Radioactive Beams at Texas A&M University New Results and Future Plans

RNB6

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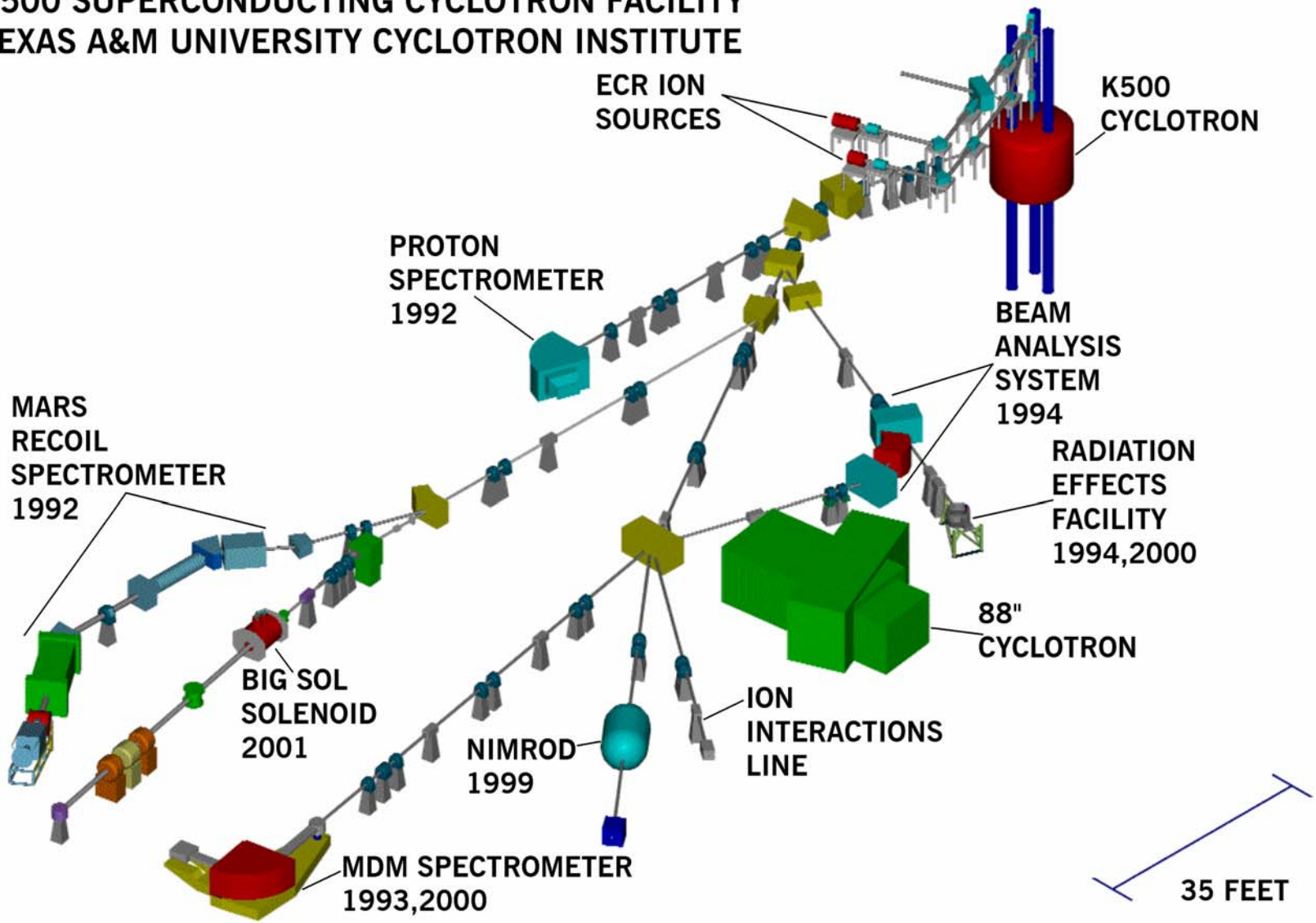
September, 2003

Rare Isotope Beams at TAMU

- Overview of Laboratory
- RNB's via **MARS/BigSol**
- Beams to date
- Physics
- Future directions

K500 SUPERCONDUCTING CYCLOTRON FACILITY
TEXAS A&M UNIVERSITY CYCLOTRON INSTITUTE



RNB Production Techniques

MARS:

- Transfer with inverse kinematics – **0°**
  - heavy-ion beams
  - gas targets (^{1}H, ^{2}H)

BigSol:

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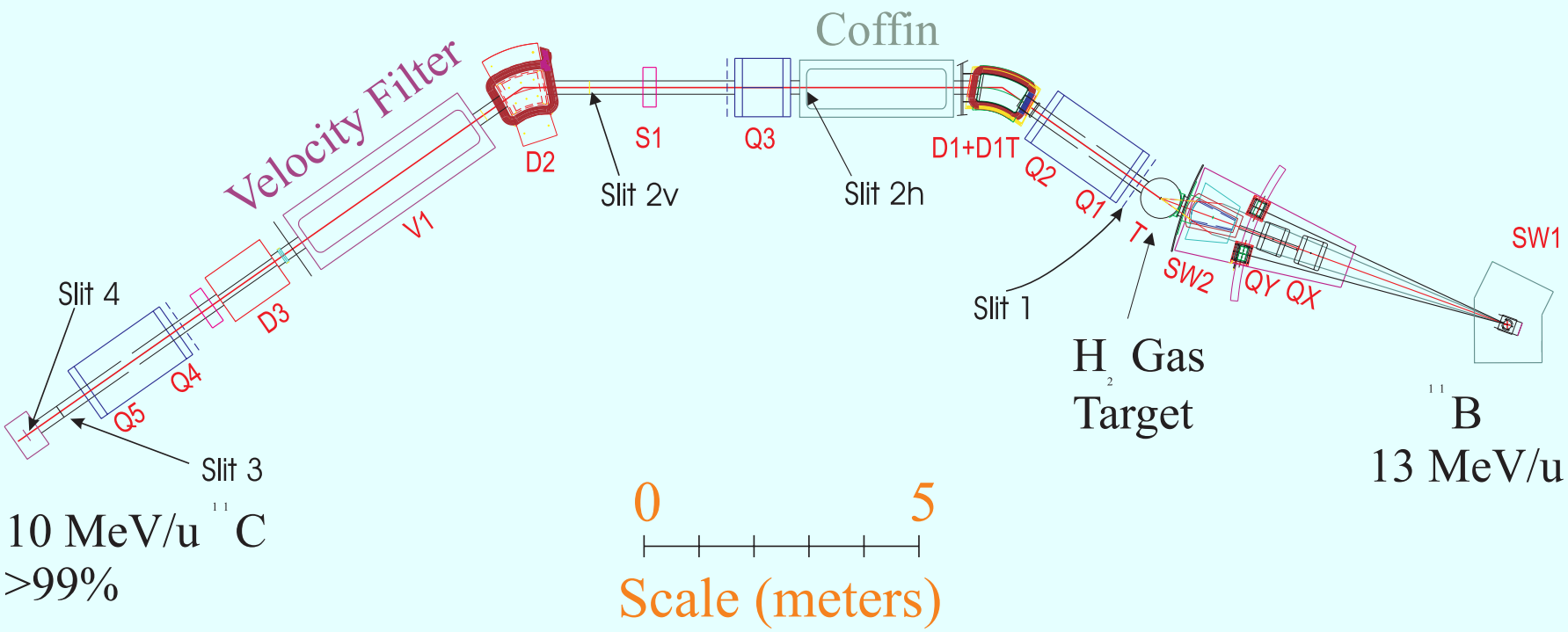
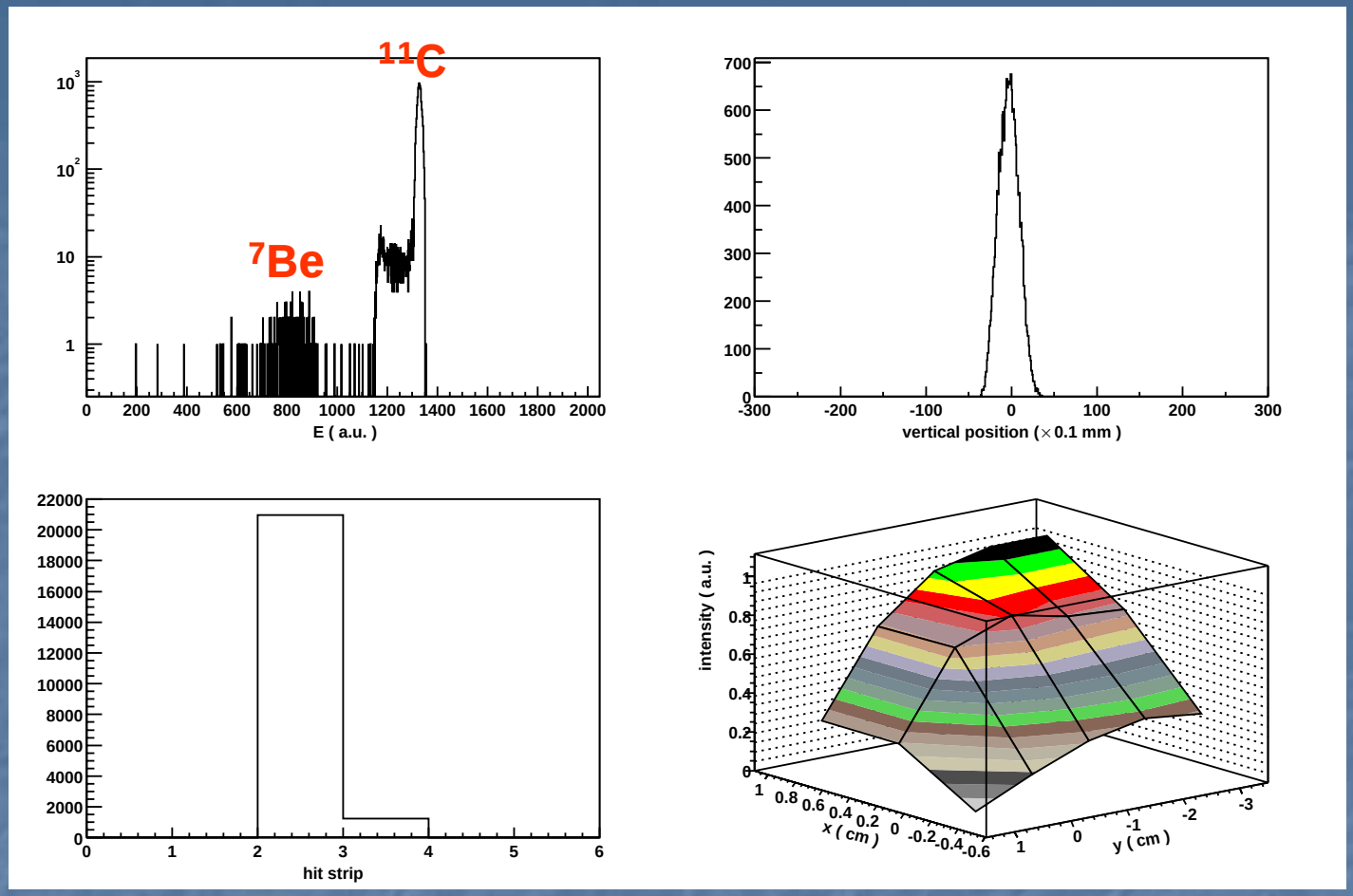
  - first beams include: Ar, Ca, Ni, Yb, Pt, U

Momentum Achromat Recoil Separator





Primary Beam : $^{11}B^{2+}$@13 MeV/u, 800 enA
Primary Reaction : $^{11}B(^{1}H,n)^{11}C$
Secondary beam : ^{11}C
Intensity>400 kHz, PURITY>99%
E=110 MeV, ΔE=1.6 MeV (FWHM)
ΔX=3 mm (FWHM), ΔY=3.2 mm (FWHM)
Δθ=1.8 deg(FW), Δϕ=1.9 deg (FW)

Secondary Beams

Beam (primary beam)	E (Mev/A)	Purity	I_{sb}(kHz)	I_{pb}(pnA)
^{7}Be (^{7}Li)	12,25	>99.5	80	80
^{8}B (^{10}B)	8	>99	10	100
^{11}C (^{11}B)	11	>99	400	200
^{13}N (^{13}C)	11	>99	1000	300
^{14}O (^{14}N)	6	>99	50	150
^{20}F (^{19}F)	32	>98	250	25
^{20}Na (^{20}Ne)	32	>98	50	25
^{22}Mg (^{23}Na)	28	>99	60	28
^{30}S (^{31}P)	28	>99	10	4
^{34}Ar (^{35}Cl)	30	>98	45	35
^{57}Cu (^{58}Ni)	27	>99	10	1
^{62}Ga (^{64}Zn)	37	94	1	2

Physics Overview - MARS

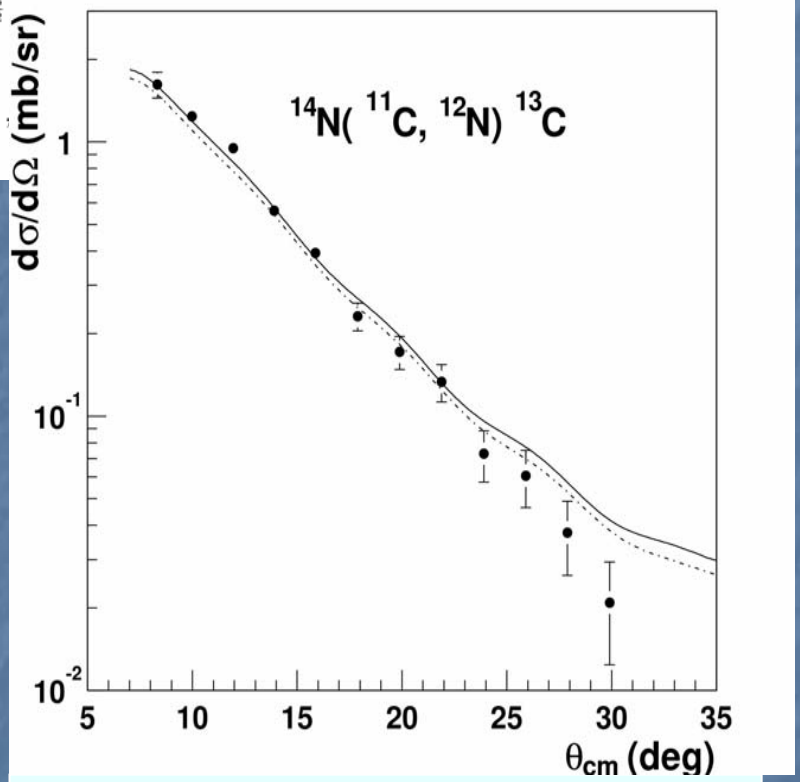
- Nuclear Astrophysics:
  - Transfer reactions to get **ANC**s
    (^{7}Be, ^{11}C, ^{13}N induced reactions)
  - Elastic scattering (^{7}Be, ^{8}B, ^{11}C, ^{13}N)
  - Resonance reactions (^{14}O)

- β-decay studies
  - $0^{+} \rightarrow 0^{+}$ transitions
    (^{22}Mg, ^{30}S, ^{34}Ar, ^{62}Ga)

$^{14}N(^{11}C,^{12}N)^{13}C$ angular distribution

$$\frac{1}{(C^{12N}_{11Cp1\frac{1}{2}})^2} = \frac{1}{\sigma_{exp}}\left(\left(\frac{C^{14N}_{13Cp1\frac{1}{2}}}{b^{14N}_{13Cp1\frac{1}{2}}\, b^{12N}_{11Cp1\frac{1}{2}}}\right)^2 \sigma^{DW}_{1\frac{1}{2}1\frac{1}{2}} + \left(\frac{C^{14N}_{13Cp1\frac{3}{2}}}{b^{14N}_{13Cp1\frac{1}{2}}\, b^{12N}_{11Cp1\frac{3}{2}}}\right)^2 \sigma^{DW}_{1\frac{1}{2}1\frac{3}{2}} + \mathcal{S}\left(\frac{C^{14N}_{13Cp1\frac{1}{2}}}{b^{14N}_{13Cp1\frac{3}{2}}\, b^{12N}_{11Cp1\frac{1}{2}}}\right)^2 \sigma^{DW}_{1\frac{3}{2}1\frac{1}{2}} + \mathcal{S}\left(\frac{C^{14N}_{13Cp1\frac{3}{2}}}{b^{14N}_{13Cp1\frac{3}{2}}\, b^{12N}_{11Cp1\frac{3}{2}}}\right)^2 \sigma^{DW}_{1\frac{3}{2}1\frac{3}{2}}\right)$$

Normalization(beam&target)	6.5%
Optical Model	8%
ANCs of ^{14}N	6.4%
Statistical Error	3%
MC parameters	2%
Total	12.7%

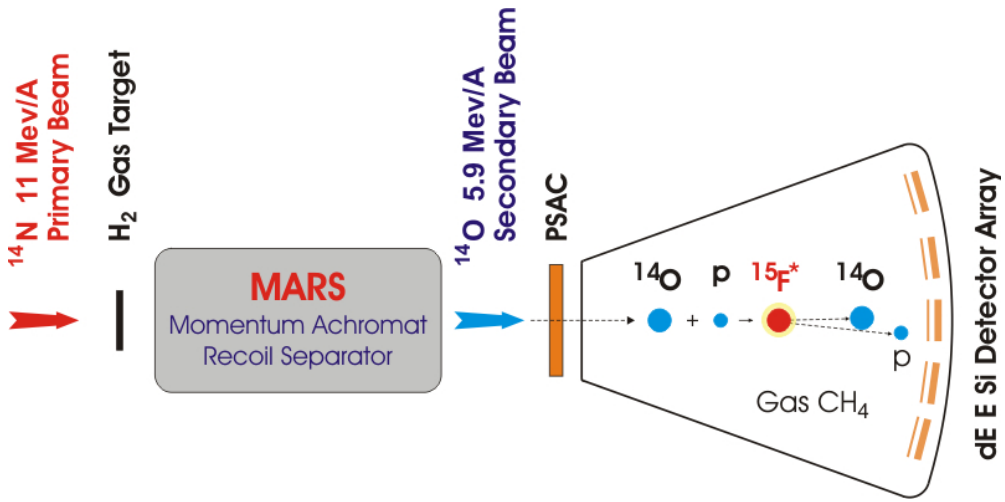


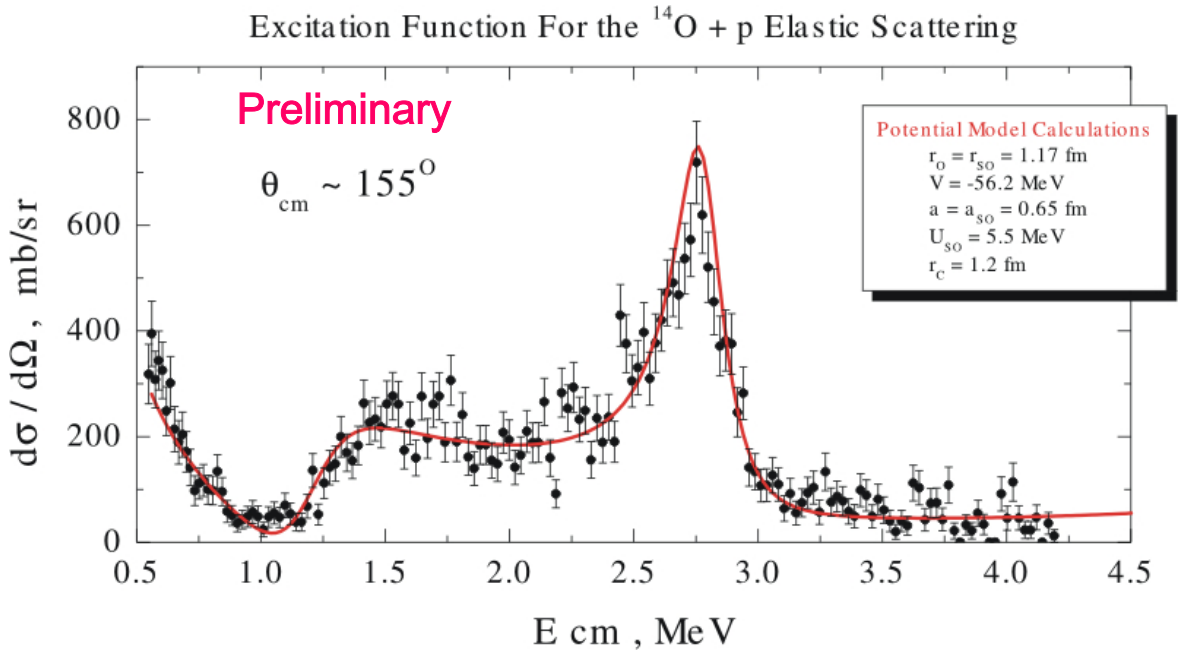
$$C^2_{1,1/2} = 1.4 \pm 0.2 \pm 0.07 \qquad fm^{-1}$$

$$C^2_{1,3/2} = 0.33 \pm 0.05 \pm 0.05 \qquad fm^{-1}$$

$$s = \frac{C^2_{1,3/2}}{C^2_{1,1/2}} = \frac{0.17}{0.71} \qquad s \sim 20\%$$

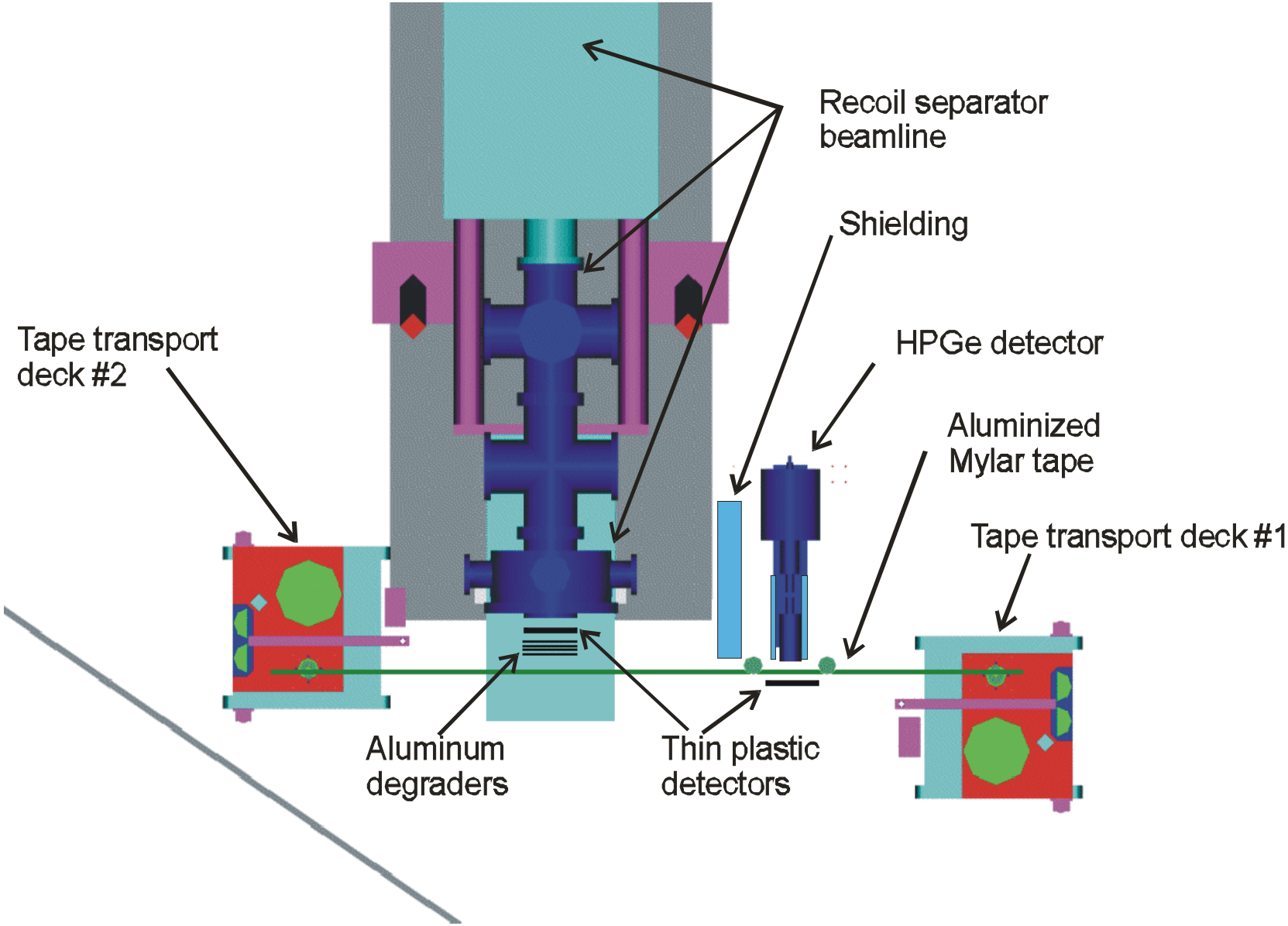
$^{14}O + p$ Resonance Scattering



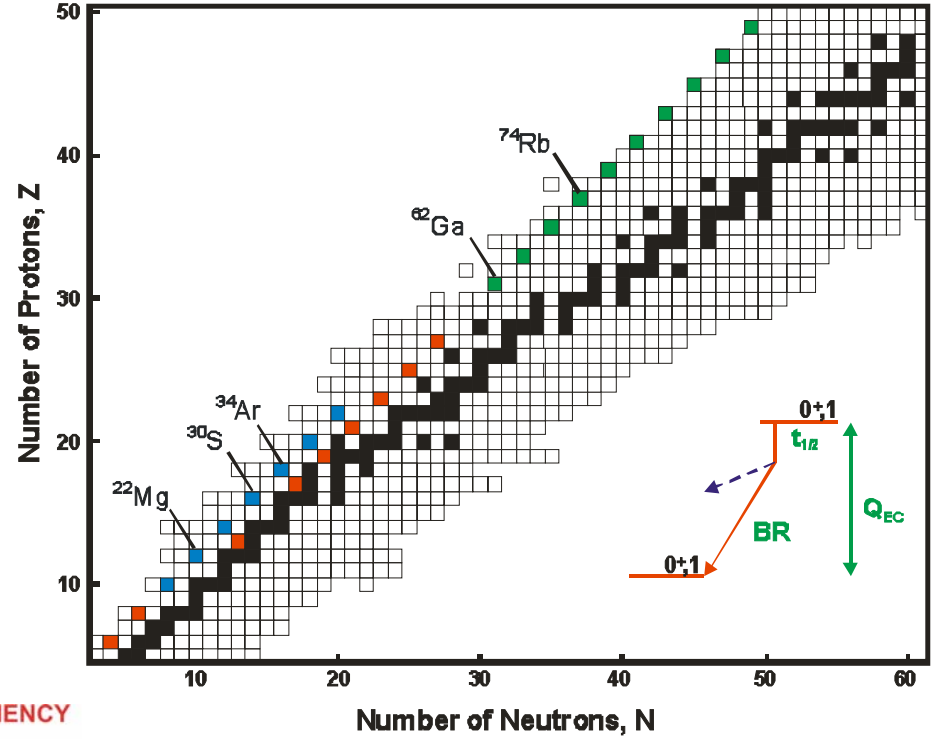


EXPERIMENTAL SET-UP

$0^+ \rightarrow 0^+$ β decay



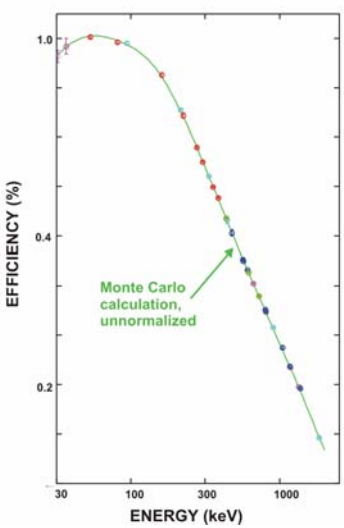
SUPERALLOWED BETA DECAY AND CKM UNITARITY

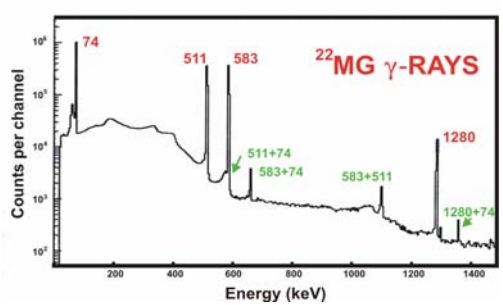


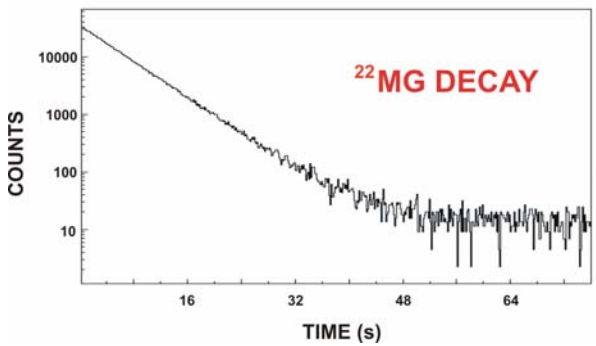
New superallowed emitters are being measured with high precision in order to test the nuclear charge correction δ_C. At Texas A&M we are determining branching ratios to 0.2% and half-lives to 0.04%. This is aimed at reducing uncertainty on the unitarity test, which currently stands at:

$$V_{ud}^2 + V_{us}^2 + V_{ub}^2 = 0.9968 \pm 0.0014$$

DETECTOR EFFICIENCY







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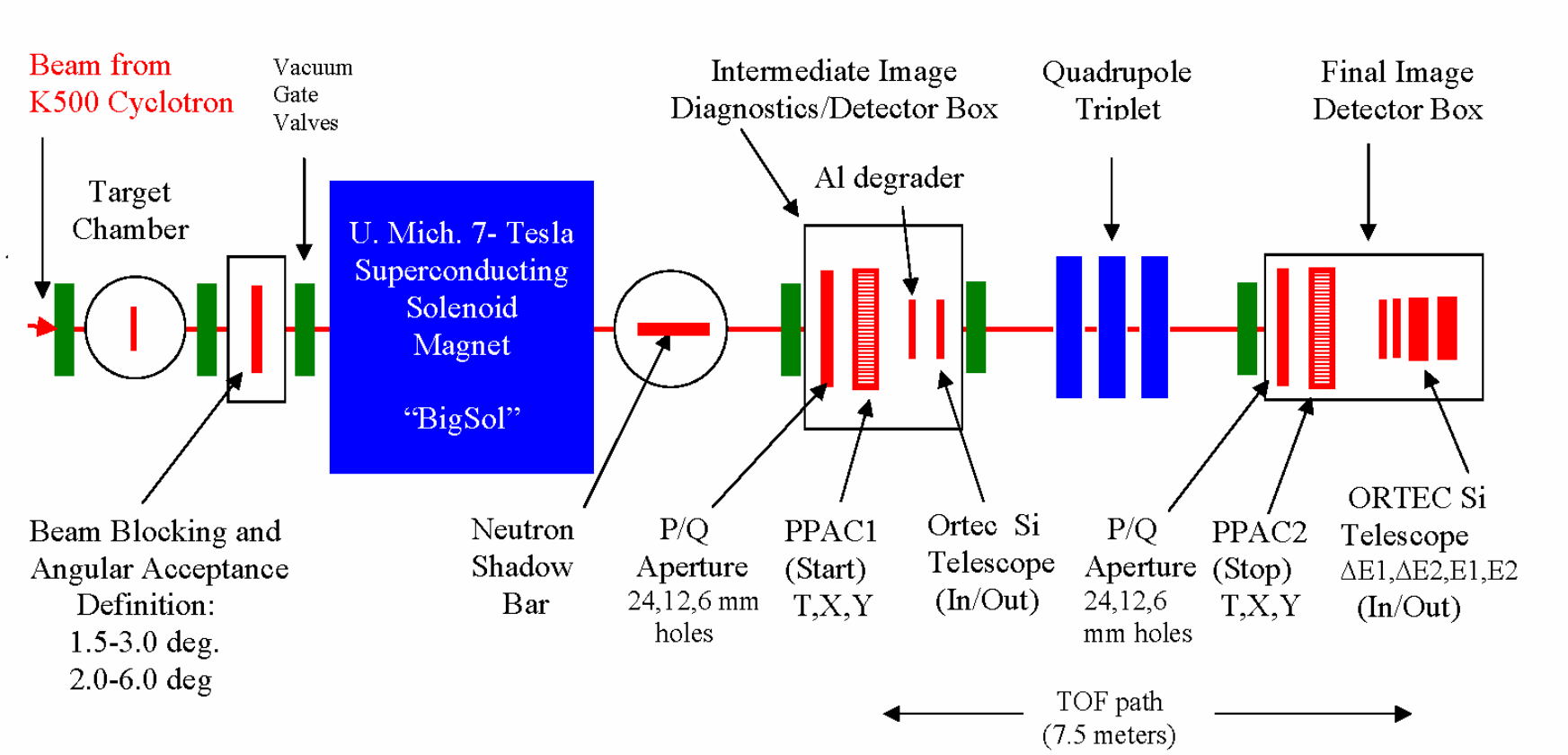
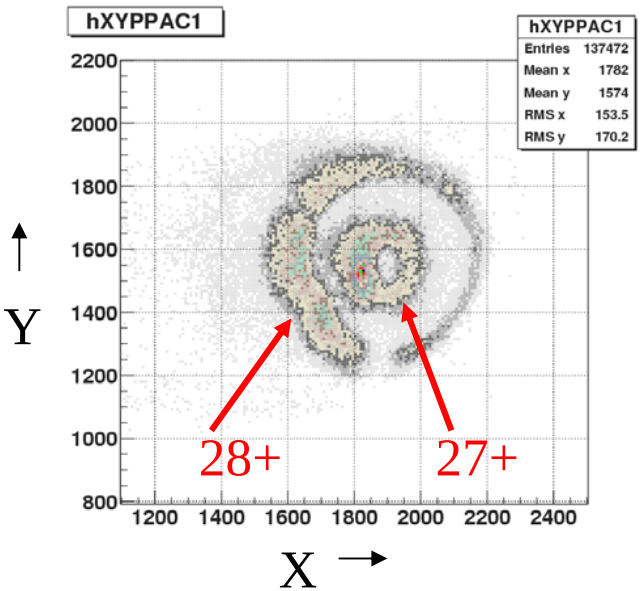
[See poster by G. Souliotis for details]

The Superconducting Solenoid Rare Isotope Line at TAMU:

Schematic diagram of the setup for heavy-residue studies from DIC (G.A. Souliotis et al., Sept. 03)



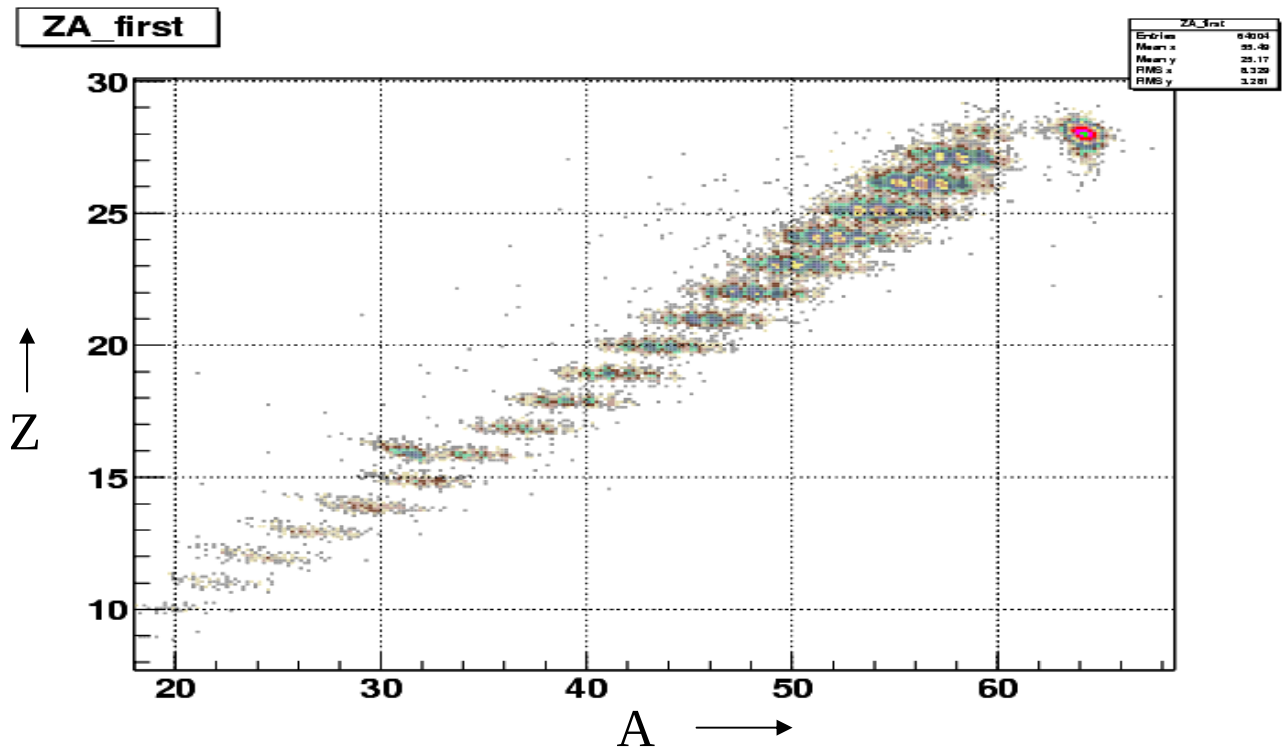
Results of BigSol Line tests (Sept. 03):



Charge state distribution at PPAC1 (thru 2-inch hole) from ^{64}Ni (35MeV/u) after a mylar stripper.

Angular acceptance: 2.0-6.0 deg.

Z-A histogram of fragments from ^{64}Ni(25MeV/u)+^{64}Ni



TAMU Upgrade Plans

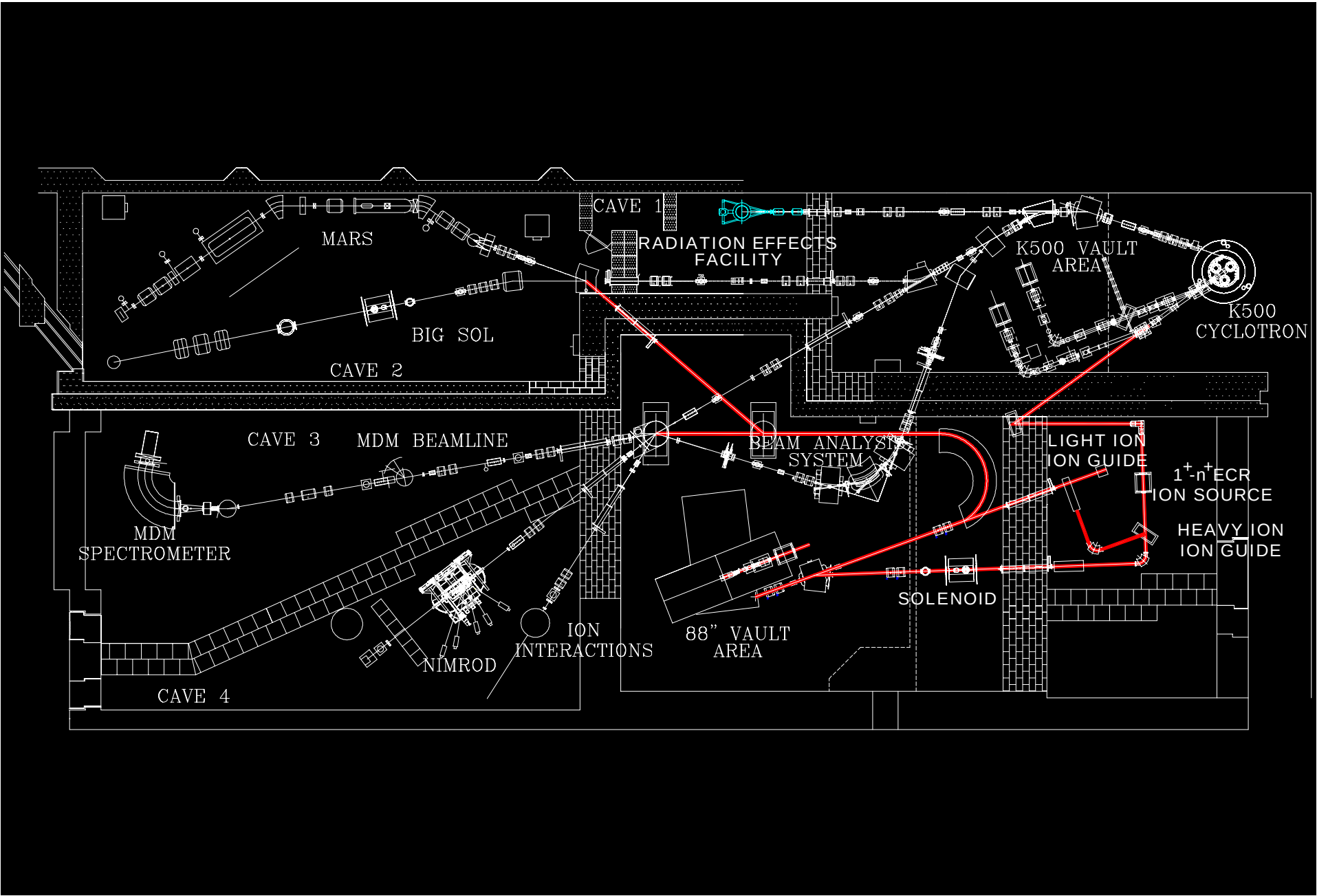
- Further develop **RIB** capability
- Produce accelerated **RIB**'s at intermediate energies

[white paper at http://cyclotron.tamu.edu/]

TAMU Upgrade Plans

- **Stage I**
  - commission K150(88”) cyclotron
  - ECR source injection
  - commission beam lines to existing apparatus
- **Stage II**
  - isotope production stations completed
  - production of rare isotopes
- **Stage III**
  - K500 acceleration of rare isotope beams

Proposed Layout



TAMU Upgrade

Stage I – Performance K150 beams

Isotope	E	I		Isotope	E	I
	MeV/u	pμA			MeV/u	pμA
p	50	27		^{20}Ne	26	3
d	30	20		^{22}Ne	24	0.5
^{3}He	40	10		^{34}S	18	0.7
^{4}He	30	10		^{40}Ar	16	1.4
^{6}Li	30	7		^{40}Ca	16	1.5
^{7}Li	22	8		^{59}Co	10	0.9
^{10}B	30	4		^{78}Kr	9	0.6
^{11}B	24	5		^{86}Kr	8	0.6
^{16}O	30	2		^{129}Xe	5.6	0.5

(**Simultaneous operation** of K150 and K500 into different experimental areas.)

TAMU Upgrade
Stage II and III

- **Couple IG** (light ion beams) and **HI** target stations to **K150**
- **Complete $1^+ \rightarrow n^+$ ECR source**
- **Begin Rare Ion production**

TAMU Upgrade
Stage III Performance
Ion Guide (heavy ions) into K500

	Isotope	Max. Energy	Intensity
		Mev/u	pps
	^{9}Li	45	3×10^{6}
	^{12}Be	45	5×10^{6}
neutron-rich isotopes	^{38}S	36	5×10^{5}
	^{44}S	26	2×10^{2}
	^{42}Ar	39	7×10^{5}
	^{62}Fe	38	4×10^{4}
	^{8}B	70	2×10^{6}
	^{14}O	63	1×10^{5}
	^{22}Mg	57	6×10^{4}
proton-rich isotopes	^{27}P	62	2×10^{3}
	^{62}Ga	47	4×10^{2}
	^{64}Ga	45	2×10^{4}

TAMU Upgrade Plans

- **Cost** ≈ $4 M

- **Time line**

  ≈ 2 years for stage I - II

  ≈ 2 more years for completion and first experiments

TAMU Upgrade

Report on progress

at **RNB7**!