# Gas cell for TAMUTRAP: Texas A&M University Penning trap facility

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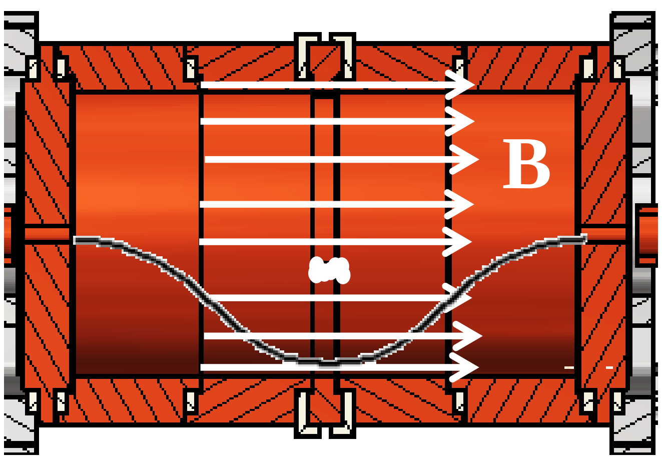
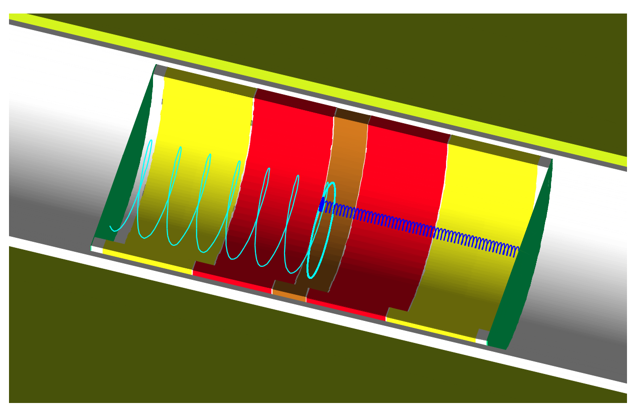
Cyclotron Institute,
Texas A&M University

Trap radioactive ions




Measure the angle between the decay products

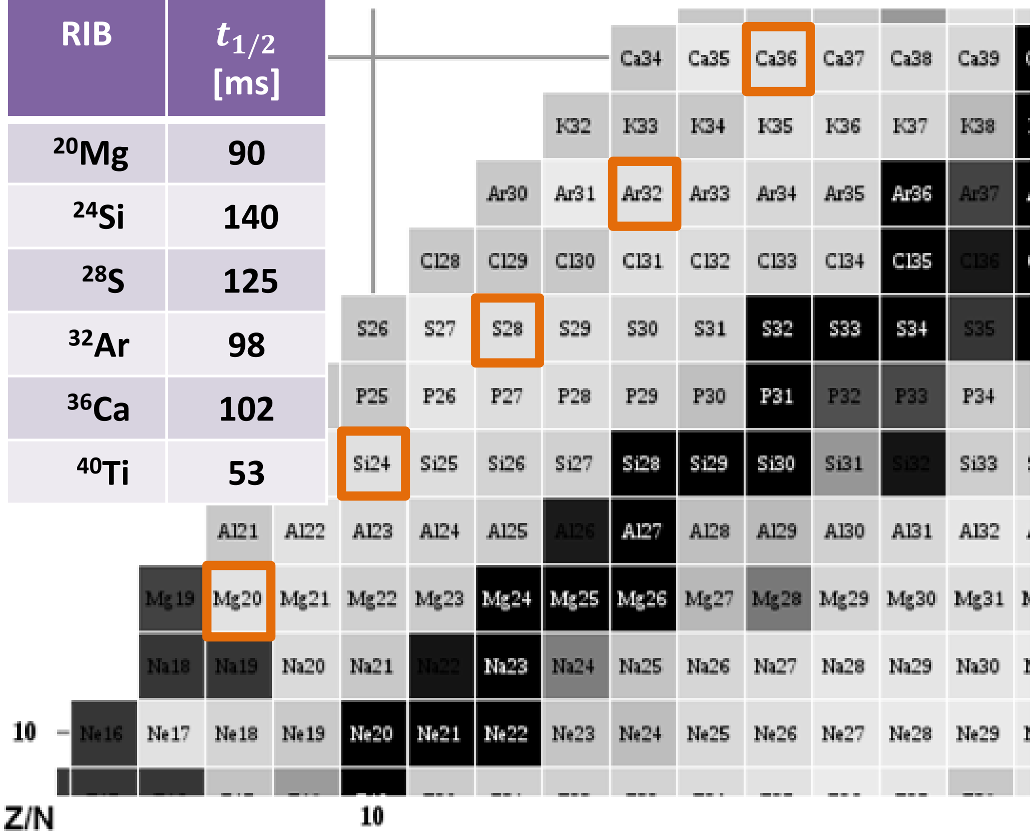


Test of SM

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

# Beta delayed proton emitters

| RIB | $t_{1/2}$ [ms] |
|---|---|
| $^{20}Mg$ | 90 |
| $^{24}Si$ | 140 |
| $^{28}S$ | 125 |
| $^{32}Ar$ | 98 |
| $^{36}Ca$ | 102 |
| $^{40}Ti$ | 53 |



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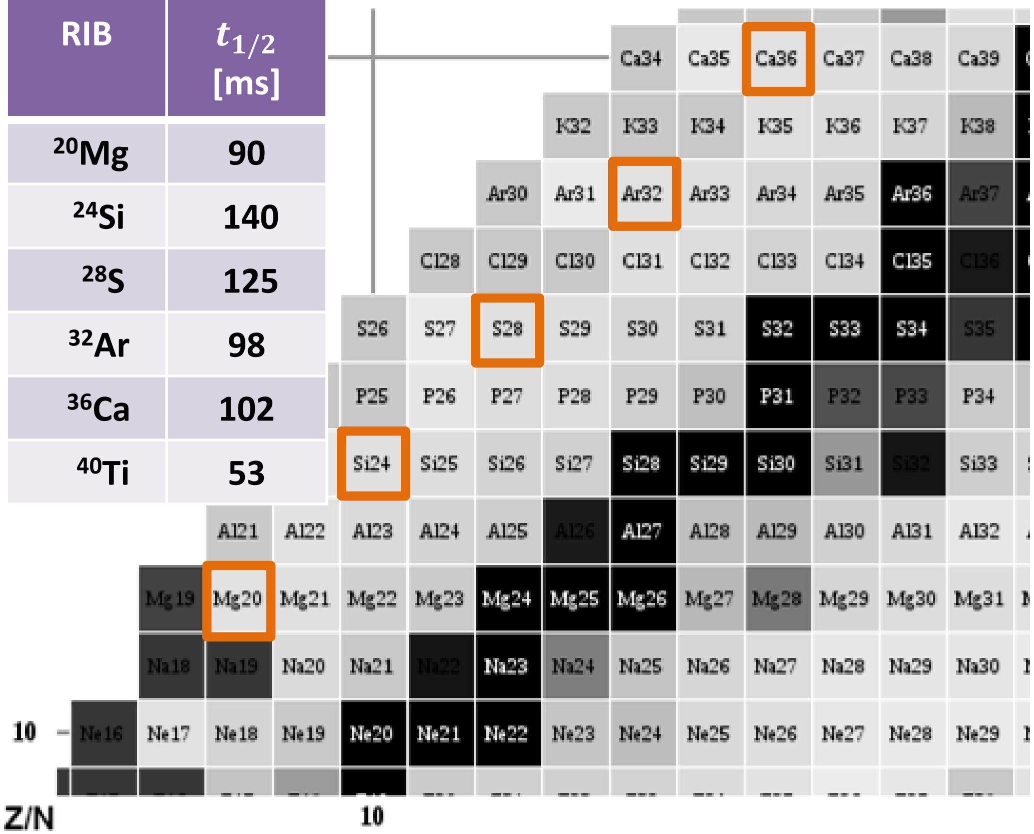


## Production of $^{32}$Ar

## Projectile fragmentation

**Primary beam: $^{36}$Ar @ 100 MeV/u**

**Target: $^{9}$Be (470 mg/cm$^2$).**

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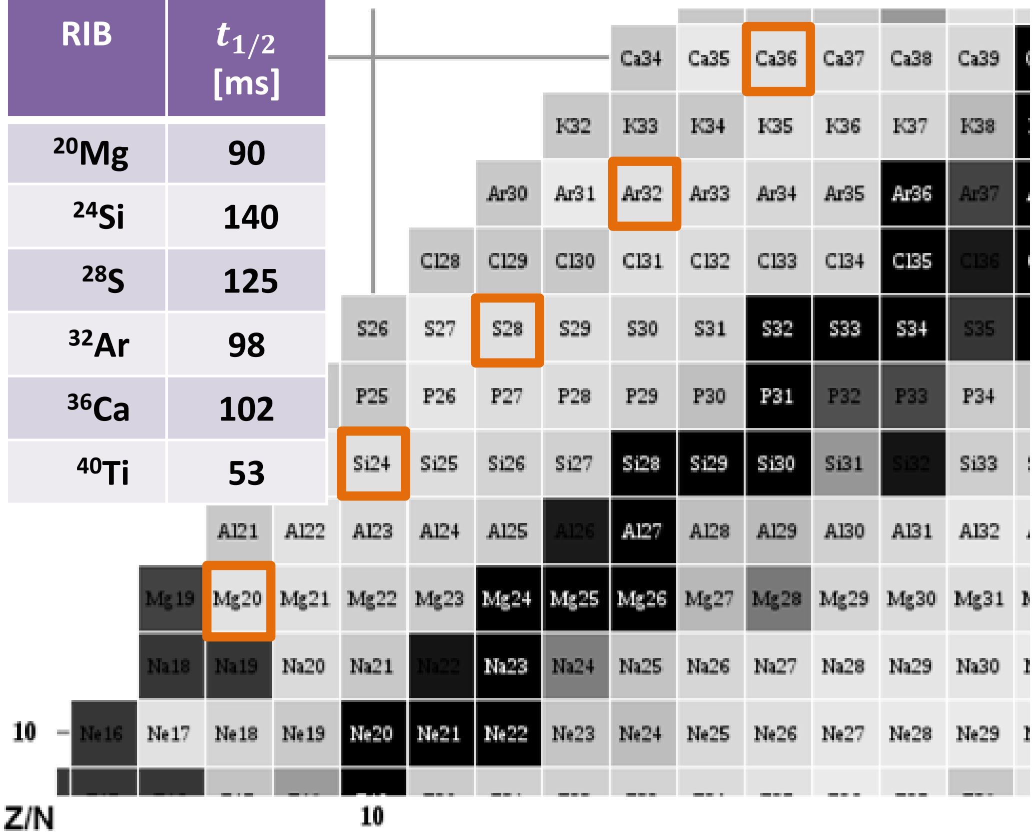



## Production of $^{32}$Ar

### Projectile fragmentation

**Primary beam: $^{36}$Ar @ 100 MeV/u**

**Target: $^{9}$Be (470 mg/cm$^2$).**

### Fusion-Evaporation reaction

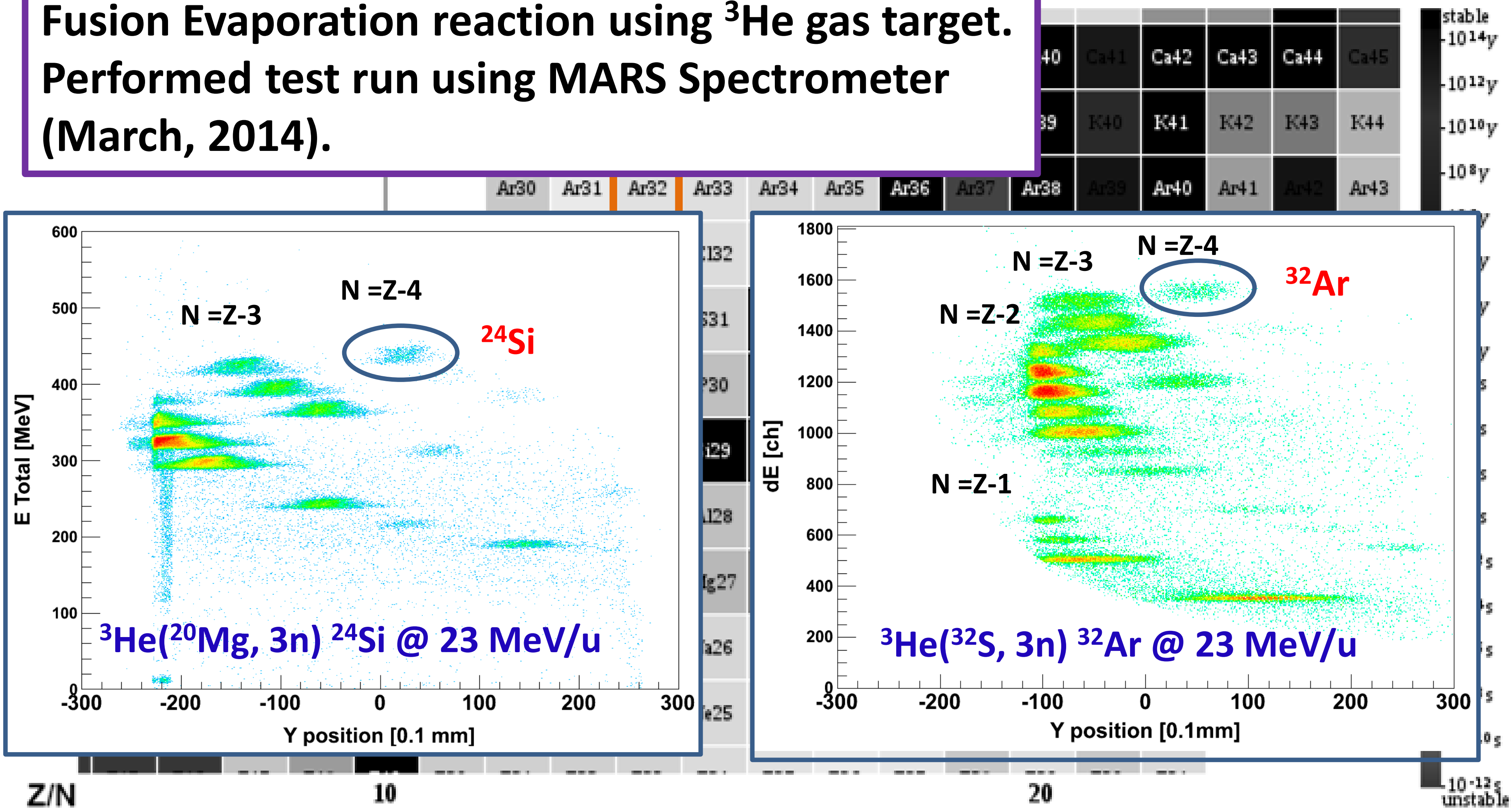
**Primary beam: $^{32}$S @ 23 MeV/u**

**Target: $^{3}$He (gas target).**

# Beta delayed proton emitters

**Production Mechanism:**

**Fusion Evaporation reaction using $^{3}He$ gas target.**
**Performed test run using MARS Spectrometer (March, 2014).**




In collaboration with B. Roeder

# Beta delayed proton emitters

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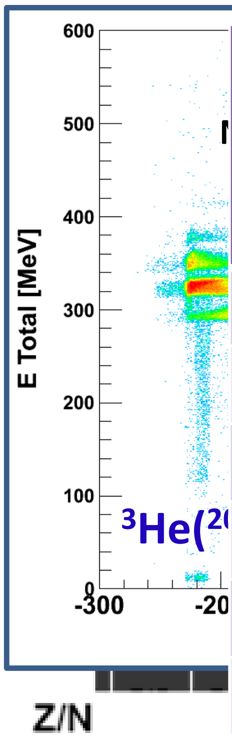
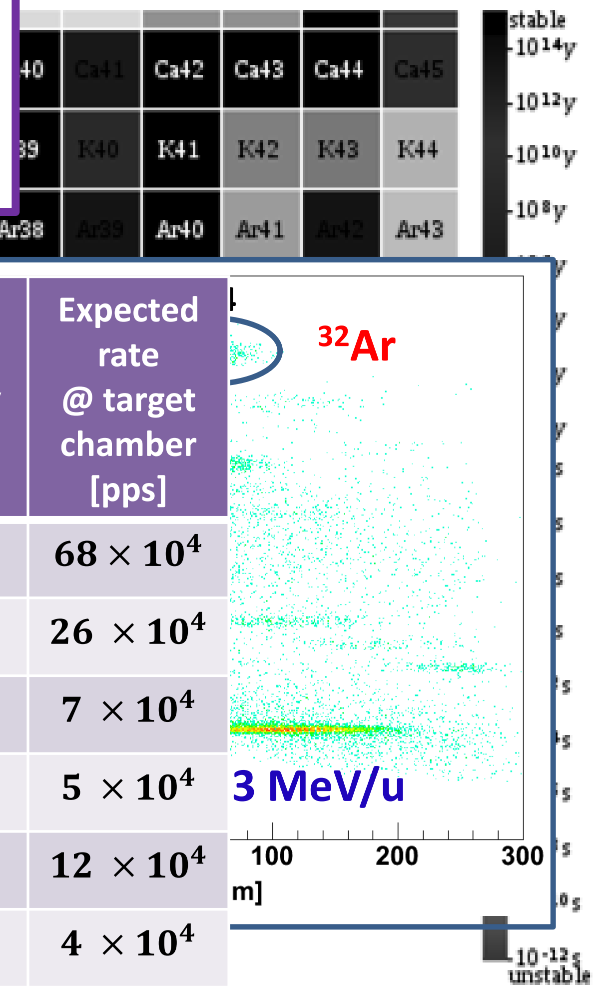
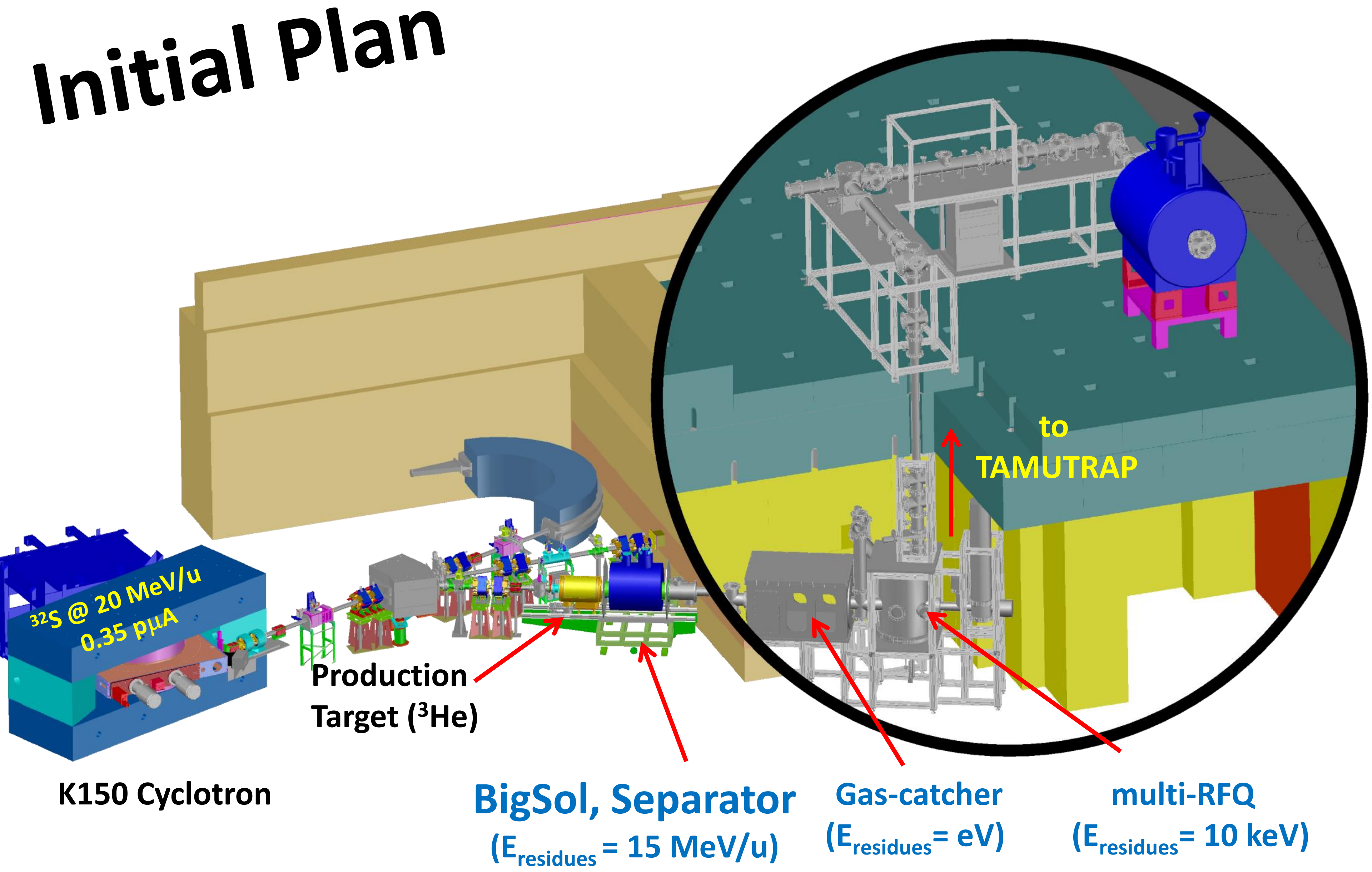



| RIB | $t_{1/2}$ [ms] | Projectile | Energy [MeV/u] | Target thickness [mg/cm²] | Beam Intensity (pμA) | Expected rate @ target chamber [pps] |
|---|---|---|---|---|---|---|
| $^{20}$Mg | 90 | $^{20}$Ne | 23-30 | 22.5 | 1.50 | $68 \times 10^4$ |
| $^{24}$Si | 140 | $^{24}$Mg | 22-30 | 22.5 | 0.6 | $26 \times 10^4$ |
| $^{28}$S | 125 | $^{28}$Si | 22-30 | 22.5 | 0.6 | $7 \times 10^4$ |
| $^{32}$Ar | 98 | $^{32}$S | 20-24 | 22.5 | 0.35 | $5 \times 10^4$ |
| $^{36}$Ca | 102 | $^{36}$Ar | 23-30 | 22.5 | 0.7 | $12 \times 10^4$ |
| $^{40}$Ti | 53 | $^{40}$Ca | 23-30 | 22.5 | 0.75 | $4 \times 10^4$ |




**In collaboration with B. Roeder**

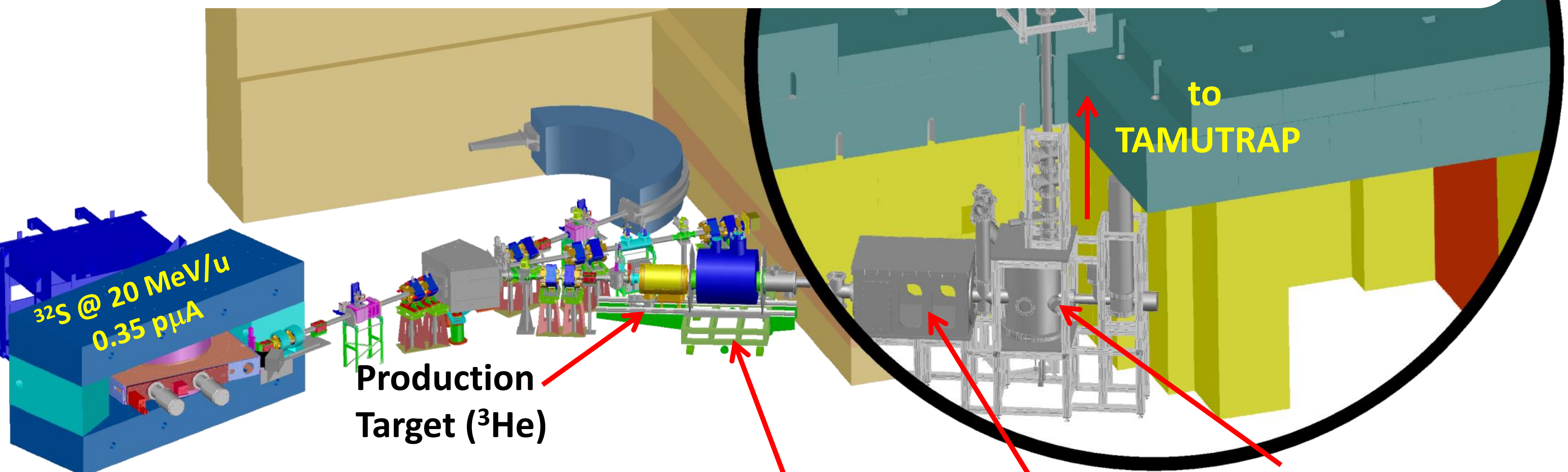
# RIB Source for TAMUTRAP facility



# RIB Source for TAMUTRAP facility

## Initial Plan

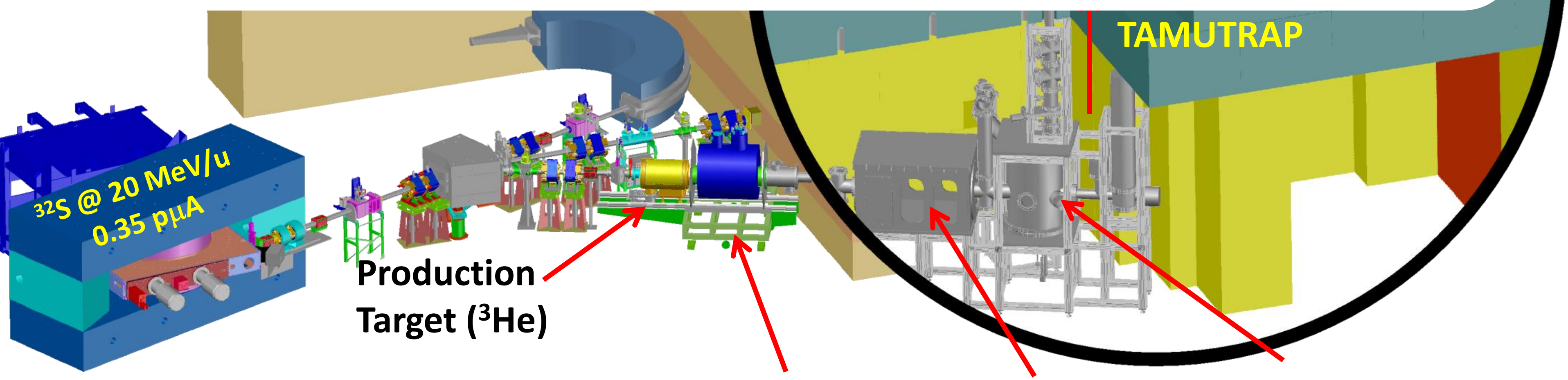
- High intensity beams from K150 in *20-40 mass region* are currently not available.
- Gas catcher need to be tested.



# RIB Source for TAMUTRAP facility

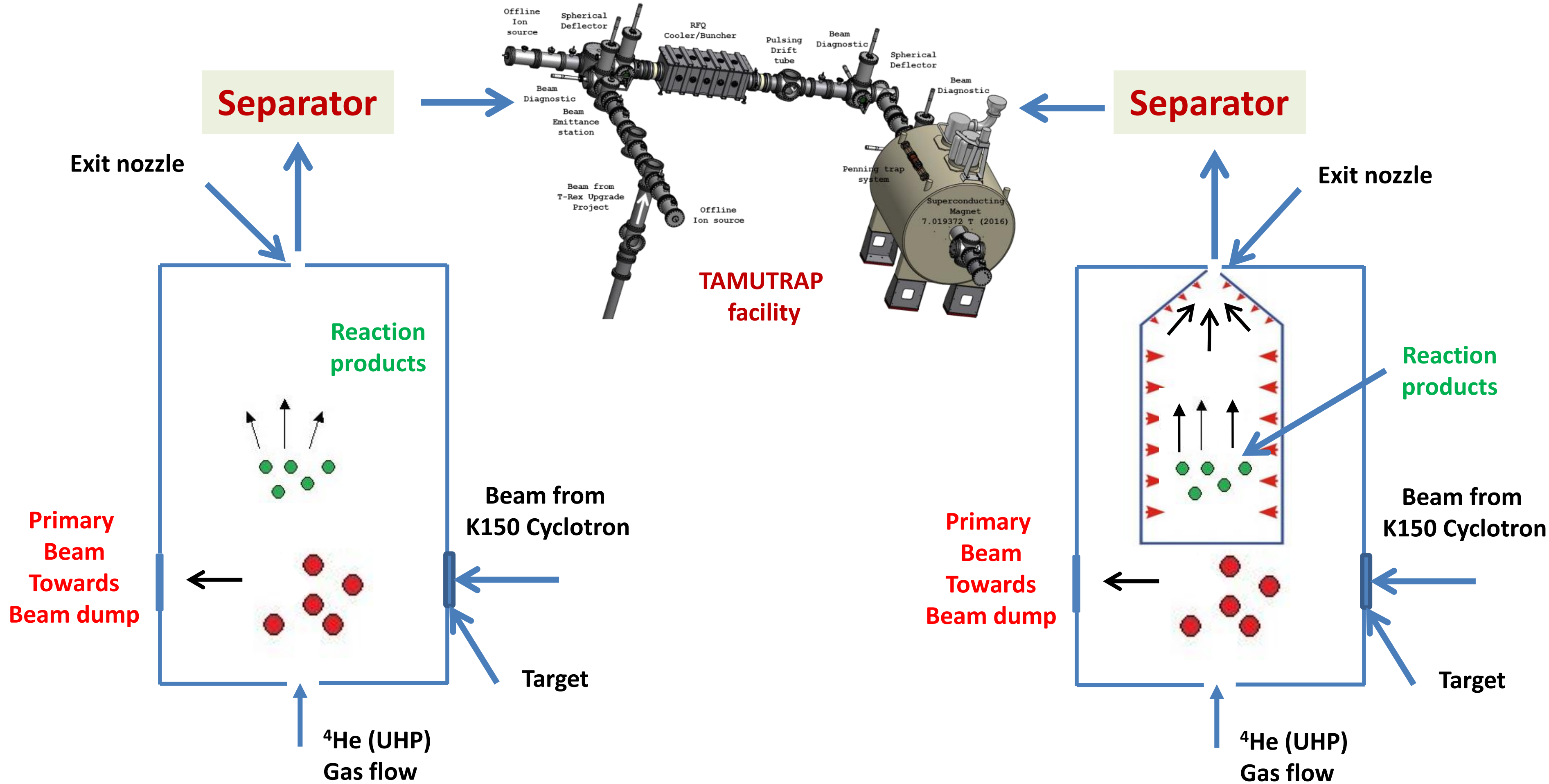
## Initial Plan

- High intensity beams from K150 in *20-40 mass region* are currently not available.
- Gas catcher need to be tested.
- Lighter beams from K150 are currently being delivered with very high intensity (for e.g., p, $^{3}He$, $^{4}He$ ; close to 4 pμA @ 20 MeV/u).



# Alternative Approach: Light Ion Guide

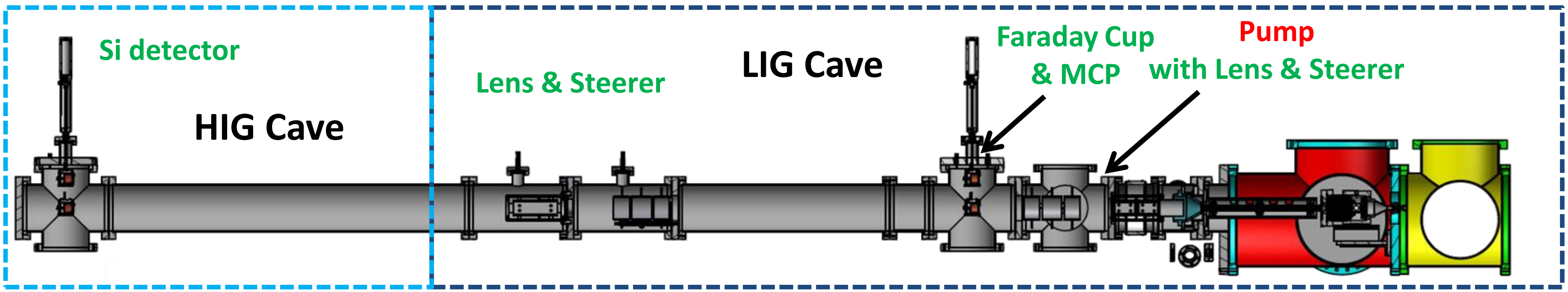
- (p,n), (d,p) and (He,n) reaction.

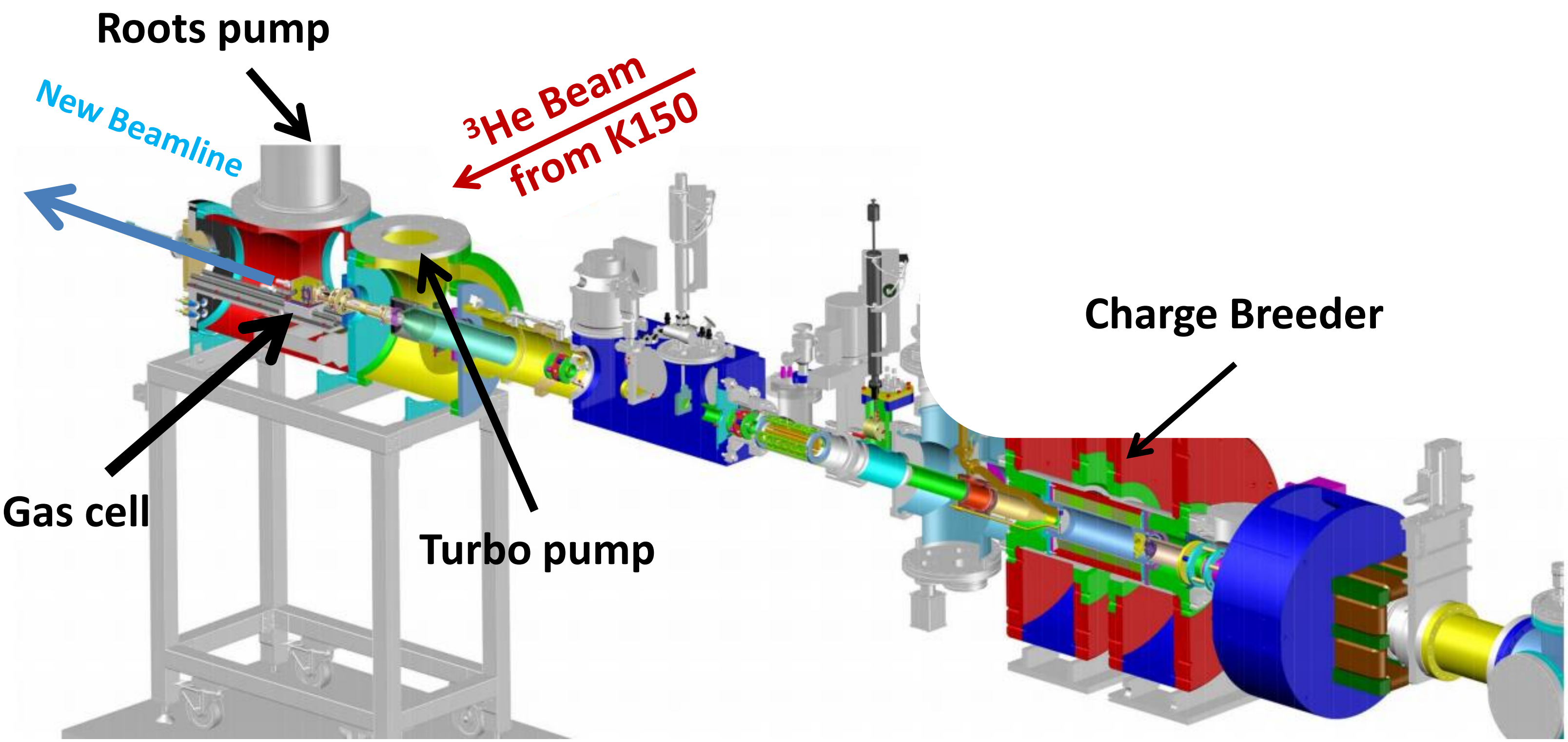



**Extraction of the ions : Gas flow**

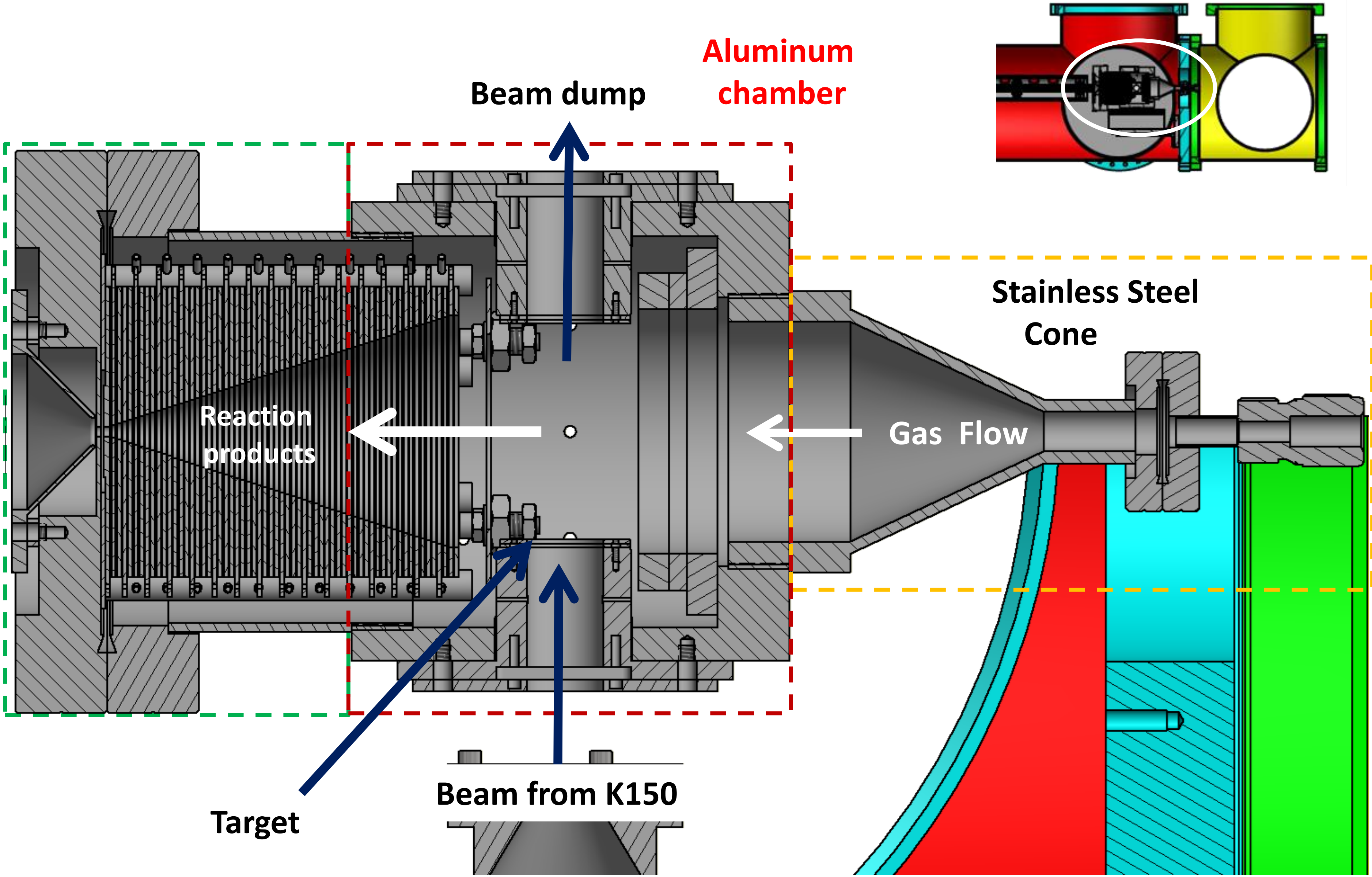
**Extraction of the ions : Gas flow + RF + DC**

# Alternative Approach: Light Ion Guide



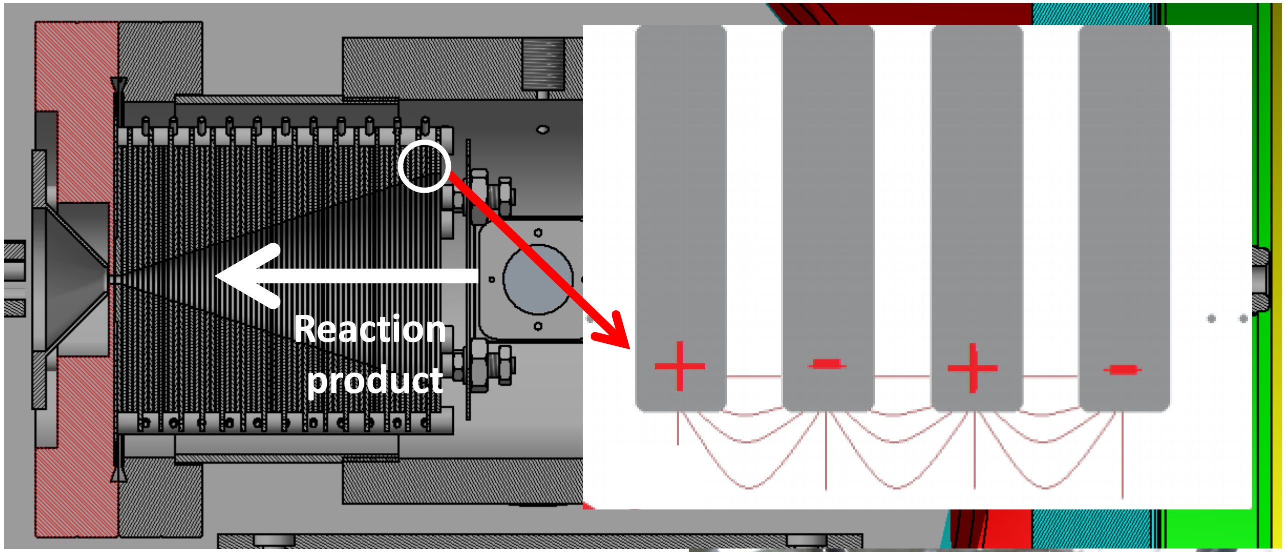



# Gas Cell



Aluminum chamber
Beam dump
Stainless Steel Cone
Reaction products
Gas Flow
Target
Beam from K150

# RF electrode structure

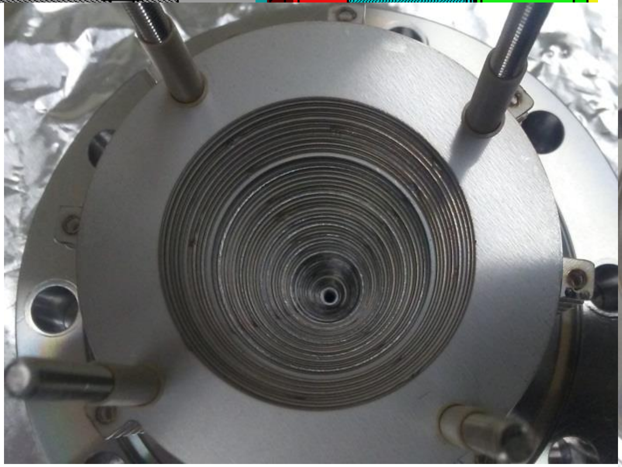


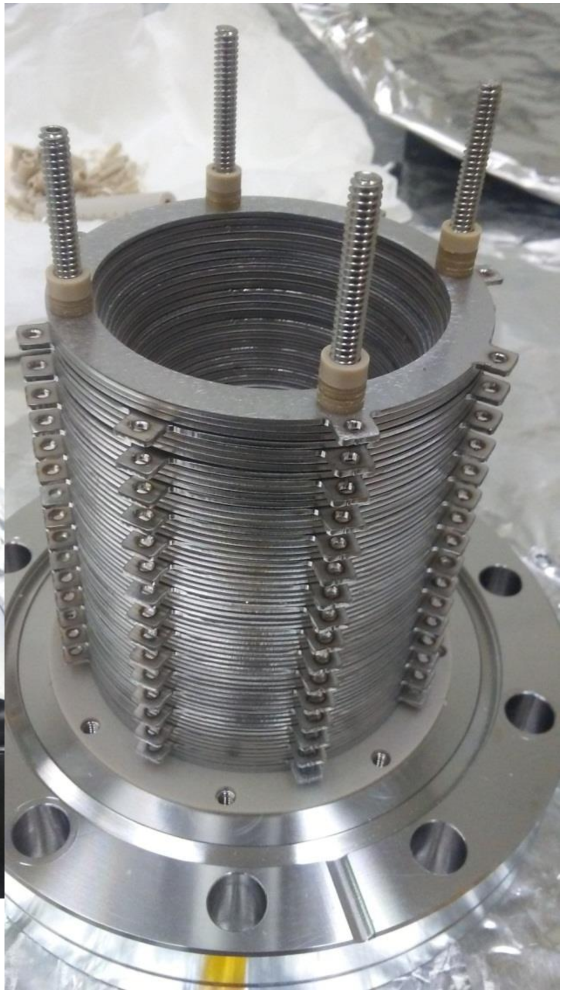

63 stainless steel ring electrodes.

0.25 mm separation between the faces of neighboring electrodes.

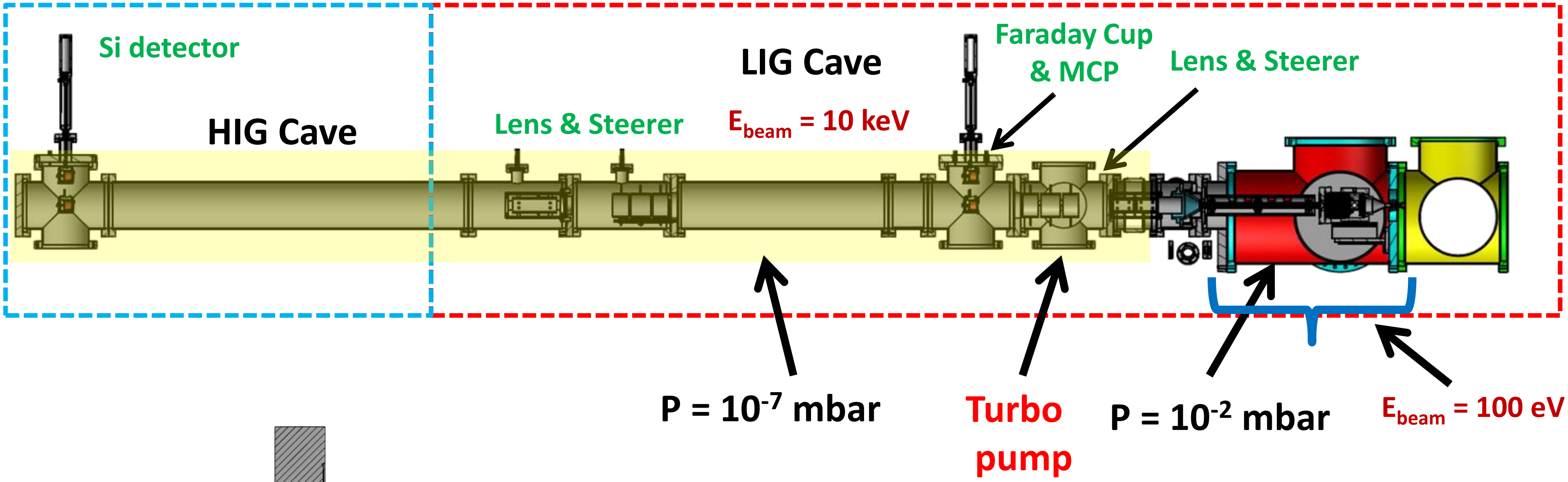
Alternating electric potential of opposing phases are applied to the even and odd electrodes.

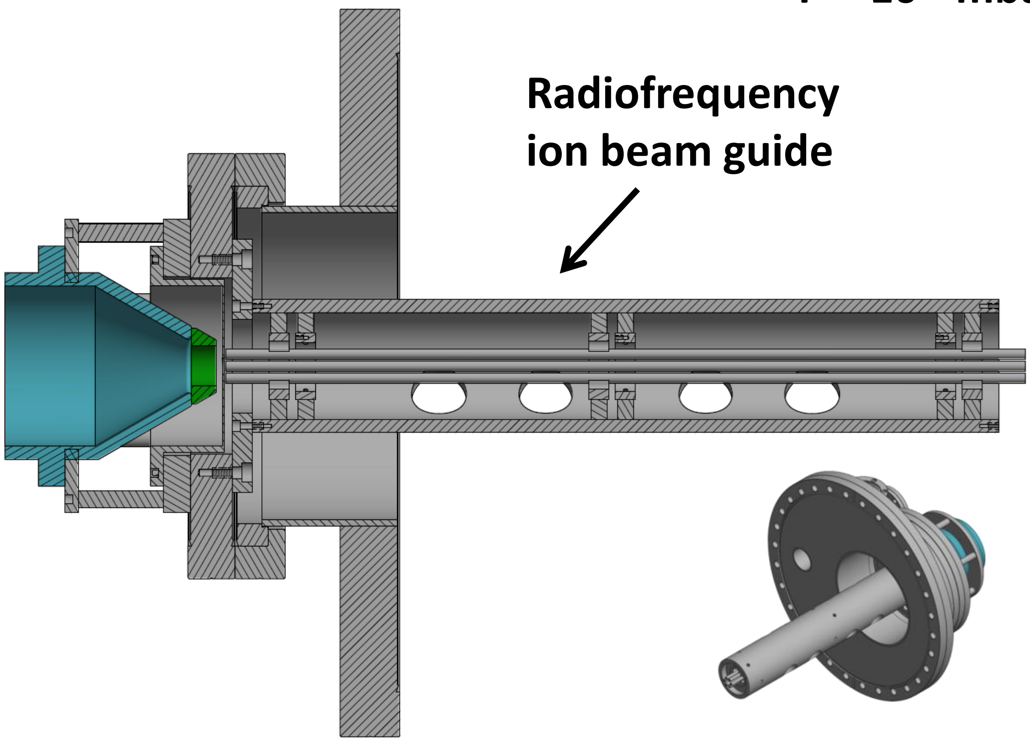
Pressure in gas cell 130 mbar.





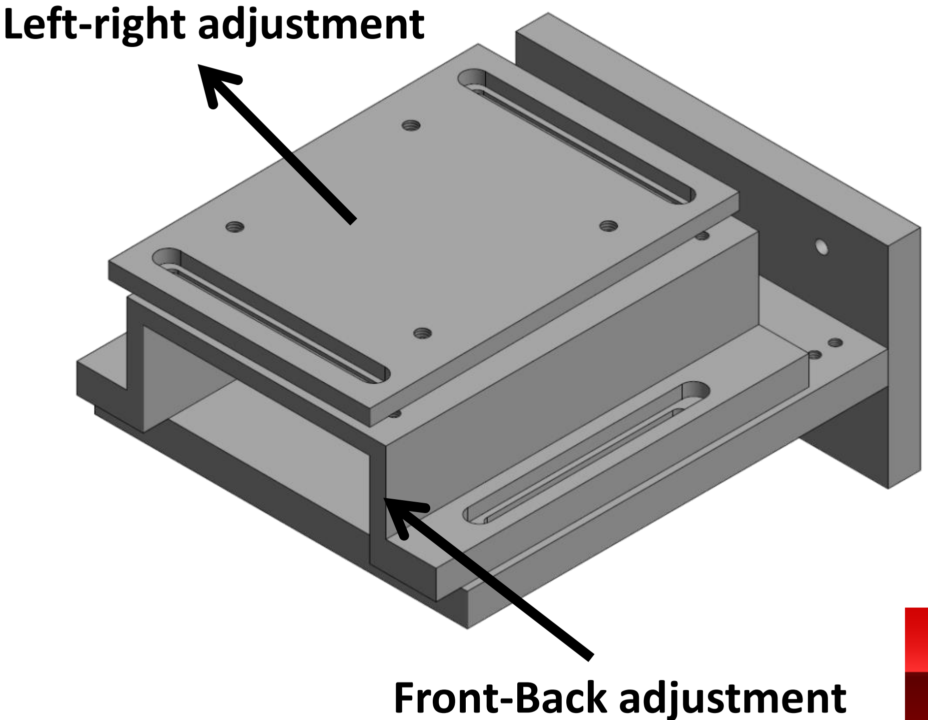
# Extraction section

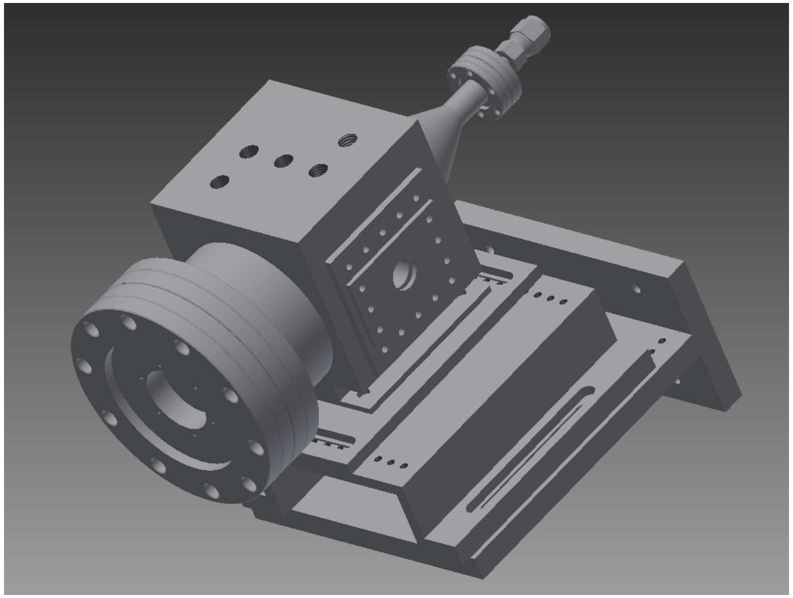


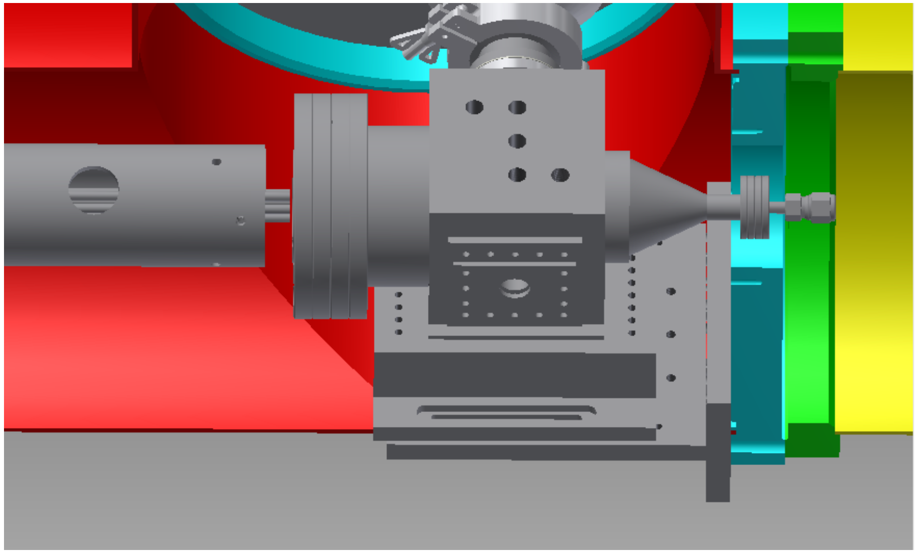




- ➢ **Efficient transport of reactions products extracted from an ion guide into a region of high vacuum.**
- ➢ **SPIG consists of 6 rod with optimum ratio of 0.563 for the ideal sextupole field using cylindrical rods.**

# Support structure



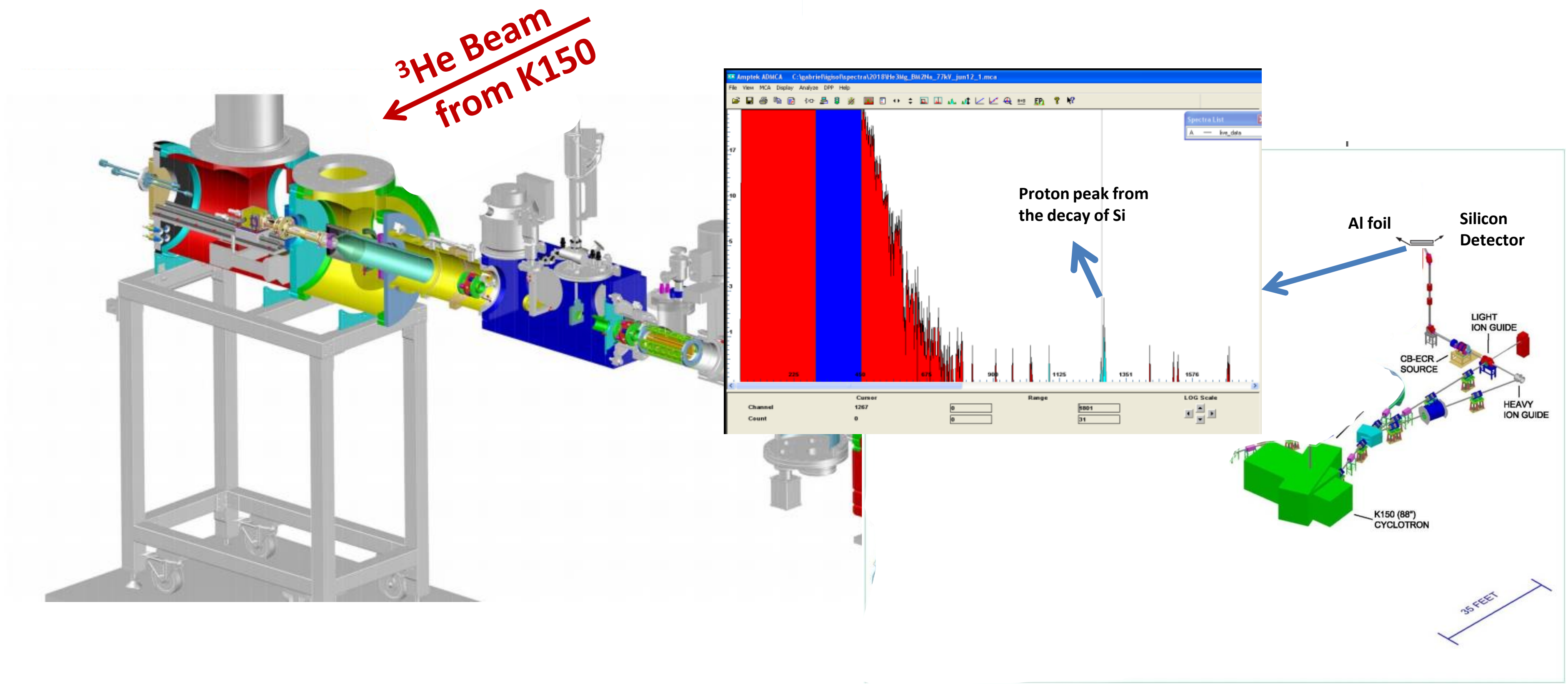





***Thank you S. Molitor for helping with the design of the gas cell.***

# LIG for producing proton rich nuclei

- Test run for producing $^{24}Si$ using existing gas cell ($^{nat}Mg\,(^{3}He, 3n)^{24}Si$ @ 20 MeV/u).
- Observed proton peak from the decay of Silicon isotopes.




**DGM Group & G. Tabacaru**

# Future plan & Current status

**Testing gas cell (with & without RF structure)**

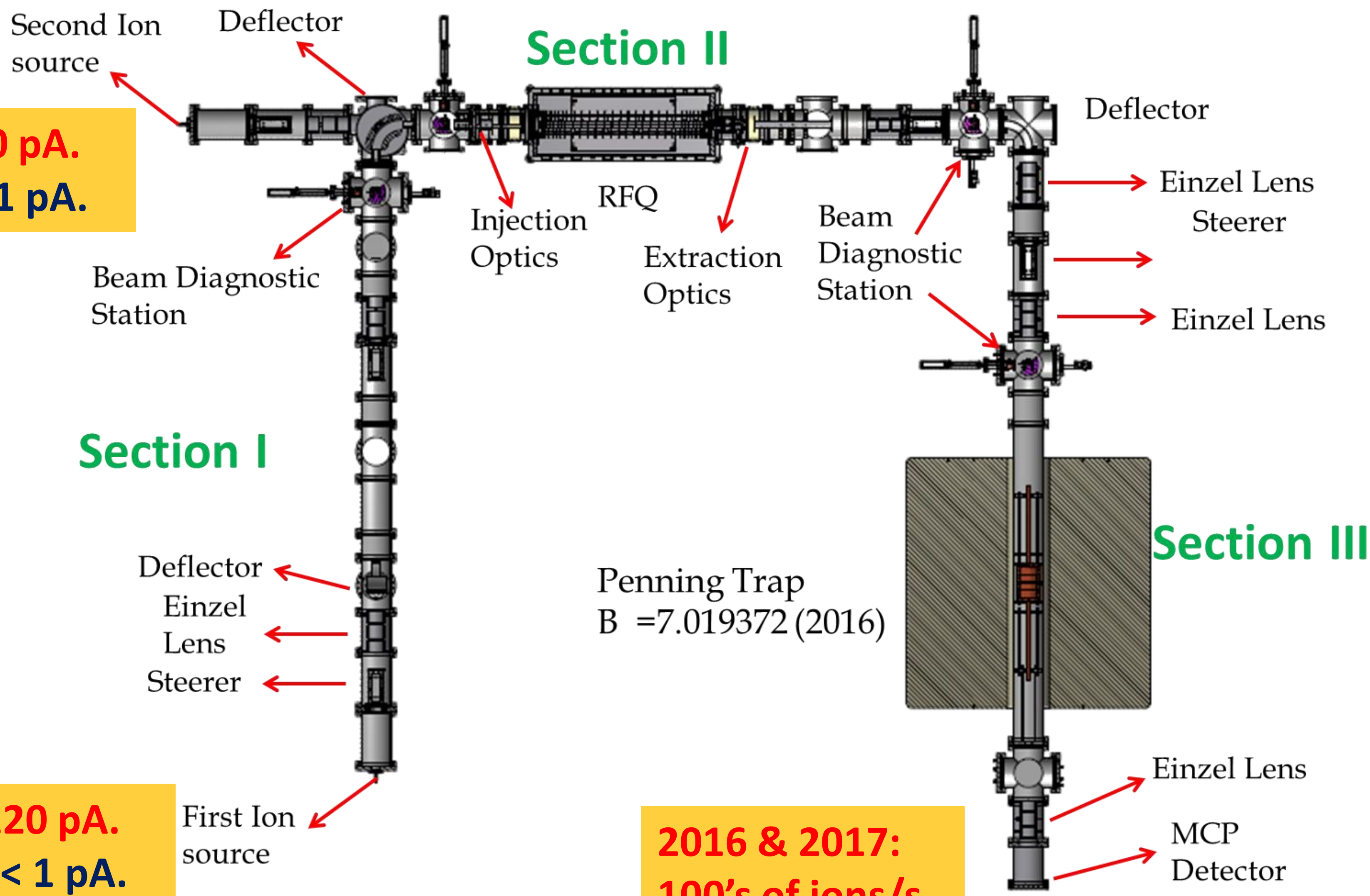
**Production of Silicon isotopes : $^{24,25}Si$.**
**Primary Beam: $^{3}He$ @ 22 MeV/u ; Intensity = 1-2 pμA**
**Target: $^{24}Mg$ target (1 mg/cm$^2$)**

- **Design of all the components for transporting the beam from gas cell to the detector station is completed.**
- **All the parts should be ready by June 15th, 2019.**
- **Currently working on the RF electronics.**
- **Plan to do first test in last week of June, 2019.**

# Thank you

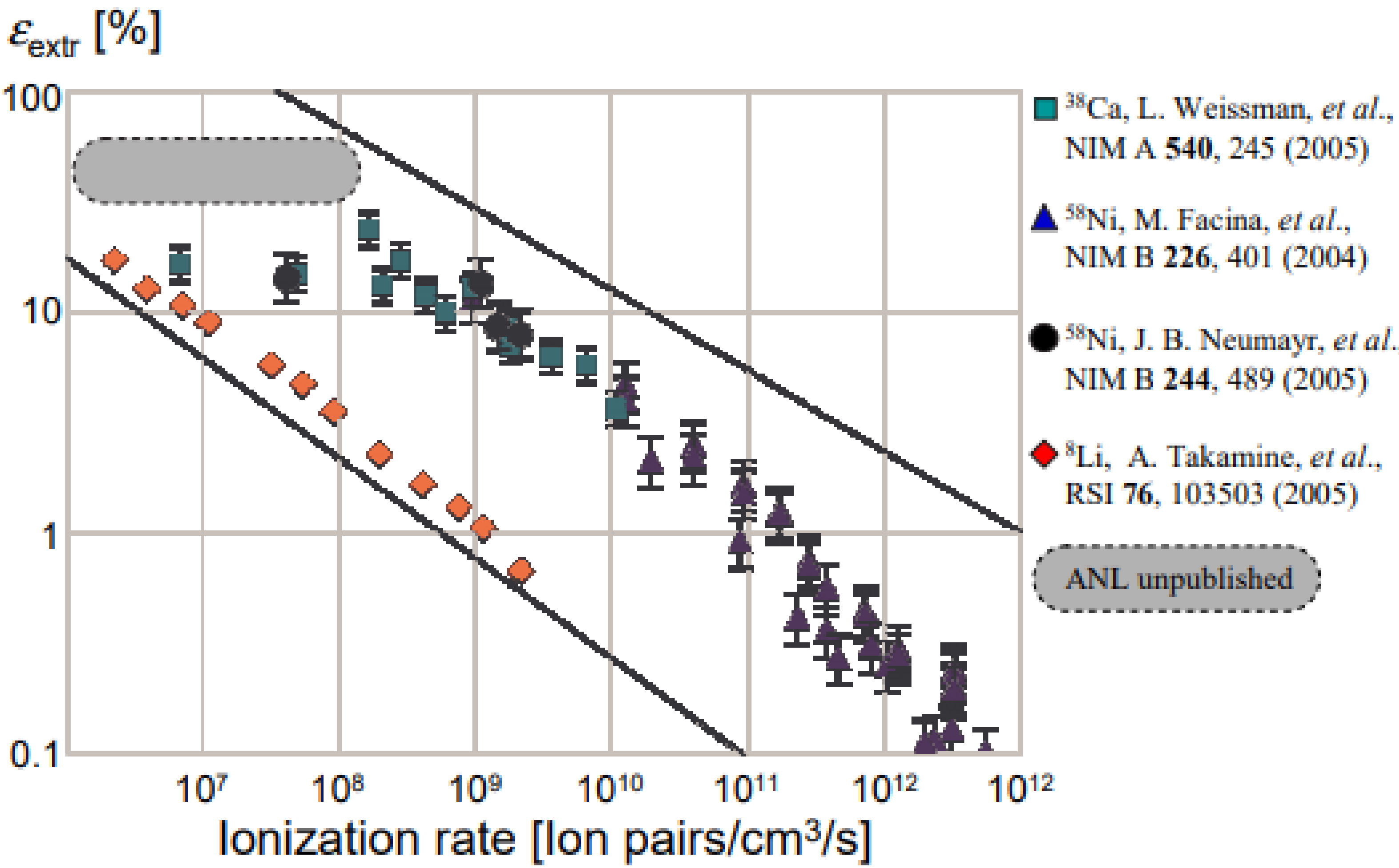
# Transport Efficiency

2016: 120 pA.
2017 : < 1 pA.




2016: 120 pA.
2017 : < 1 pA.

2016 & 2017:
100's of ions/s



$\varepsilon_{extr}$ [%]
100
10
1
0.1
$10^7$
$10^8$
$10^9$
$10^{10}$
$10^{11}$
$10^{12}$
$10^{12}$
Ionization rate [Ion pairs/cm³/s]
$^{38}$Ca, L. Weissman, *et al.*, NIM A **540**, 245 (2005)
$^{58}$Ni, M. Facina, *et al.*, NIM B **226**, 401 (2004)
$^{58}$Ni, J. B. Neumayr, *et al.*, NIM B **244**, 489 (2005)
$^{8}$Li, A. Takamine, *et al.*, RSI **76**, 103503 (2005)
ANL unpublished

| Calculating $^{32}Ar$ requirements | | DOWN |
|---|---|---|
| Element | Efficiency (%) | Rate After Element (p/s) |
| Measurement trap | 100 | 250 |
| Beamline | 95 | 250 |
| Purification Trap | 100 | 263 |
| Beamline | 95 | 263 |
| RFQ (bunched mode) | 50 | 277 |
| Beamline | 95 | 554 |
| Magnet (coarse selection) | 100 | 583 |
| Multi-RFQ | 80 | 583 |
| Gas catcher | 15 | 729 |
| Big Sol | 35 | 4,860 |
| Production | 100 | 13,886 |

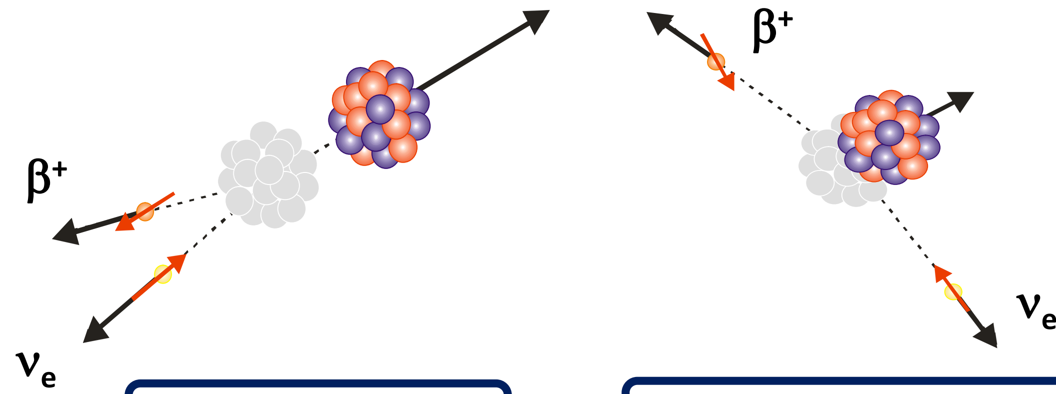
**Table 1. – Expected 88" beam intensities and energies assuming ECR2 type source, K=140 and 25% transmission.**

| Isotope | Energy MeV/u | Intensity pμA | | Isotope | Energy MeV/u | Intensity pμA |
|---|---|---|---|---|---|---|
| p | 55 | 27 (14) | | $^{20}Ne$ | 28 | 3.0 (1.5) |
| d | 35 | 21 (10.5) | | $^{22}Ne$ | 29 | 0.5 (0.25) |
| $^{3}He$ | 45 | 11 (5.5) | | $^{34}S$ | 20 | 0.7 (0.35) |
| $^{4}He$ | 35 | 10 (5.0) | | $^{40}Ar$ | 17 | 1.4 (0.7) |
| $^{6}Li$ | 35 | 7 (3.5) | | $^{40}Ca$ | 17 | 1.5 (0.75) |
| $^{7}Li$ | 25 | 8 (4.0) | | $^{59}Co$ | 11 | 0.9 (0.45) |
| $^{10}B$ | 35 | 4 (2.0) | | $^{78}Kr$ | 10 | 0.6 (0.3) |
| $^{11}B$ | 29 | 4.7 (2.35) | | $^{86}Kr$ | 8.3 | 0.6 (0.3) |
| $^{16}O$ | 35 | 2.3 (1.15) | | $^{129}Xe$ | 5.6 | 0.5 (0.25) |

# How do we plan to test the Standard Model (SM) ?

In Standard Model (SM)
weak interaction is
**V-A**

**Pure Fermi transition**

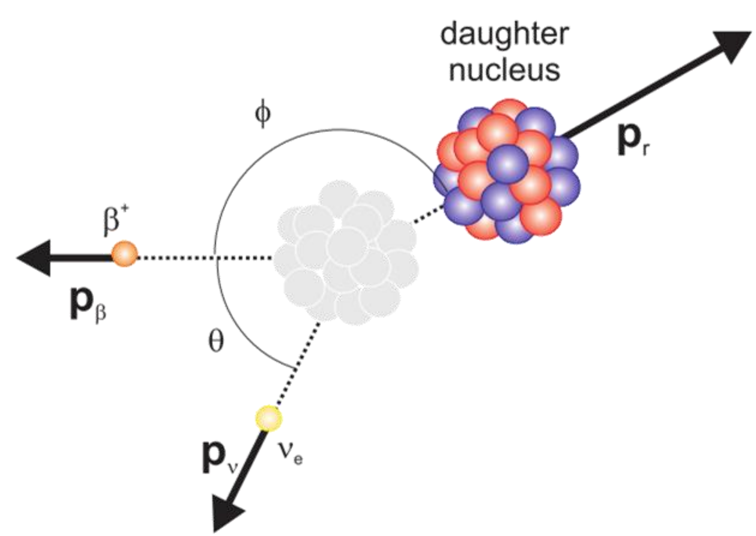



**SM Interaction**

**Non SM Interaction**

**Correlation parameter**

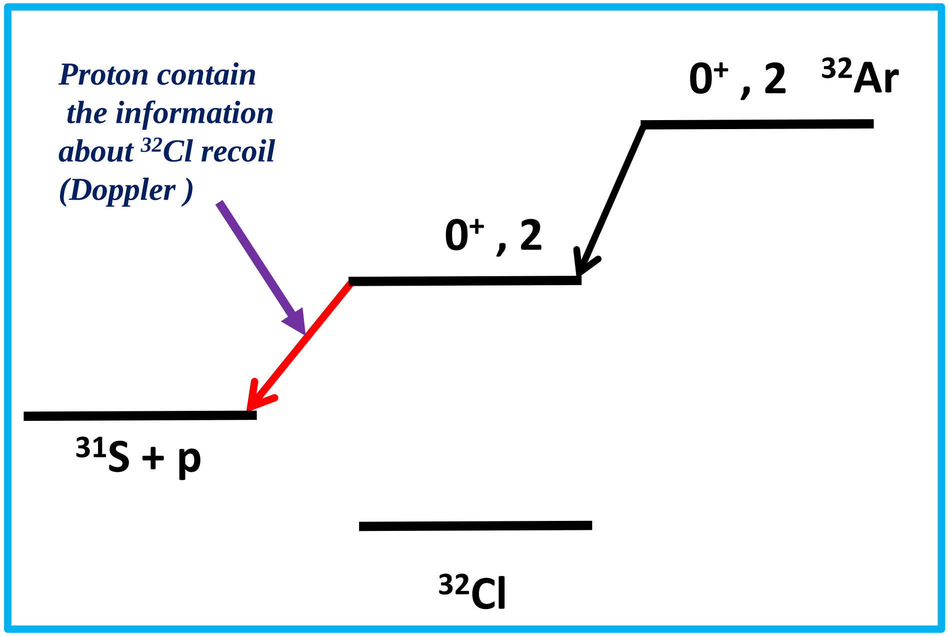
$$W(\theta) \cong \left(1 + a_{\beta\nu}\frac{p_e p_\nu}{E_e E_\nu}\cos\theta_{e\nu} + b\frac{m_e}{E_e}\right)$$

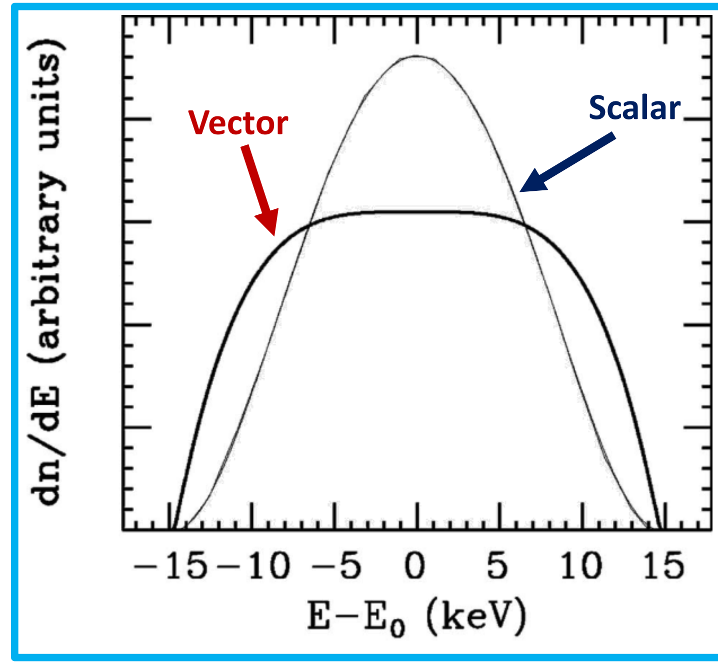



$$a_{\beta\nu} \overset{?}{=} 1$$

**Test of SM**

# Beta delayed proton emitters




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