RIB capabilities expected from the Upgrade Project of the Texas A&M Cyclotron Institute

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Outline :

λ Discuss Layout of facility – major equipment/research

λ Describe Upgrade project of the Cyclotron Institute (CI)

λ RIB production with present means at TAMU:

Transfer/exchange reactions + MARS
Multinucleon transfer / DIC + MARS or BigSol

λ Research in RIB production in peripheral (quasielastic/deep-inelastic) collisions at the energy range offered by the K150/K500 Cyclotrons

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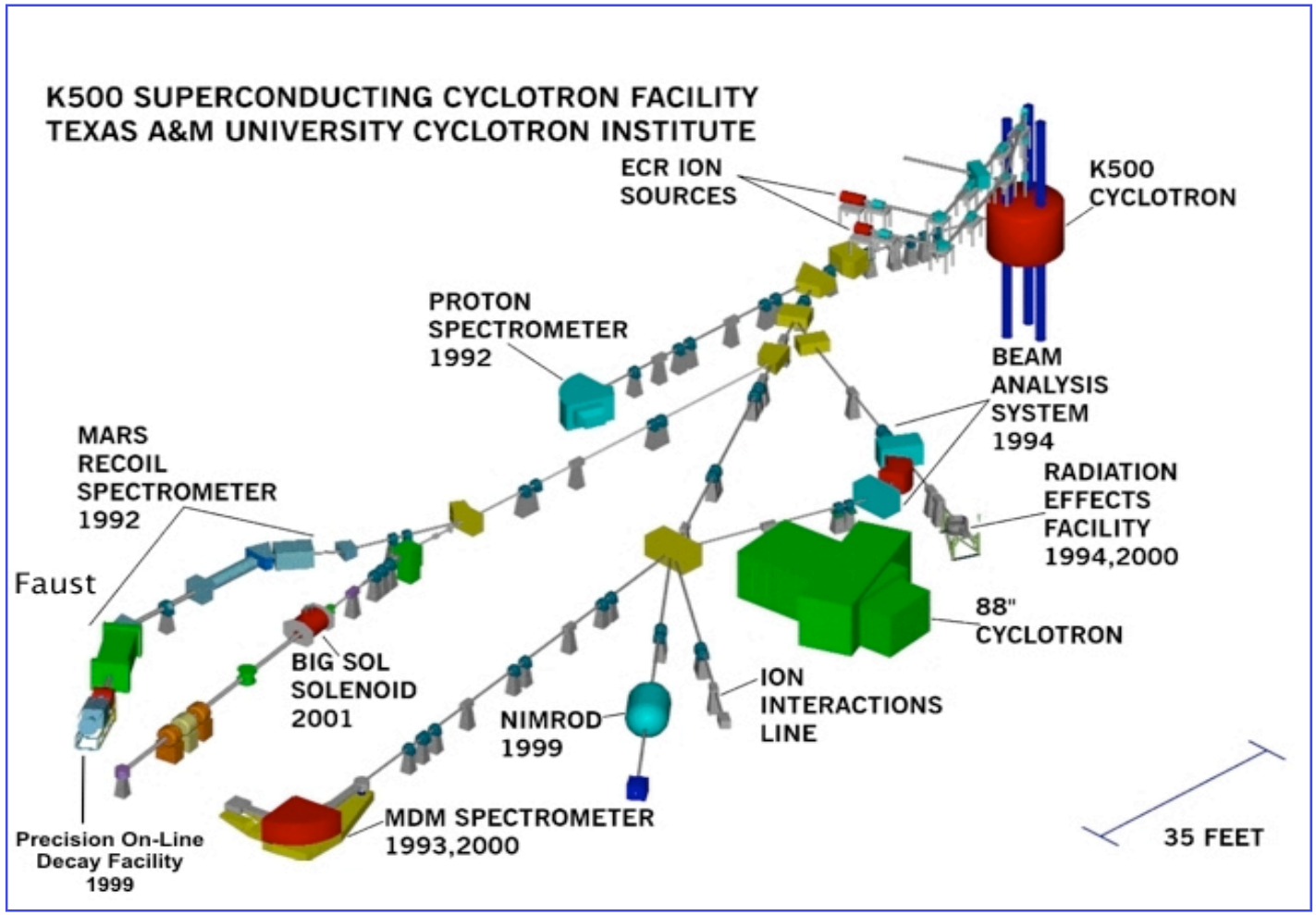

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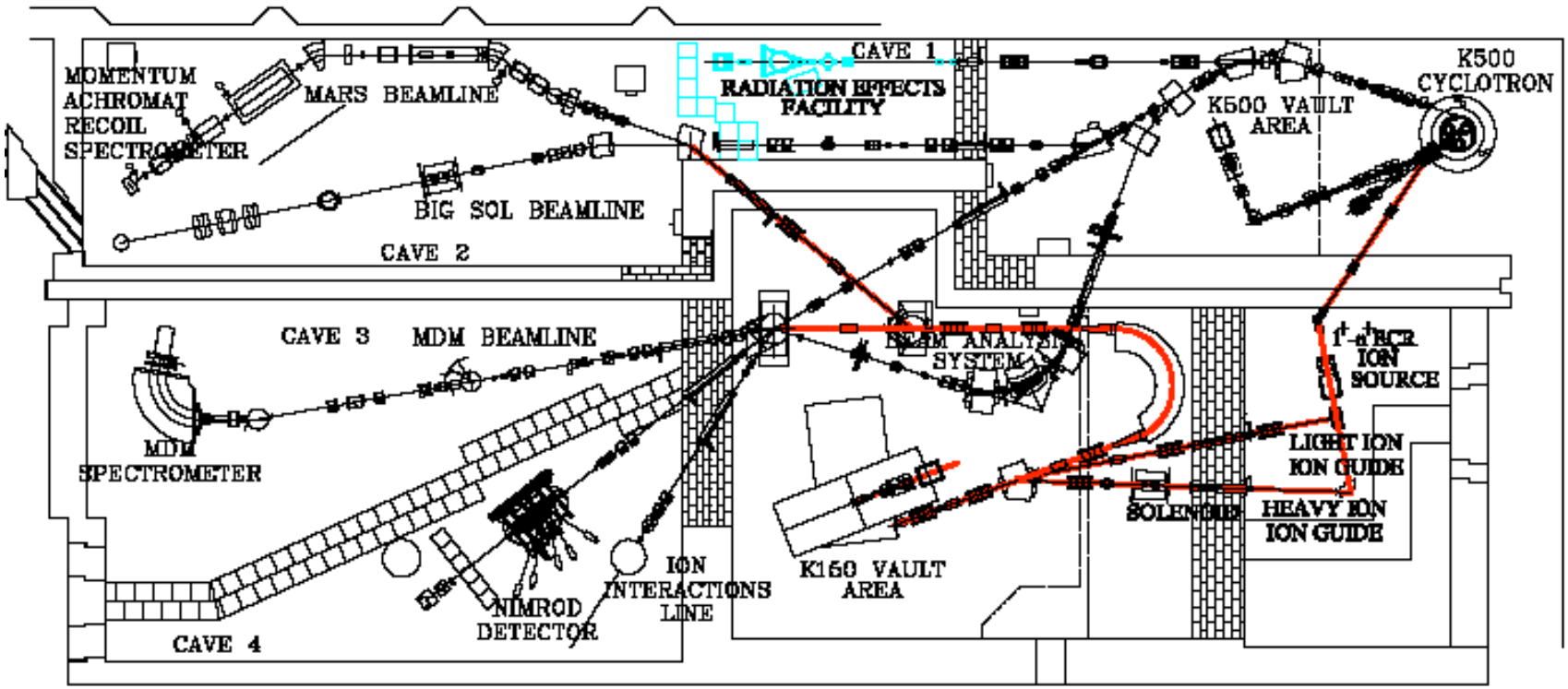
Outline of Upgraded Facility at TAMU



Upgraded TAMU Facility : **New additions** are drawn in **red lines**. High intensity light stable beams from the re-commissioned K150 Cyclotron will be used with ion guide techniques to produce high quality re-accelerated RIBs from the K500 Cyclotron. Direct delivery of these K150 beams to existing lines is also possible.

Funding Sources : DOE (1.8 M), TAMU matching (0.8M), Welch Foundation (1.0 M), TAMU CI (1.5 M)
Total cost: ~5.1 M. Expected completion: 2011

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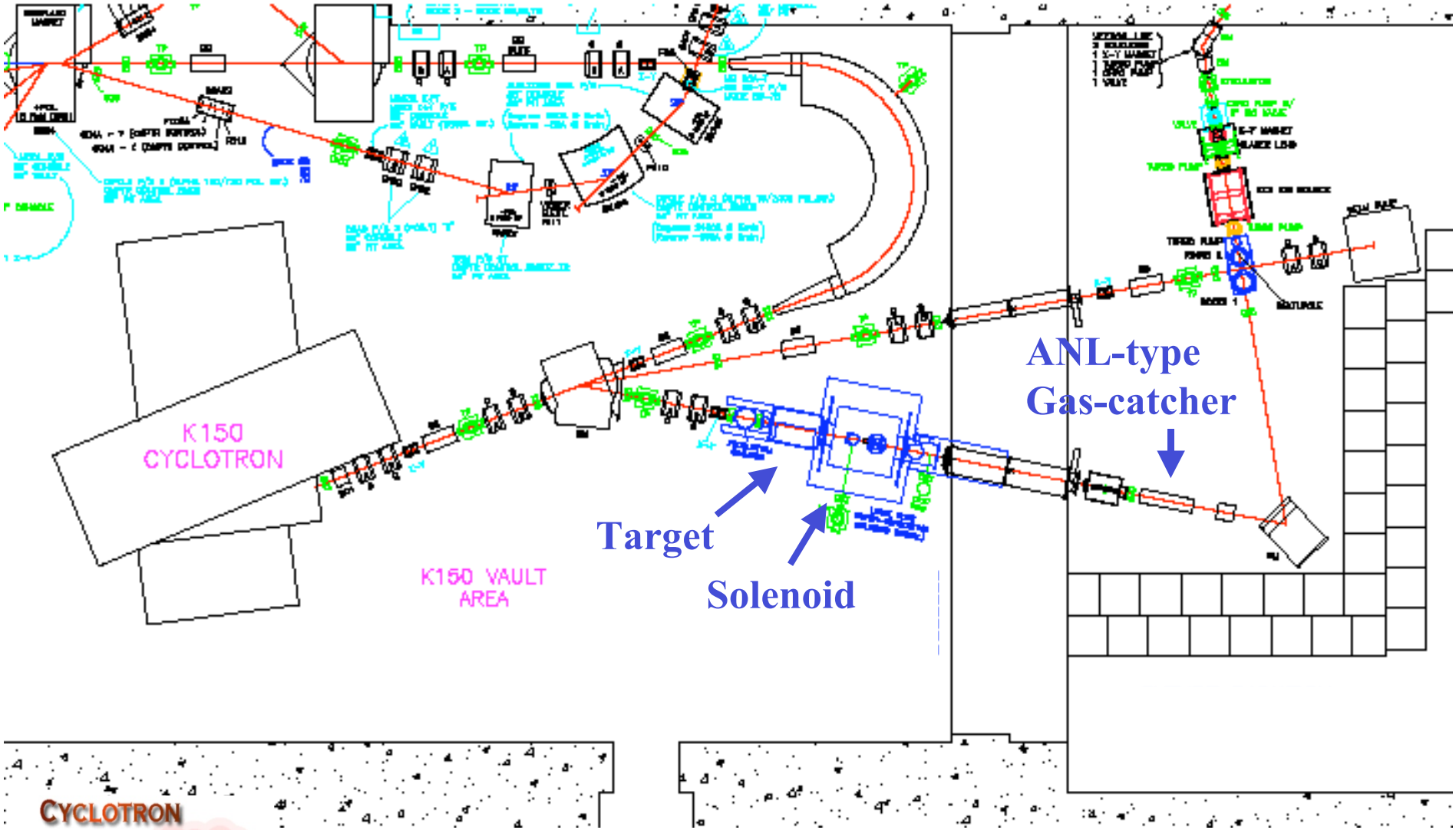
Heavy-ion target station : solenoid+ gas catcher after K150:



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Plans for RIB from DIC

λ Experience in deep-inelastic collisions at the K150 energy range, and relevant instrumentation

λUse of MARS as in-flight separator to exploit RIBs from K150 primary beams

λ Installation of a large-bore superconducting solenoid (e.g. BigSol) as a separator before an ANL/RIA-type gas catcher.

λInitial phase : test one of the ANL/RIA prototypes at the end of the BigSol line (in collaboration with ANL)

λFinal phase: use a Solenoid after the K150 cyclotron, construct a gas catcher similar to the ANL prototypes for permanent installation and use at the CI.

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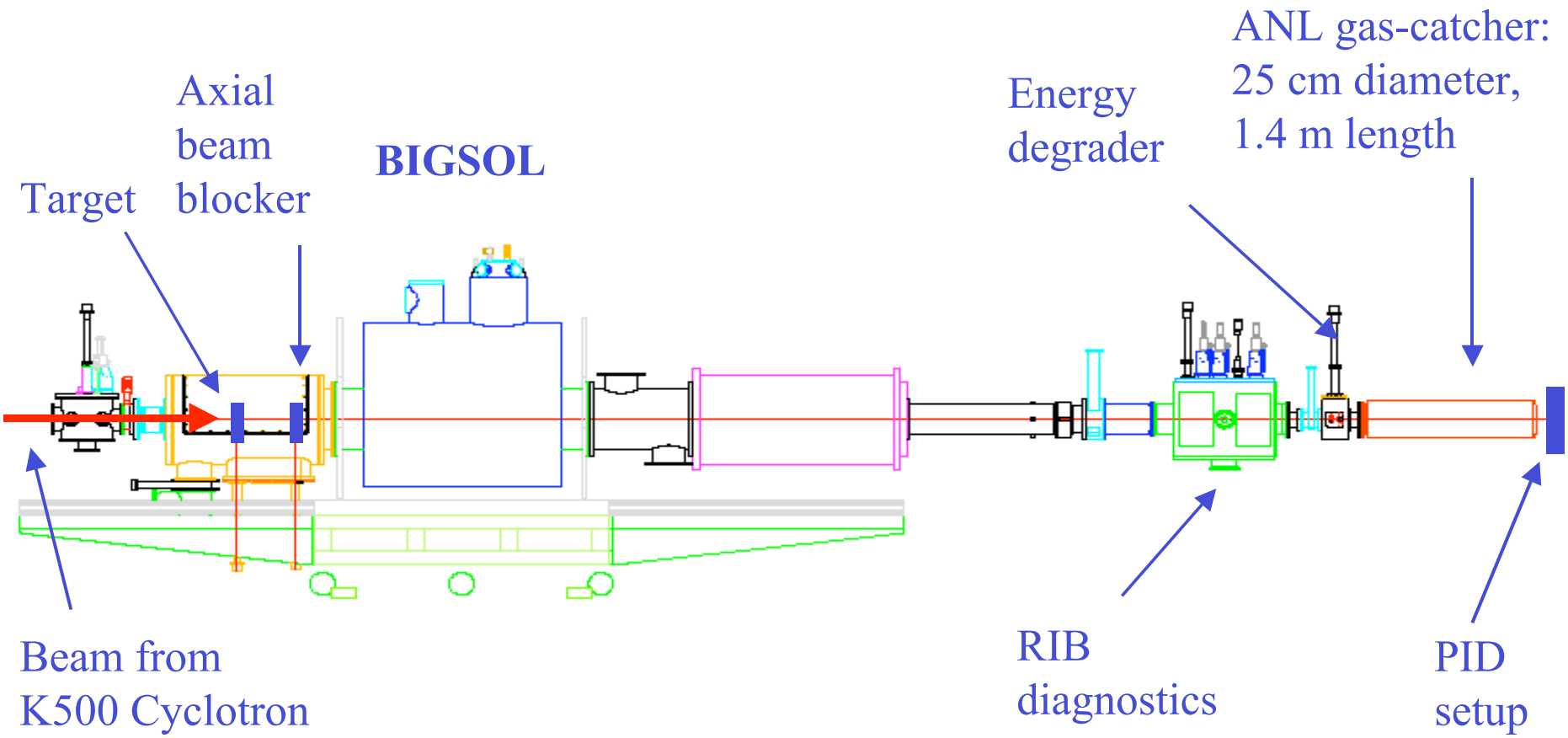
BigSol - ANL gas catcher setup



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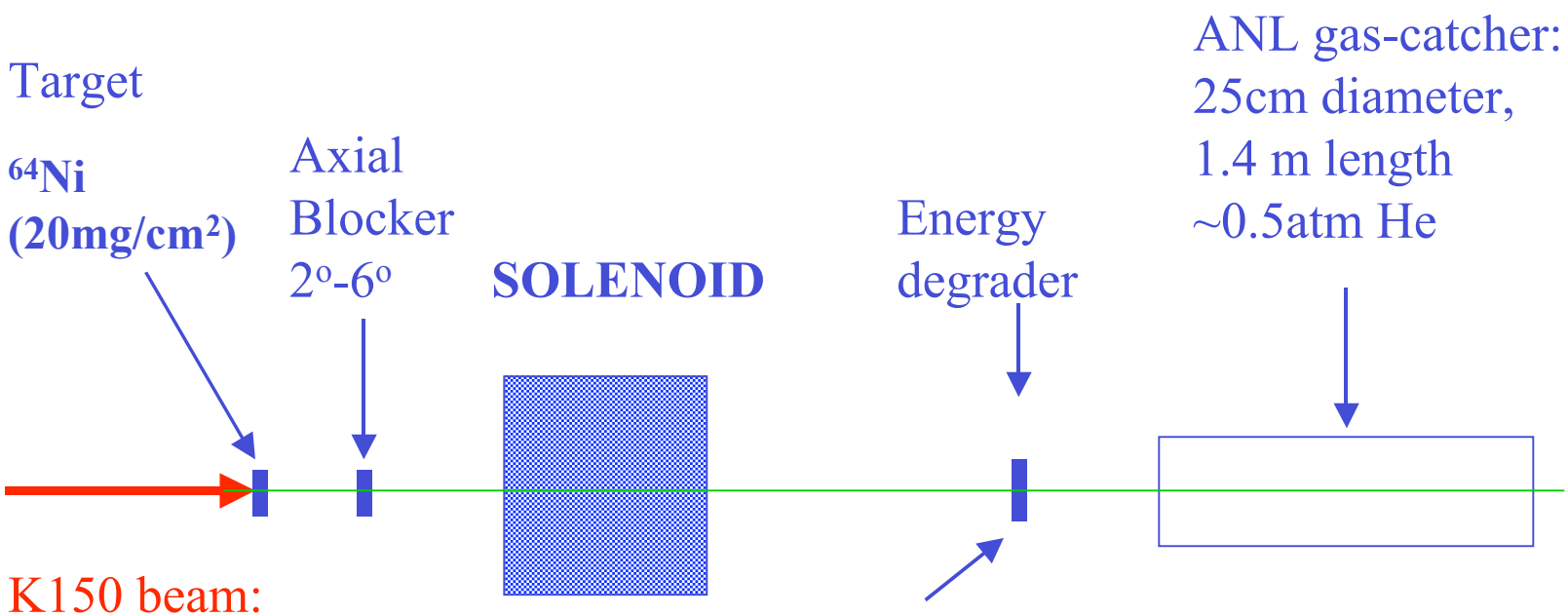
Example of RIB: ^{38}S from ^{40}Ar (14MeV/u) + ^{64}Ni



K150 beam:
^{40}Ar (14 MeV/u)
~1.0 p_A

40 mg/cm^2 Al
^{38}S energy :
~2.0 MeV/u
(0.0-5.0 MeV/u)

Range in the gas cell (SRIM-2003)
^{38}S at 2.0 MeV/u: 35.0cm
at 5.0 MeV/u : 100.0 cm

^{38}S cross section: 6.0 mb

Energy: 12.0 MeV/u (9.0-14.0 MeV/u)

Total production rate : 1.6×10^7 pps

Rate after the solenoid: 8×10^6 pps

(~50% calculated collection efficiency)

Cell efficiency: ~40%
Charge boosting+reacceleration ~1%)

Final Rate: 3.2×10^4 pps

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Examples of reaccelerated beams produced in DIC:

$t_{1/2}$>100ms

Isotope	Max. Energy MeV/u	Intensity Pps
Neutron rich		
^{9}Li	45	$1.7\text{-}3.4\times10^{6}$
^{11}Be	45	$0.7\text{-}1.4\times10^{6}$
^{22}O	40	$2.0\text{-}4.0\times10^{4}$
^{24}Ne	40	$1.0\text{-}5.0\times10^{4}$
^{32}Mg	40	$1.3\text{-}2.6\times10^{4}$
^{38}S	36	$2.5\text{-}5.0\times10^{4}$
^{40}S	32	$1.0\text{-}5.0\times10^{3}$
^{42}S	29	$1.8\text{-}3.6\times10^{2}$
^{42}Ar	39	$3.3\text{-}6.6\times10^{5}$
^{44}Ar	38	$0.9\text{-}1.8\times10^{5}$
^{46}Ar	35	$1.8\text{-}3.6\times10^{4}$
^{62}Fe	38	$1.9\text{-}3.8\times10^{4}$
^{60}Cr	32	$0.5\text{-}1.0\times10^{3}$
Proton rich		
^{7}Be	60	$0.5\text{-}1.0\times10^{6}$
^{8}B	70	$1.2\text{-}2.4\times10^{6}$
^{11}C	63	$1.3\text{-}2.6\times10^{6}$
^{14}O	70	$0.7\text{-}1.4\times10^{5}$
^{22}Mg	57	$3.1\text{-}6.3\times10^{4}$
^{23}Al	60	$1.2\text{-}2.4\times10^{3}$
^{27}P	62	$1.0\text{-}2.0\times10^{3}$
^{62}Ga	47	$2.1\text{-}4.3\times10^{2}$
^{64}Ga	45	$0.9\text{-}1.9\times10^{4}$

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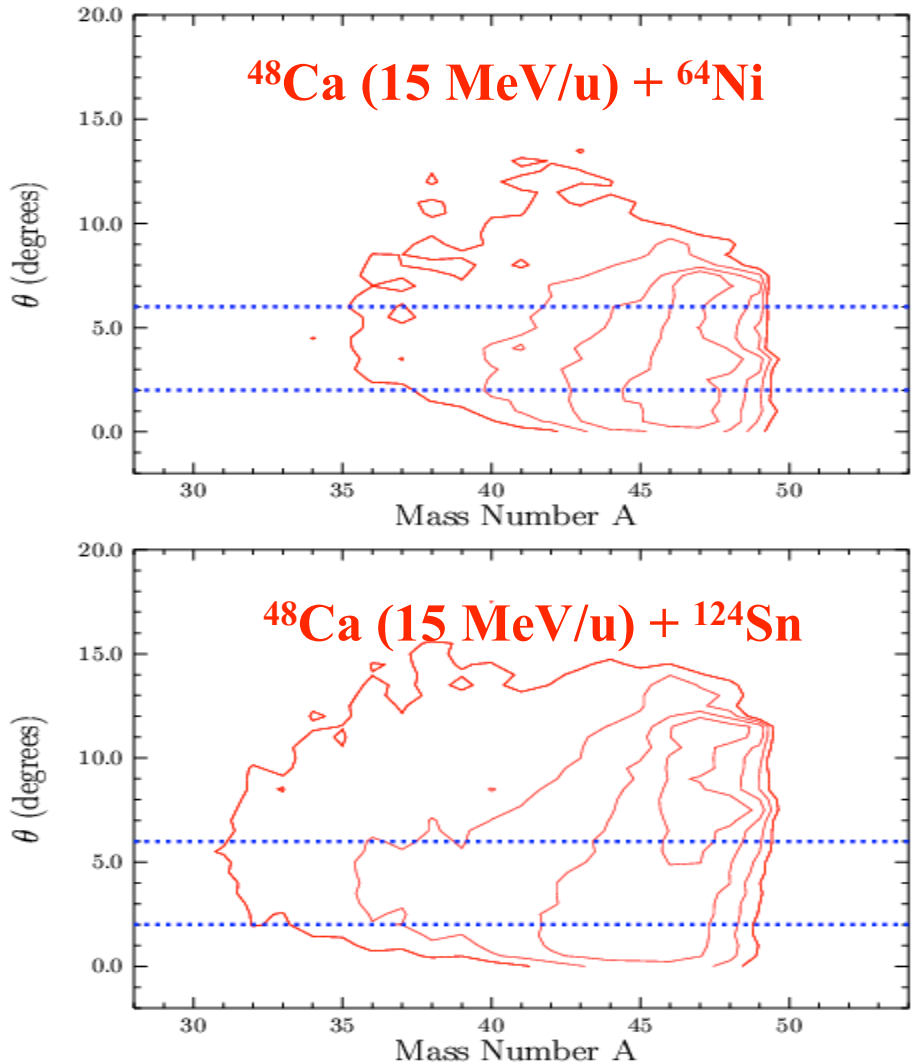
Challenge with DICs: wide angular and charge state distributions: large acceptance separator necessary

Calculated angular distributions:



Calculations*:

DIT: (interaction, nucleon exchange)

GEMINI : de-excitation

2-6 degrees indicative ang. acceptance of BigSol

*References:

DIT: L. Tassan-Got and C. Stephan, Nucl. Phys. A524 121 (1991)

GEMINI: R. Charity et al., Nucl. Phys. A483 391 (1988)

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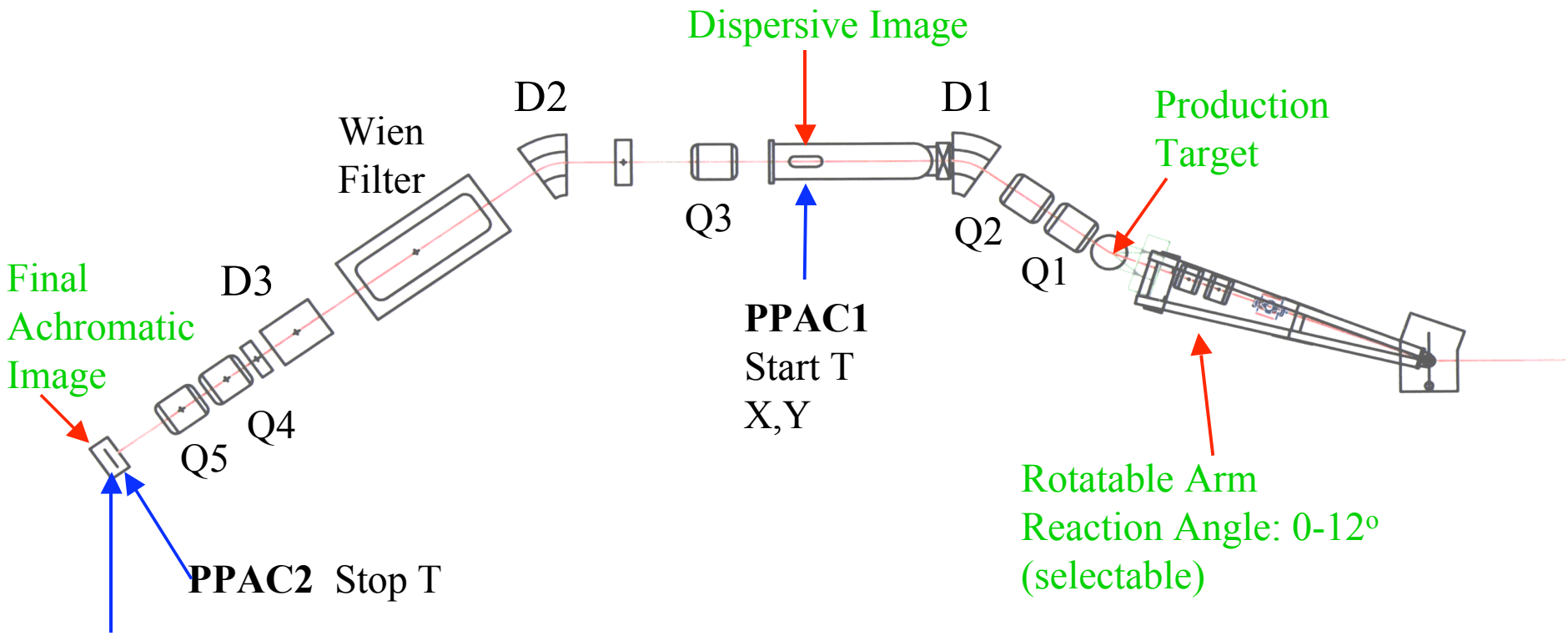
MARS Recoil Separator and Setup for RIB Production in DIC



Silicon Telescope:
_E_1, X,Y (Strips)
_E_2, $E_{residual}$

MARS Acceptances:
Anglular: 9 msr
Momentum: 4 %

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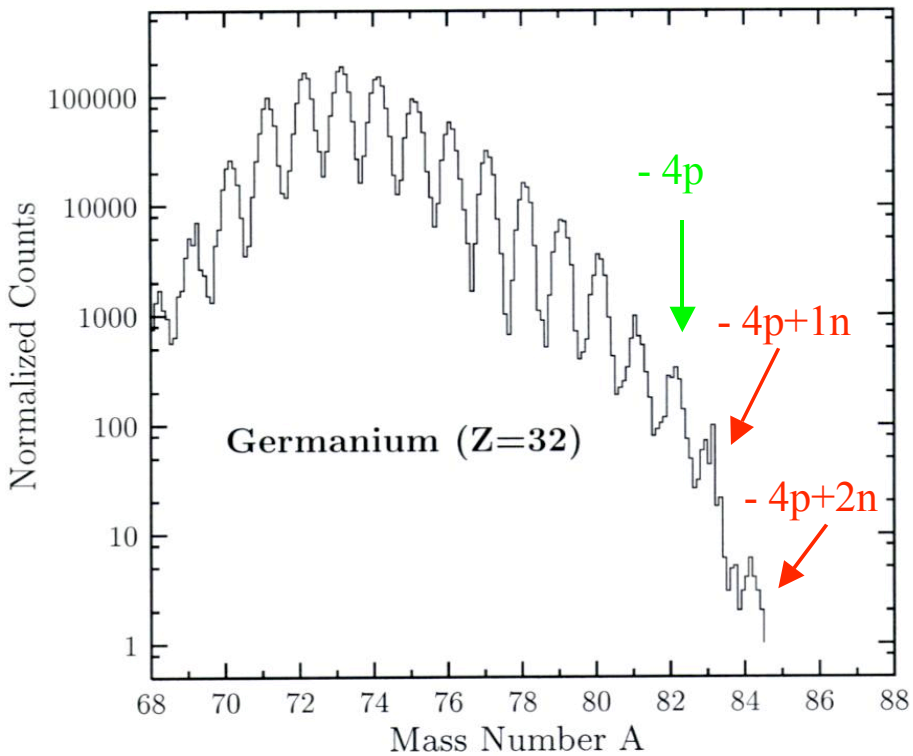
Mass distribution of Ge (Z=32) isotopes

^{86}Kr (25 MeV/u) + ^{64}Ni



* G.A. Souliotis et al., Phys. Lett. B 543, 163 (2002)

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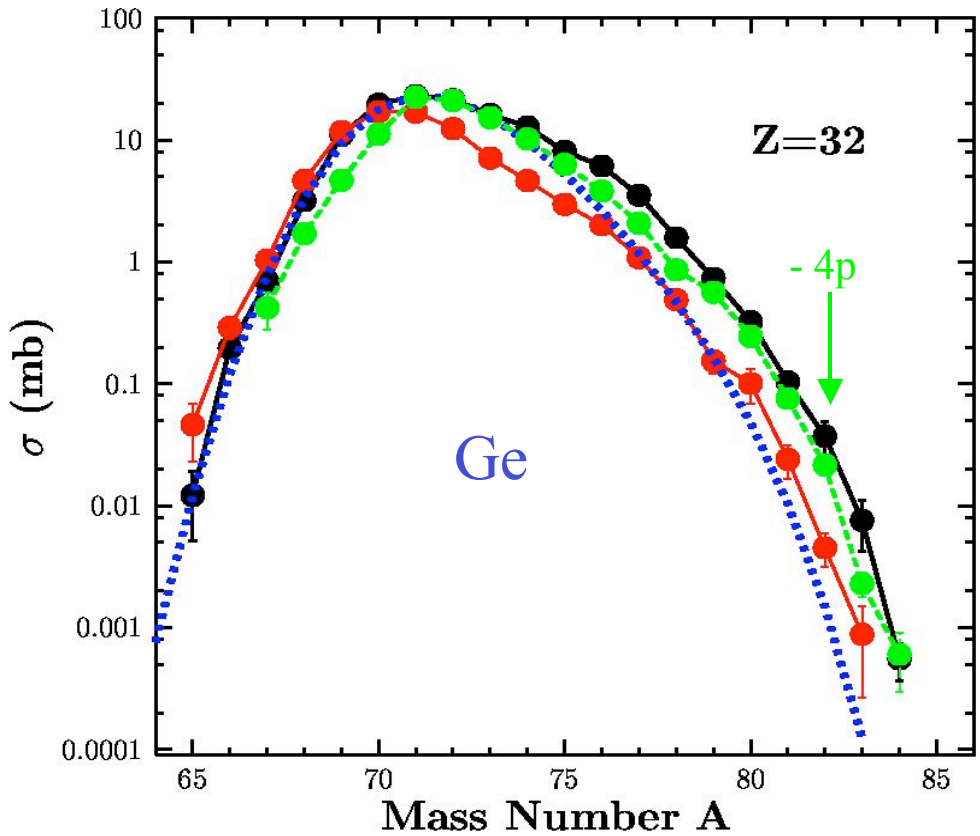
Mass Distribution of Germanium from ^{86}Kr(25MeV/u) + ^{124}Sn,^{112}Sn, ^{64}Ni



Data using targets:

- ^{124}Sn
- ^{112}Sn
- ^{64}Ni

------ EPAX2

G.A. Souliotis et al., Phys. Rev. Lett. 91 022701 (2003)

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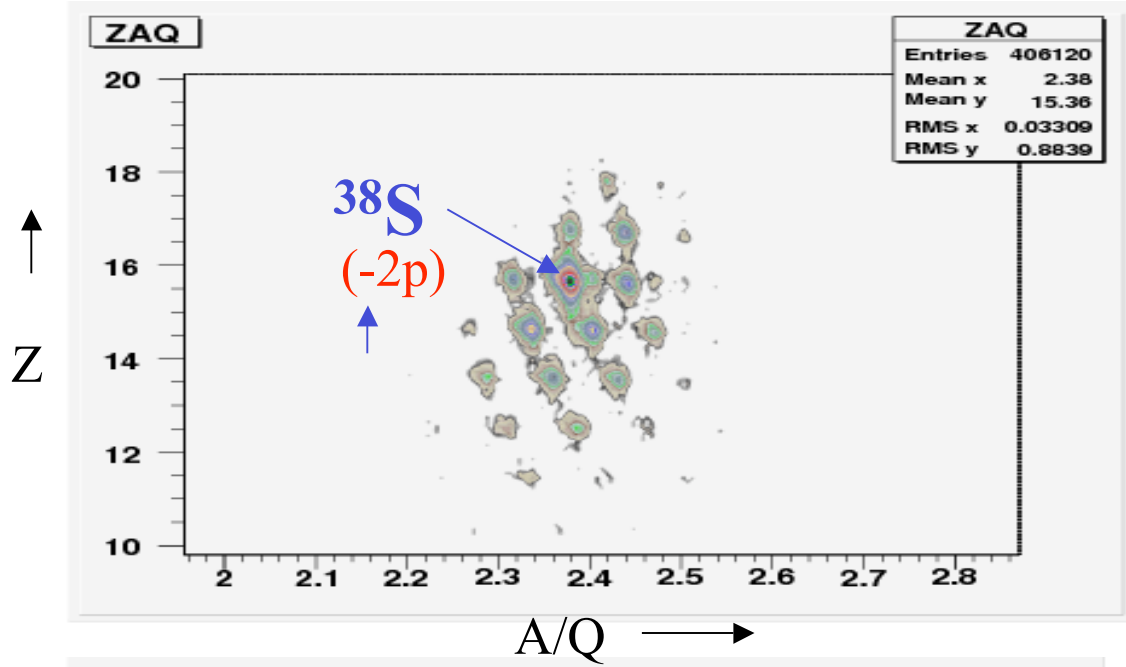
Results RIB tagging run (June 2005) with MARS

Z-A/Q distribution of fragments from
^{40}Ar(35MeV/u)+^{48}Ti
(30mg/cm^2)

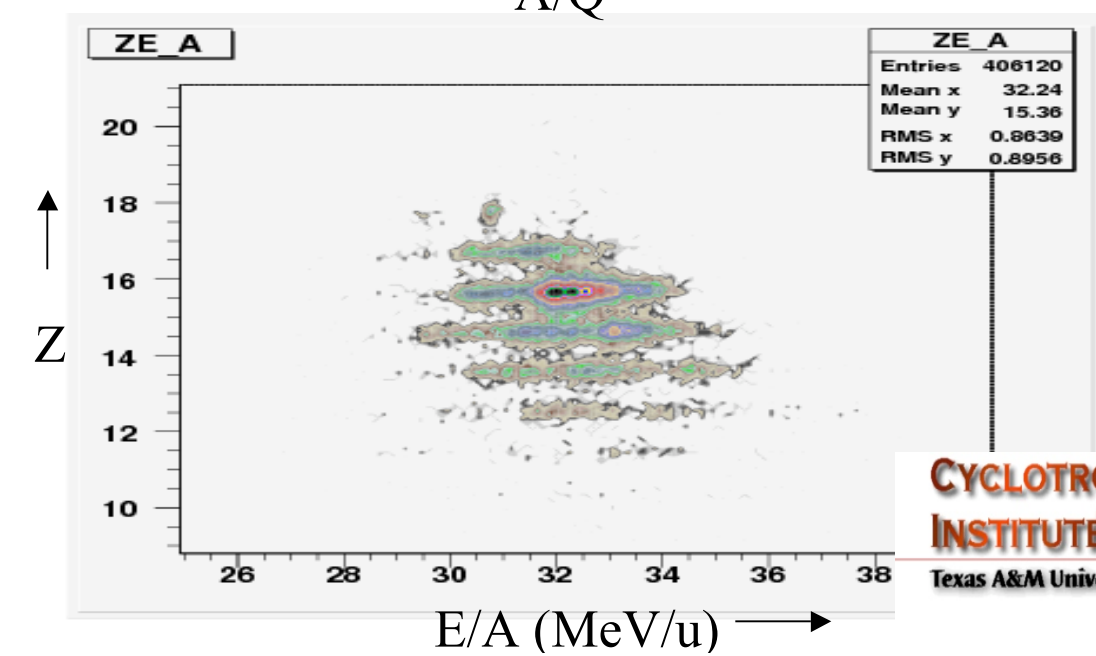
Bρ=1.950 _m

Angular acceptance:
1.0-3.0 deg.



Neutron-Rich fragments:
optimize for ^{38}S :

~1000 pps/pnA



Bρ ~ A/Q × υ

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Results RIB tagging run (June 2005) with MARS

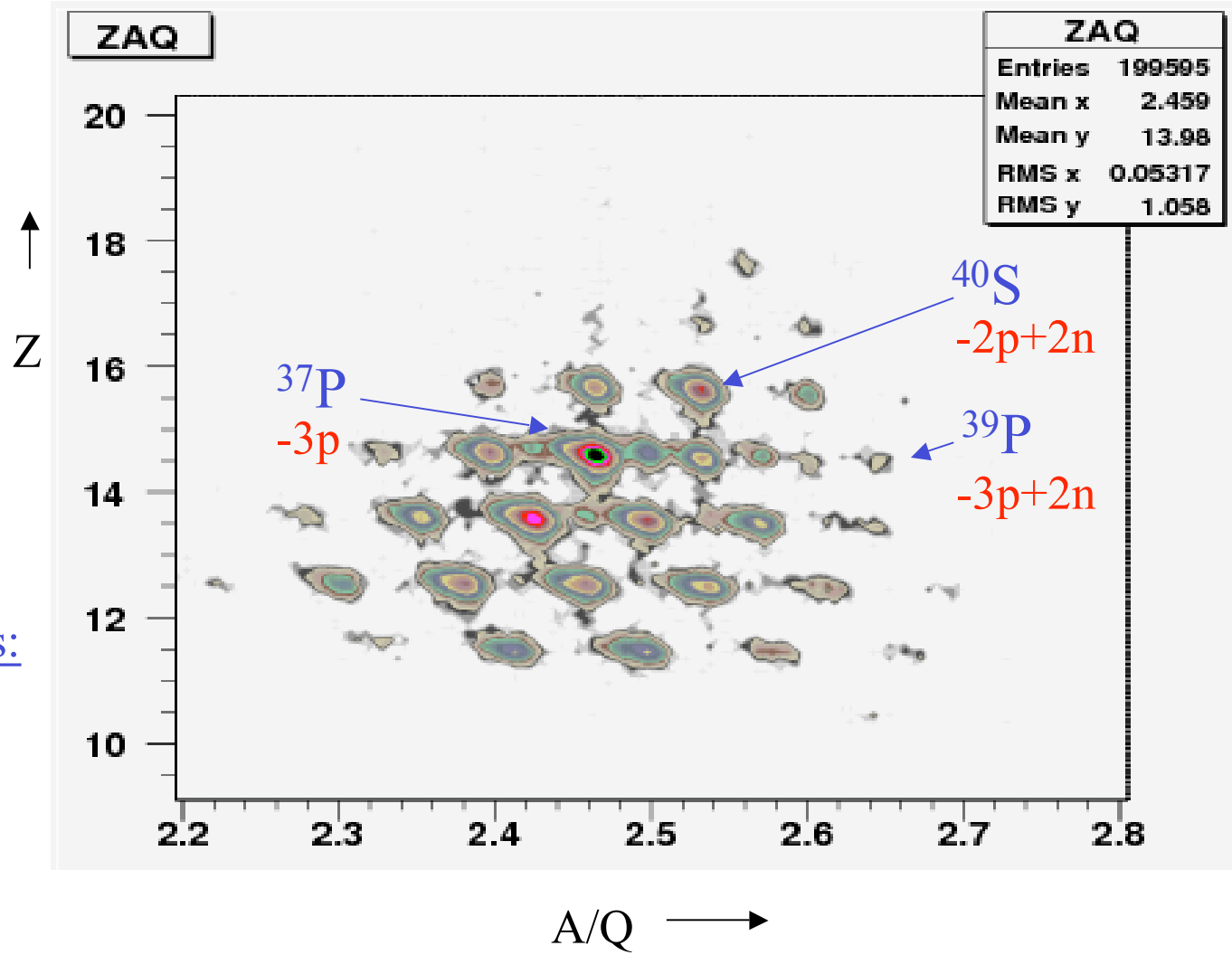
Z-A/Q distribution of fragments from :

^{40}Ar(35MeV/u)+^{48}Ti
(60mg/cm^2)

Bρ=1.955 Tm

<u>Neutron-Rich fragments:</u>
optimize for **^{37}P:**

~100 pps/pnA



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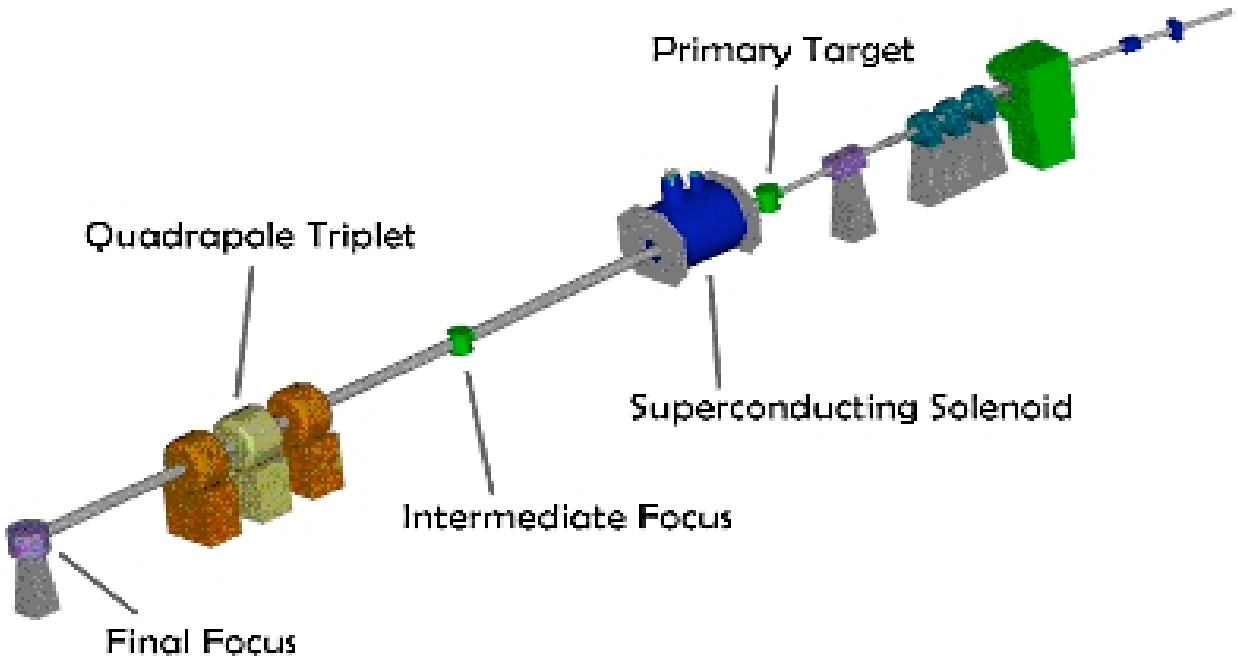
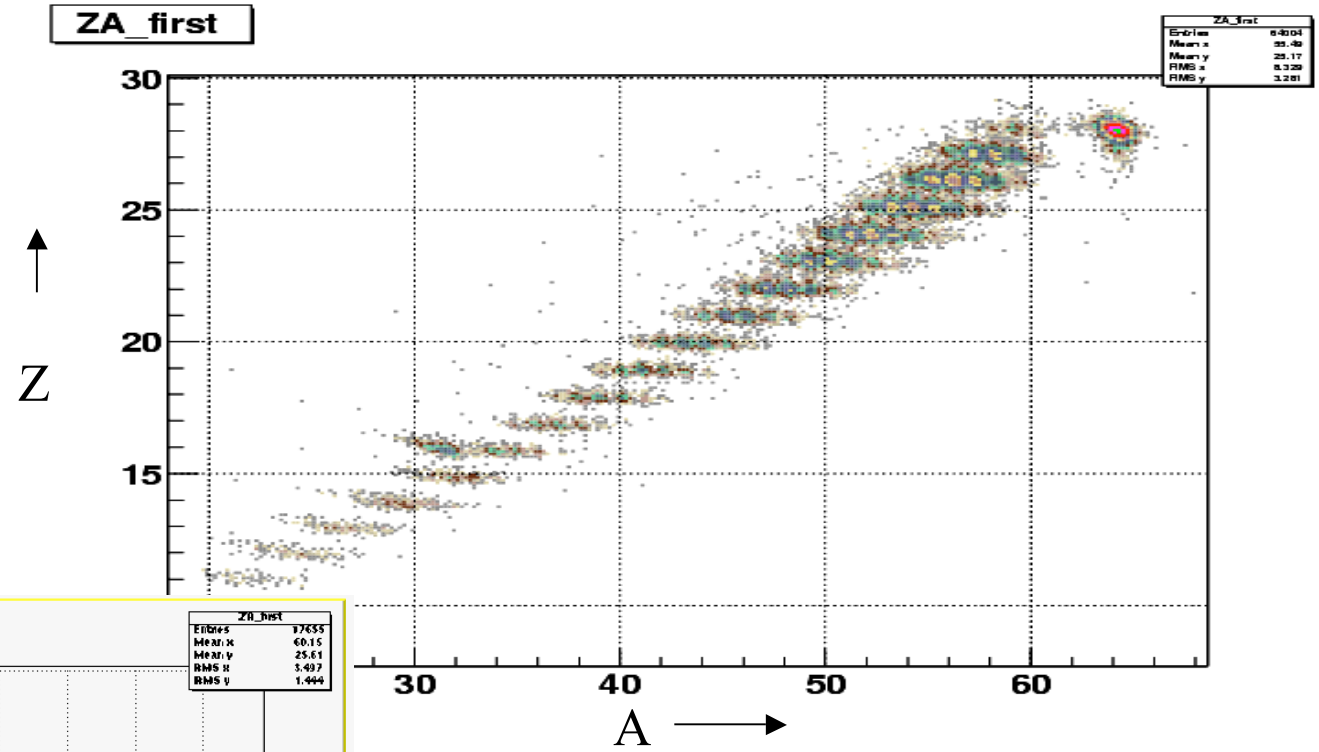
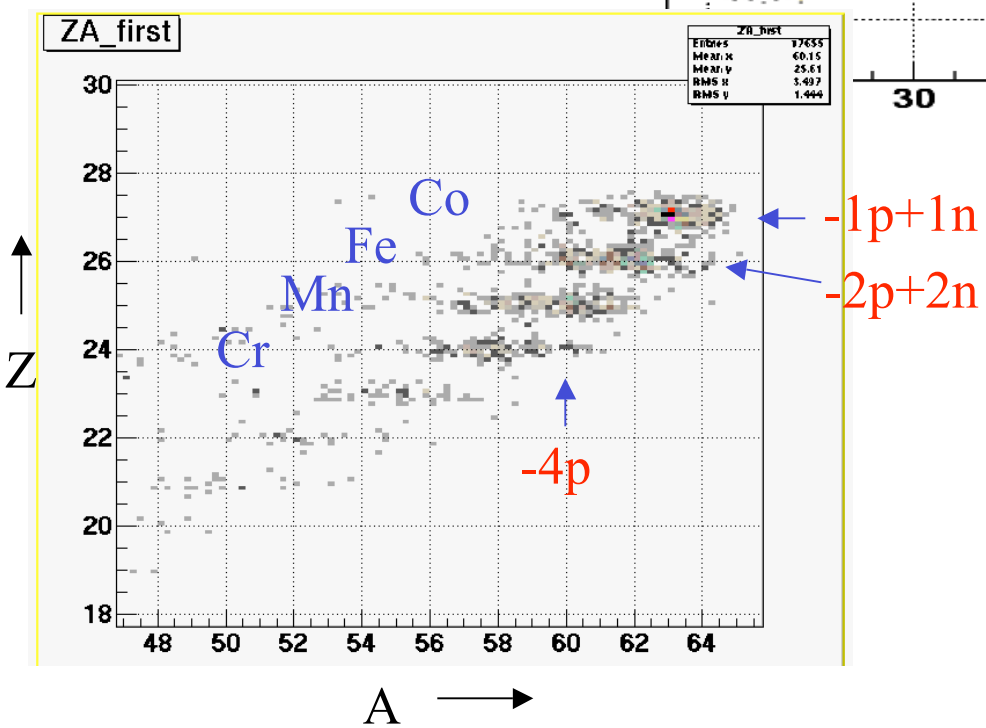
The Superconducting Solenoid Rare Isotope Line at TAMU



Results from BigSol Line: Rare Isotope Production

Example of Z-A distribution of fragments from $^{64}Ni(25MeV/u)+^{64}Ni$
$B\rho=1.473$,
$I_{BigSol}=79.3$ A
Angular acceptance: 1.5-3.0 deg.





Neutron-Rich fragments from
^{64}Ni (25MeV/u) + ^{64}Ni (4.0mg/cm^2)
$B\rho=1.900$ Tm, $I_{BigSol}=102.5$ A
i_{beam} = 1 pnA, 4 hour run
Angular acceptance: 1.5-3.0 deg.

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Summary and Plans :

CI upgrade project: Extend CI capabilities towards RIBs.

How RIBs will be produced?

- Use K150 Cyclotron as driver.
- Use light and heavy ion guides to produce 1+ ions
- Charge boosting with an ECR source.
- Reaccelerate RIBs with the K500 Cyclotron (E/A=2-60 MeV/u)

Physics program:

- Nuclear Astrophysics, measurements of ANC's
- Beta-decay studies
- Giant resonance studies, Nuclear compressibility
- Multifragmentation/EOS studies
- …..

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People Involved in the RIB Upgrade project

R. Tribble (CI Director)

H. Clark (Project Manager)
F. Abegglen (Operations chief)
G. Derrig (Mech. Engineering Chief)
G. Kim (K150/K500 Cyclotrons)
D. May (Ion Sources),
G. Tabacaru (Light-ion guide),
G. Chubarian (Heavy-ion guide)
G. Souliotis (Heavy-ion separator)

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