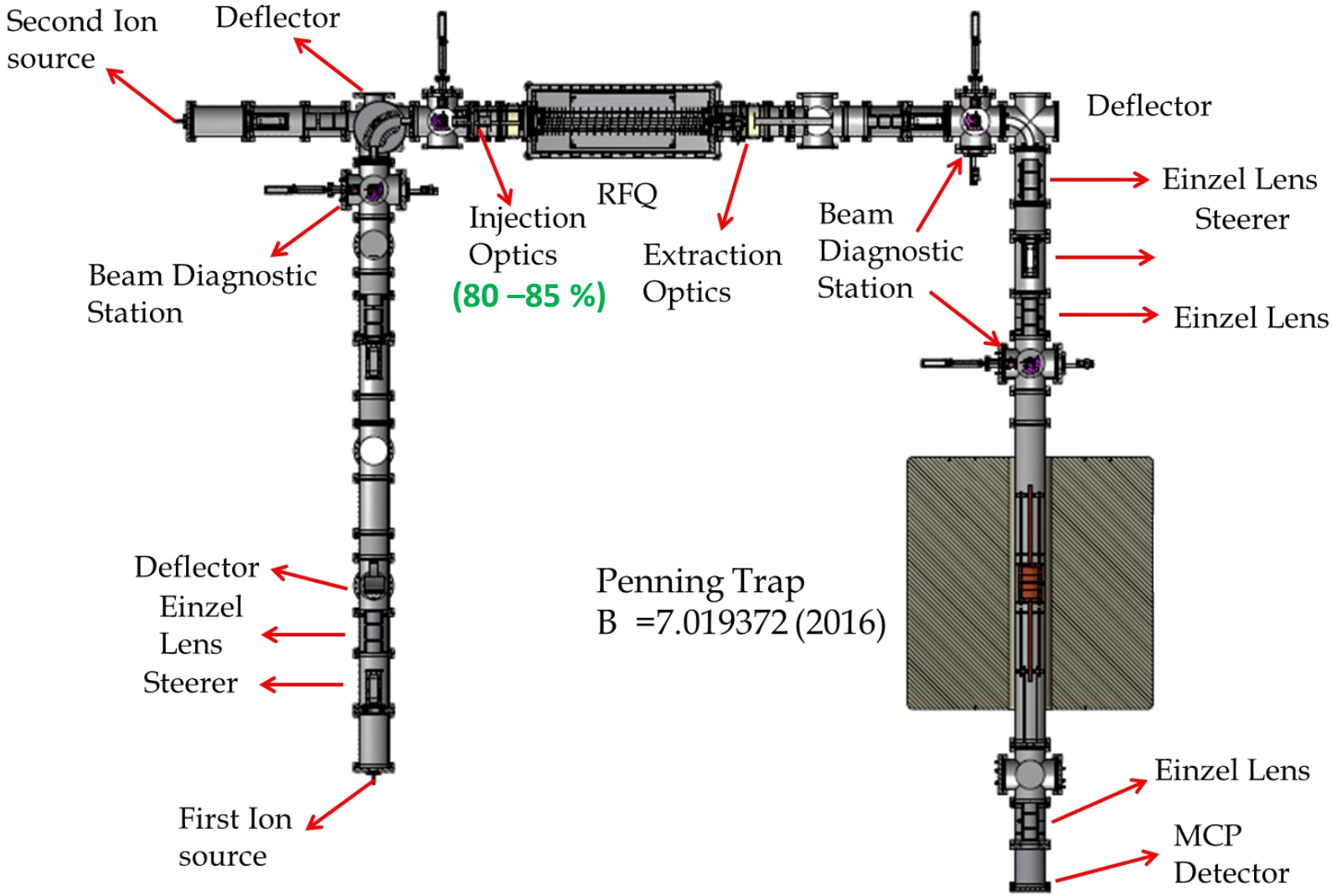


Transport Efficiency



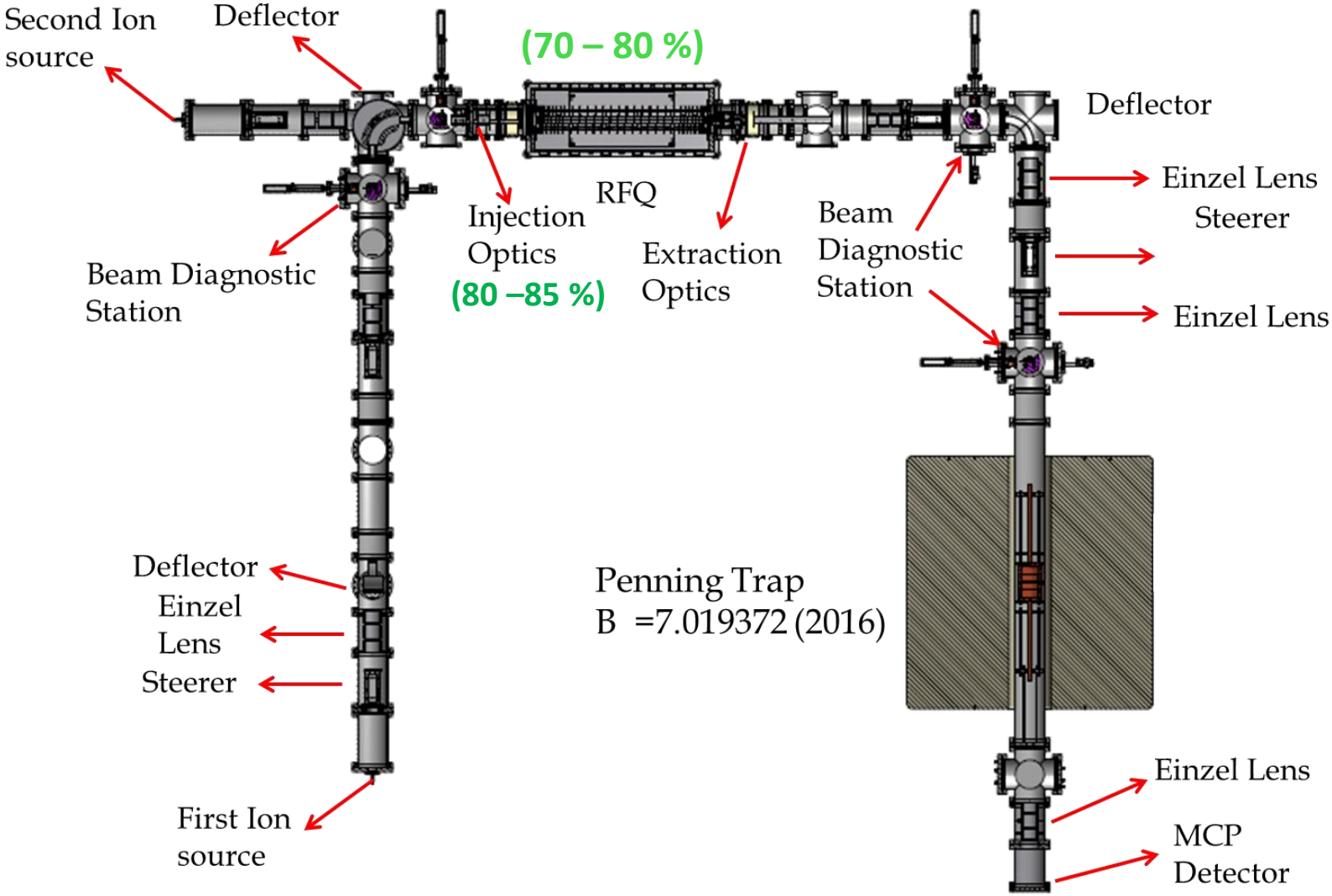
Texas A&M University Penning Trap Facility (TAMUTRAP)

Transport Efficiency



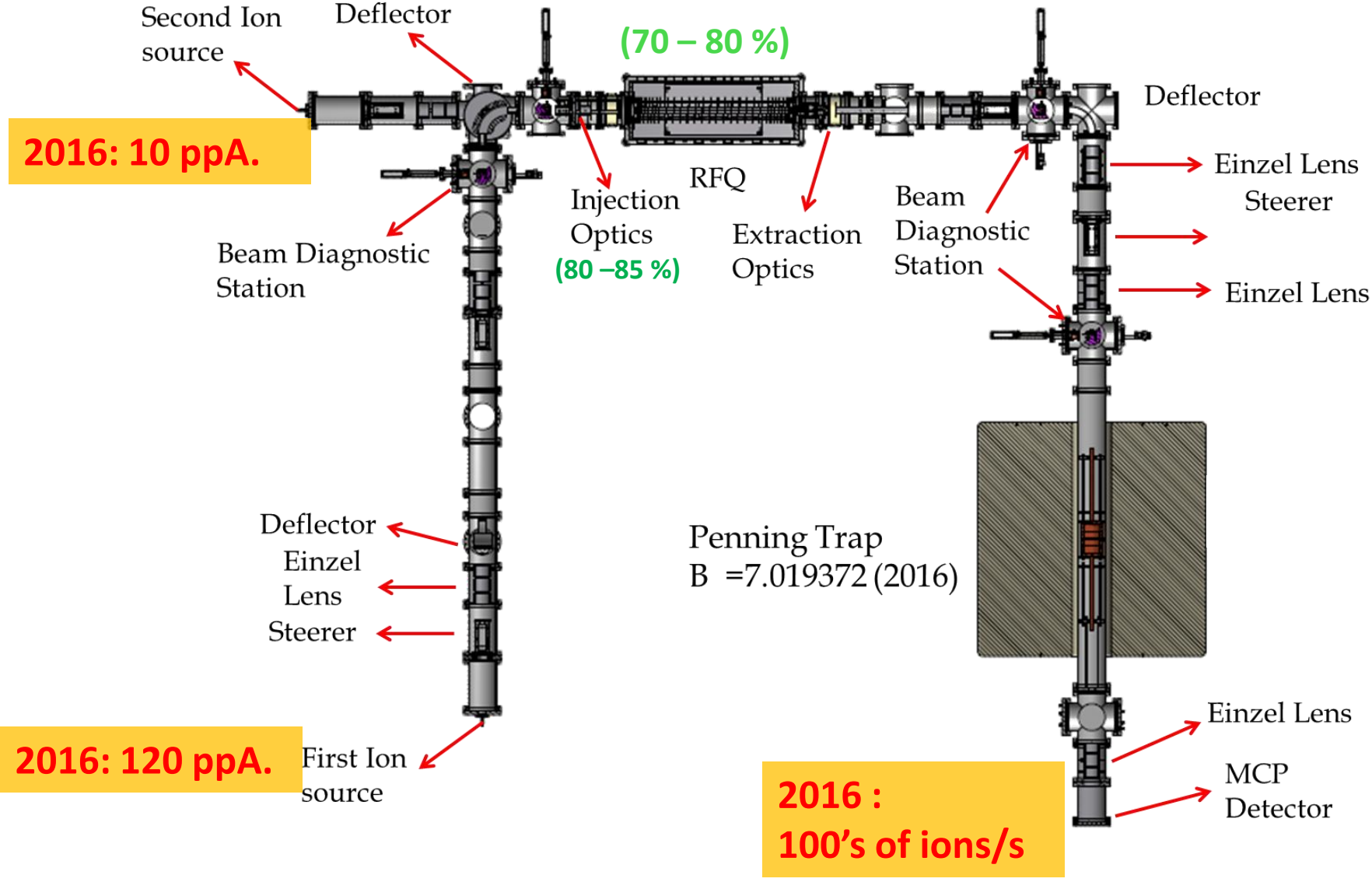
Texas A&M University Penning Trap Facility (TAMUTRAP)

Transport Efficiency



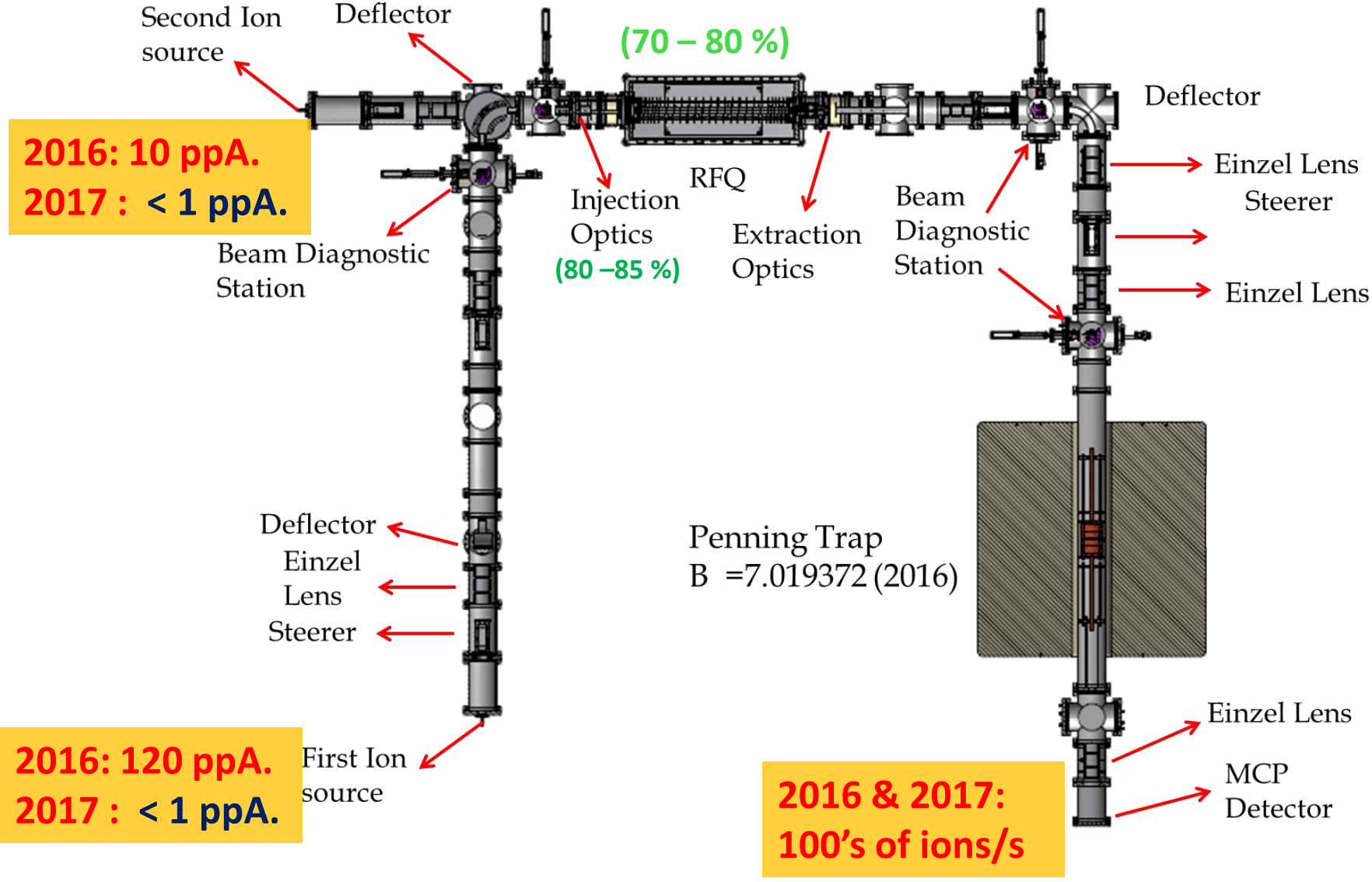
Texas A&M University Penning Trap Facility (TAMUTRAP)

Transport Efficiency



Texas A&M University Penning Trap Facility (TAMUTRAP)

Transport Efficiency

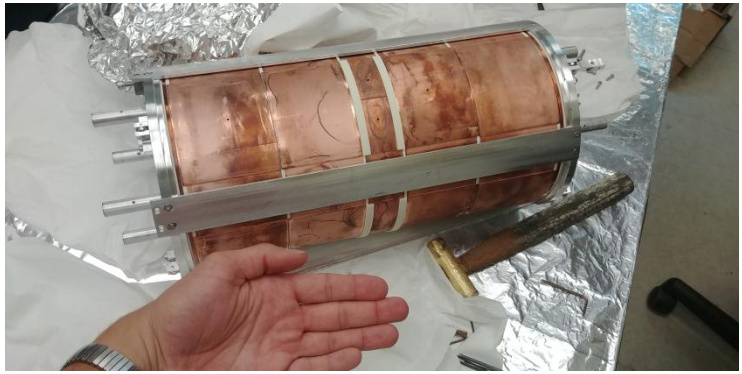


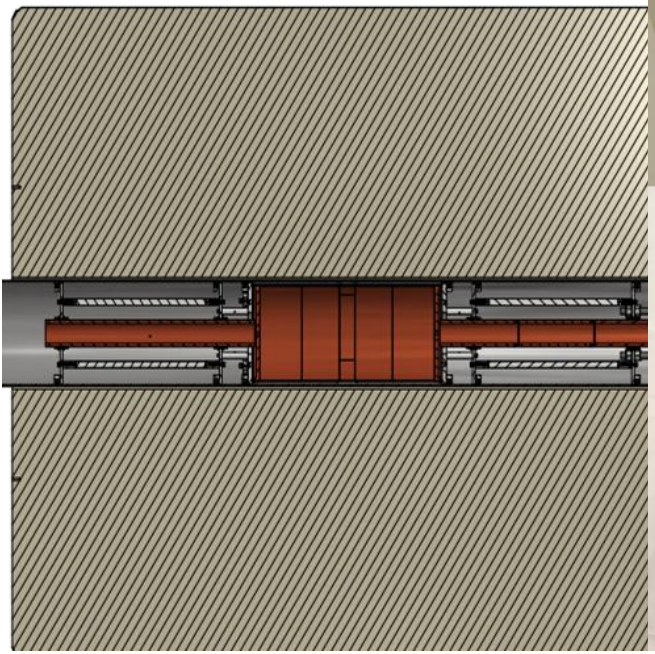
Texas A&M University Penning Trap Facility (TAMUTRAP)

TAMUTRAP: Penning trap

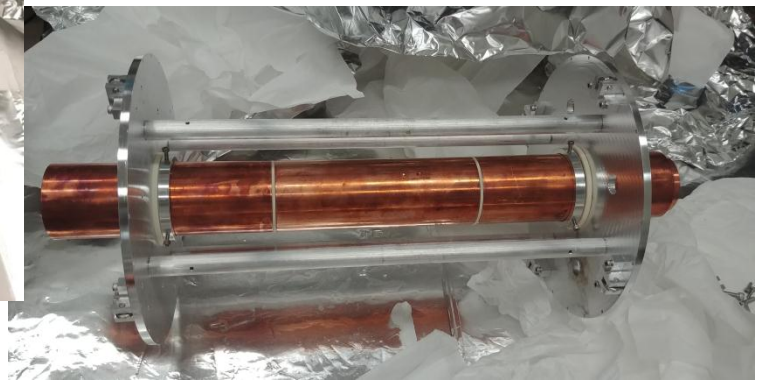
Installation in November 2018.

Inner Diameter of Penning Trap: 7.087 in (180mm).
Outer Diameter of Penning Trap system: 7.68 in (196 mm).
Magnet Bore : 8.27 in (210 mm).
Beam pipe Outer Diameter: 8 inch (203.2 mm).
Beam Pipe ID : 7.75 inch (197 mm).



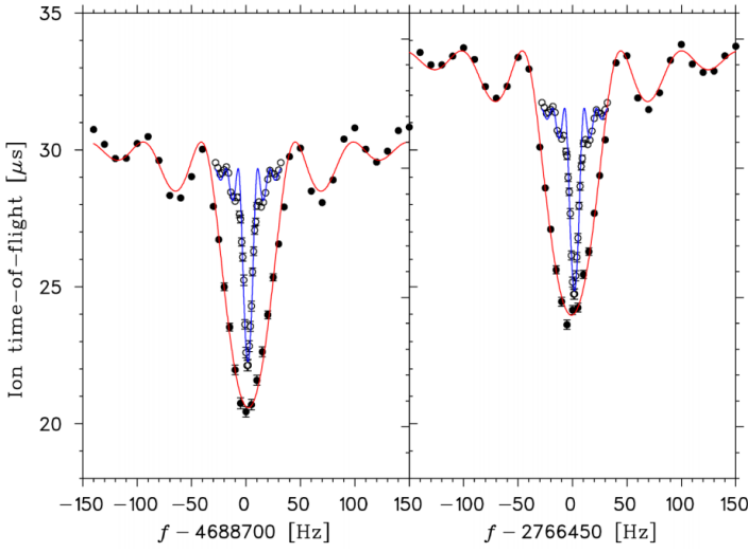


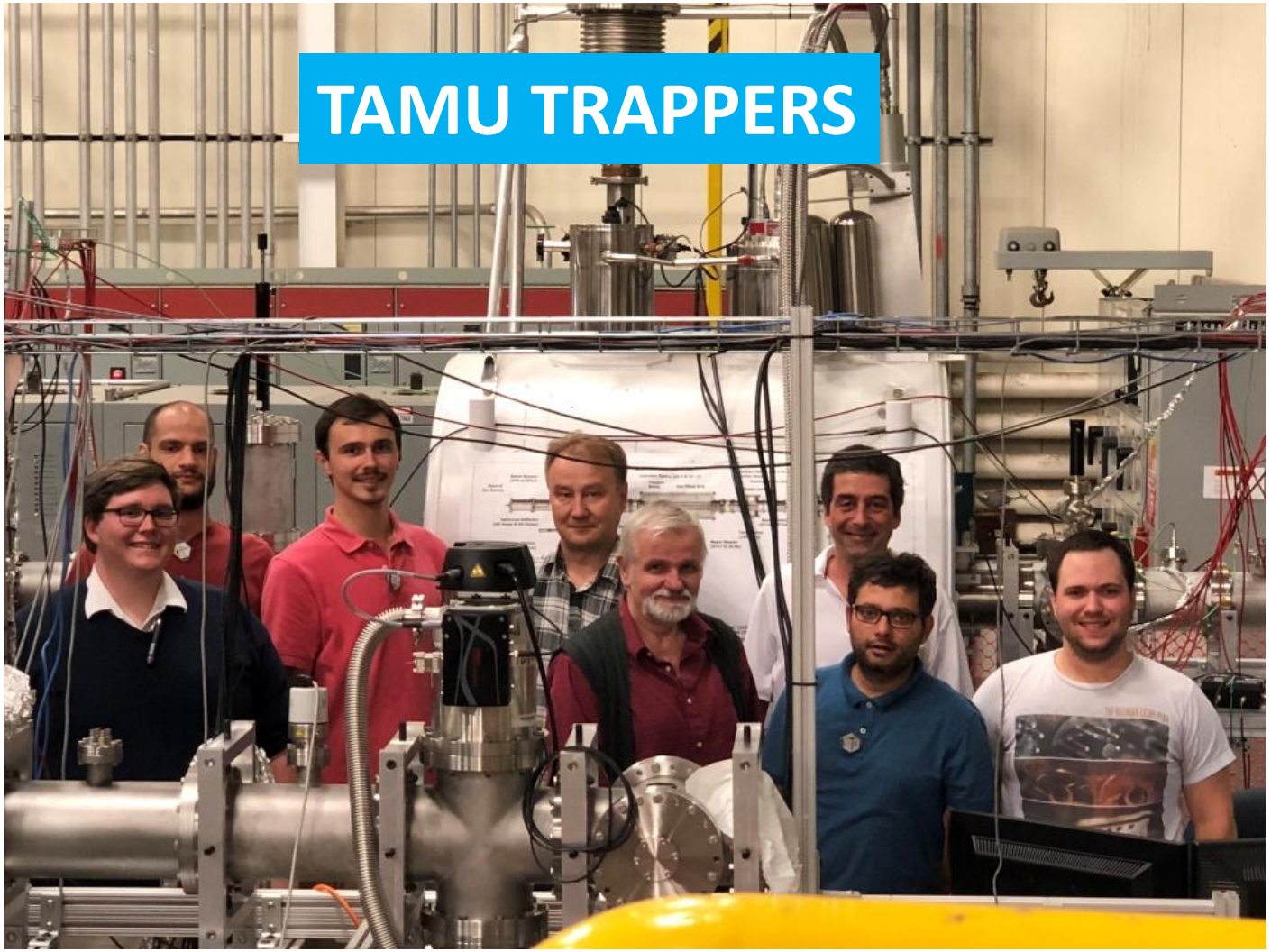
Extraction Section



Conclusion & Future plan

- Commissioned TAMUTRAP facility.
- Complete the GEANT4 Simulation.
- Finalize the design of p/β detectors.
- Couple LIG/HIG to TAMUTRAP facility.





Funding/Support:

DOE DE-FG02-93ER40773, Early Career ER41747.

State of Texas

U.S. DEPARTMENT OF ENERGY