Thermalized and Reaccelerated Beams at the National Superconducting Cyclotron Laboratory

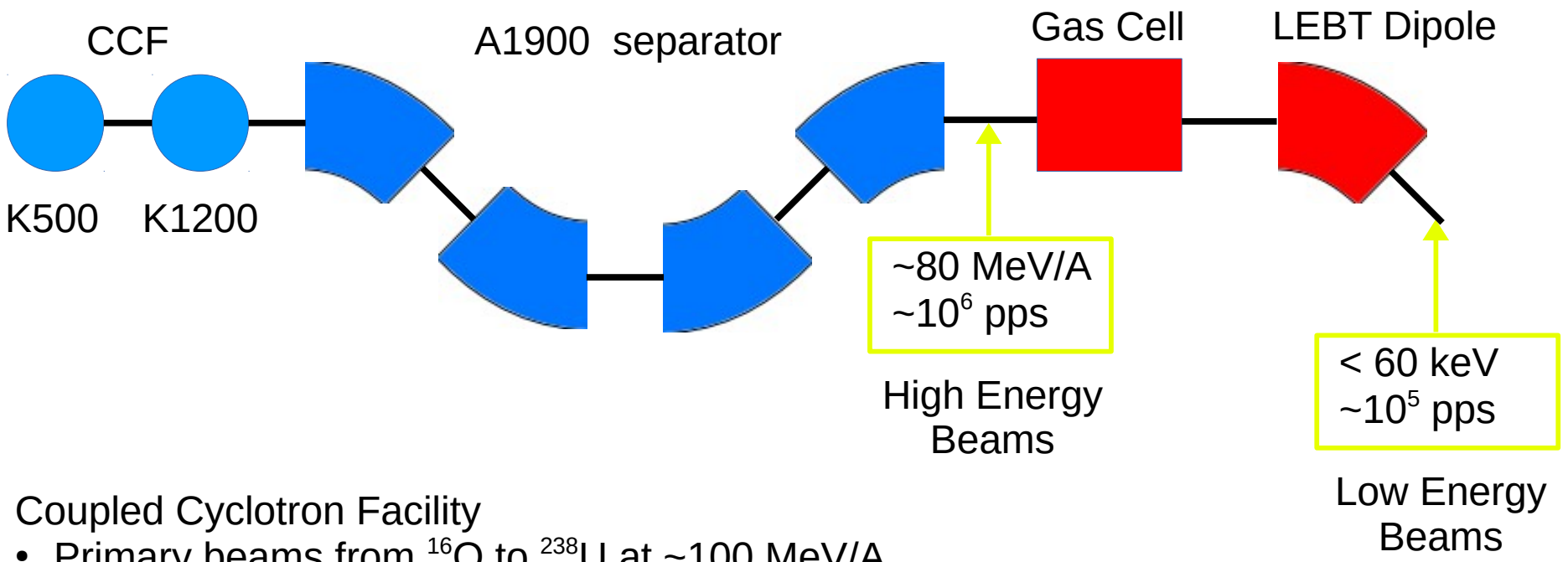
Scott Williams

MICHIGAN STATE
UNIVERSITY

Overview

- Beam production at NSCL – diagnostic challenges
- Diagnostic devices in use – overlap of techniques with experimental nuclear physics
- Commissioning experiment, ^{37}K thermalization and re-acceleration – focus on RIB diagnostics
- Conclusions/outlook

Beam Production at NSCL

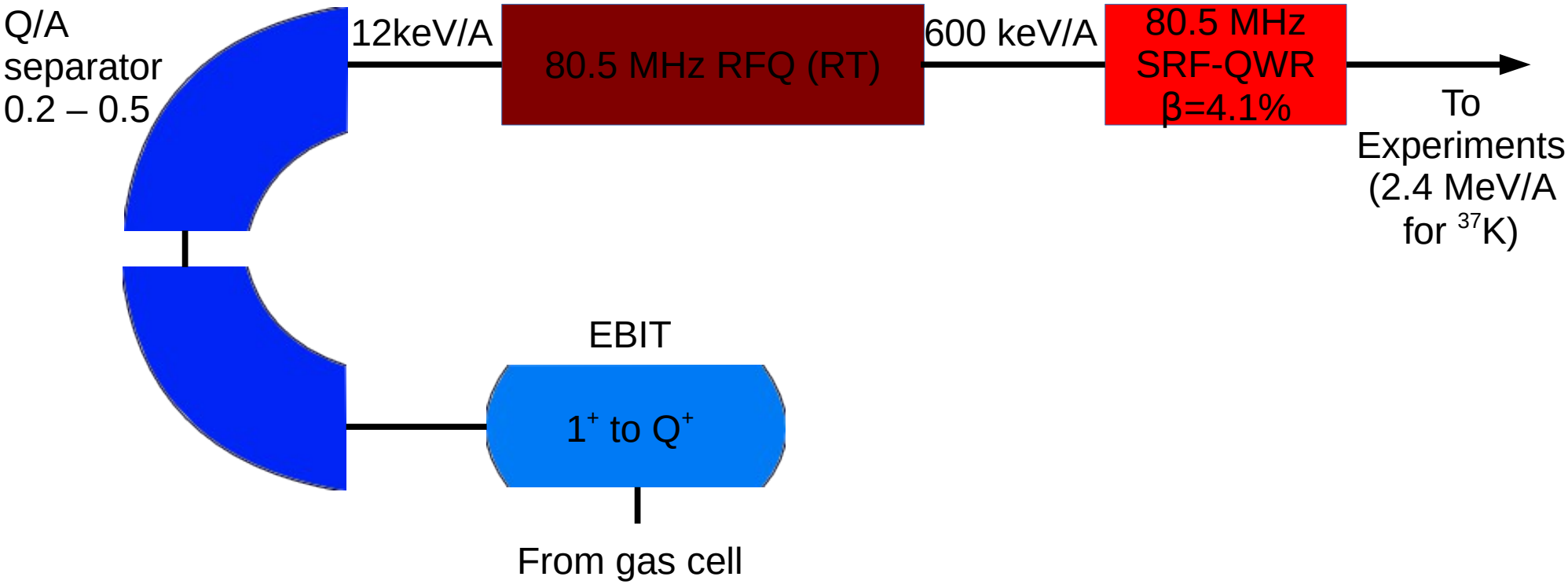


- Coupled Cyclotron Facility
  - Primary beams from ^{16}O to ^{238}U at ~100 MeV/A

- Fragmented, then separated by Bρ1, wedge, Bρ2
  - High energy beams ~80 MeV/A, ~10^6 pps
  - Available to high energy areas for experiments (S800, MONA, beta decay, etc)

- Thermalized in the gas cell, extracted and separated by LEBT dipole
  - Low energy beams < 60 keV, ~10^5 pps
  - Available to low energy areas (LEBIT, BECOLA) and re-acceleration in ReA

Beam Production at NSCL



- Injected into EBIT, charge bred for 10s of milliseconds
- Selected by Q/A, injected into RFQ at 12 keV/A
- Accelerated to 600 keV/A in RFQ
- ReA can currently give 2.4 MeV/A for ^{37}K, energy upgrades over time
- 12 MeV/A design goal
  - Radioactive and stable beams from 12keV/A to several MeV/A

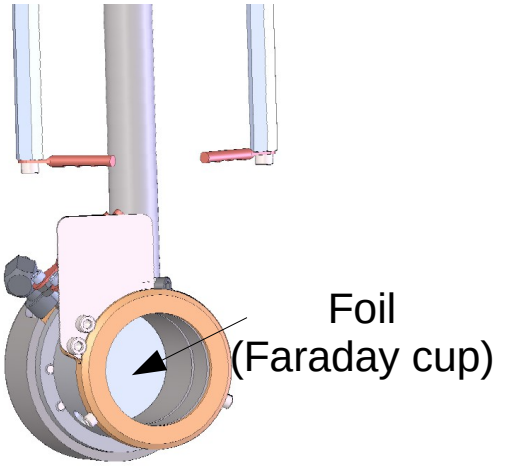
Diagnostics challenges for RIBs

- A1900 gives strong separation of fragments, but cocktail remains
  - High energy, high rate
- Gas cell is selective for one RIB fragment, but intensity distributed in molecules
  - Chemistry analysis after LEBT dipole, intense SIB background
- EBIT breeds to a distribution of charge states, with contamination from stable ions
  - Select RIB charge state in Q/A from a region free of SIB charge states
- Wide range of energies following thermalization and re-acceleration
  - Need diagnostics sensitive only to RIB with single ion counting capabilities

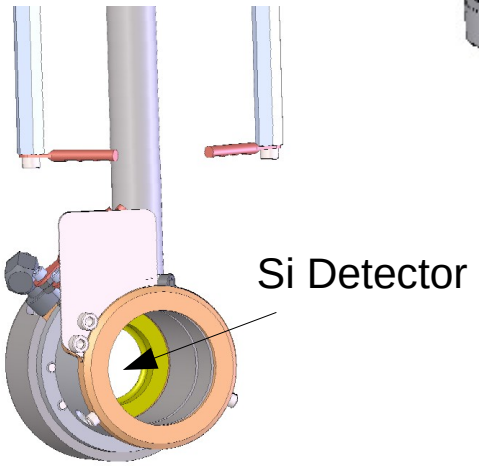
RIB Diagnostics

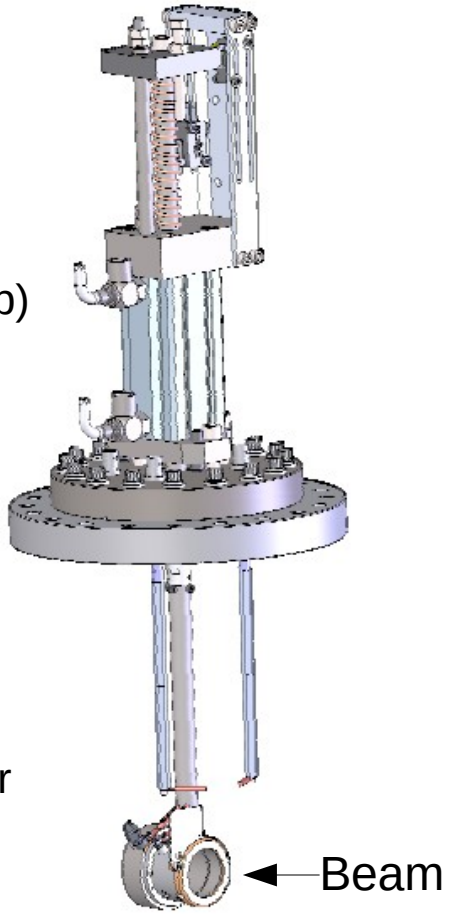
- Decay Counter
  - Stop beam on foil – silicon detector only sensitive to decaying isotopes
  - Foil connected to current integrator performs as a Faraday cup
  - Secondary electron suppressor ring
- Energy Detector
  - Remove foil – silicon detector measures incident beam energy directly
- Workhorse for RIB delivery

Decay Counter



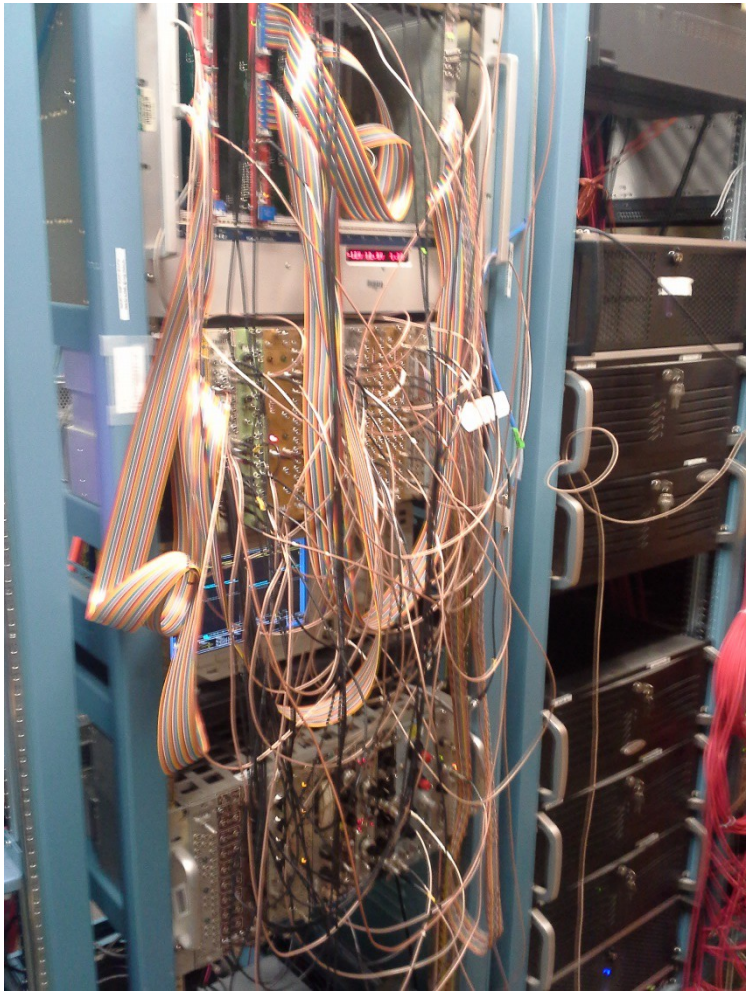
Energy Detector



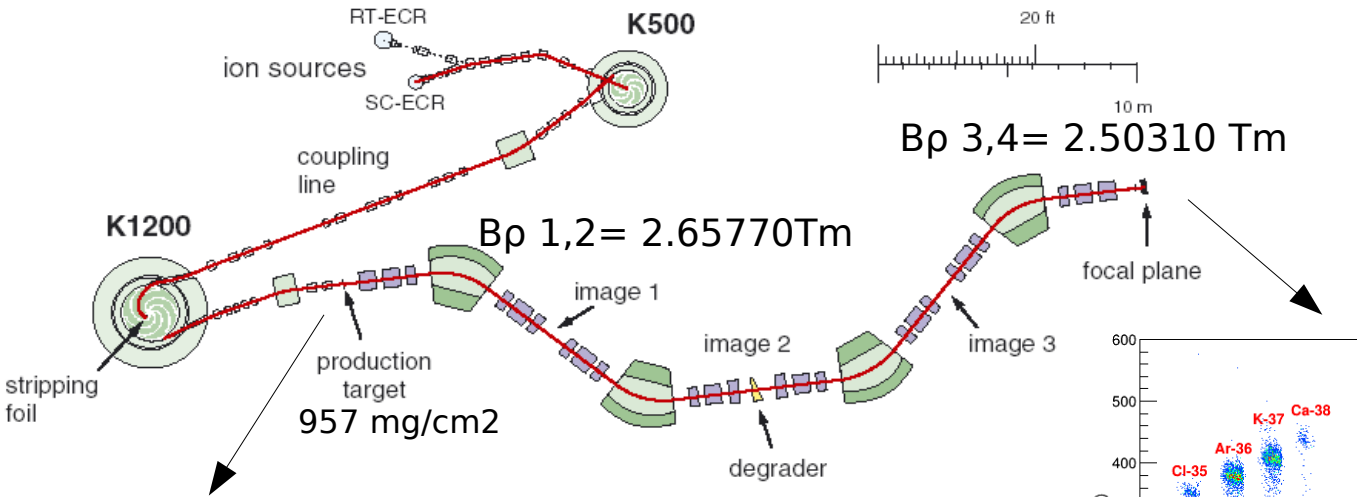


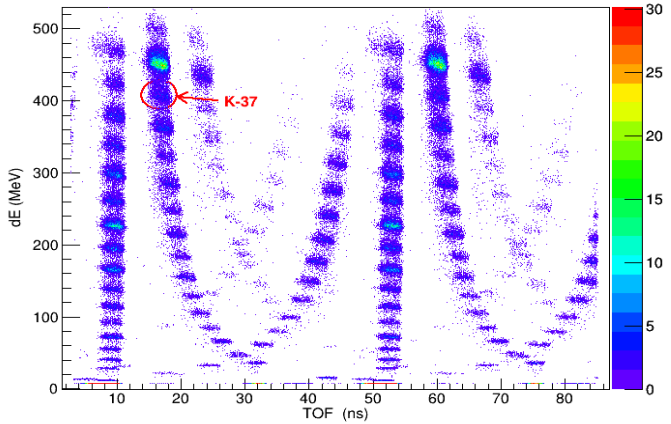
Data Acquisition

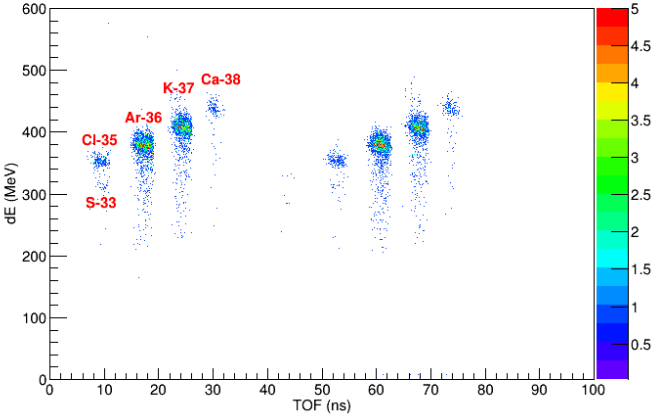
- Leverage nuclear physics techniques for increased sensitivity and measurable parameters
- Silicon detectors and decay counters connected to data acquisition system
- Event-by-event timestamped readout of up to 16 detectors per DAQ
  - Ability to measure energy as a function of time
- Energy, time, scalers, live ratio



^{37}K Commissioning Experiment



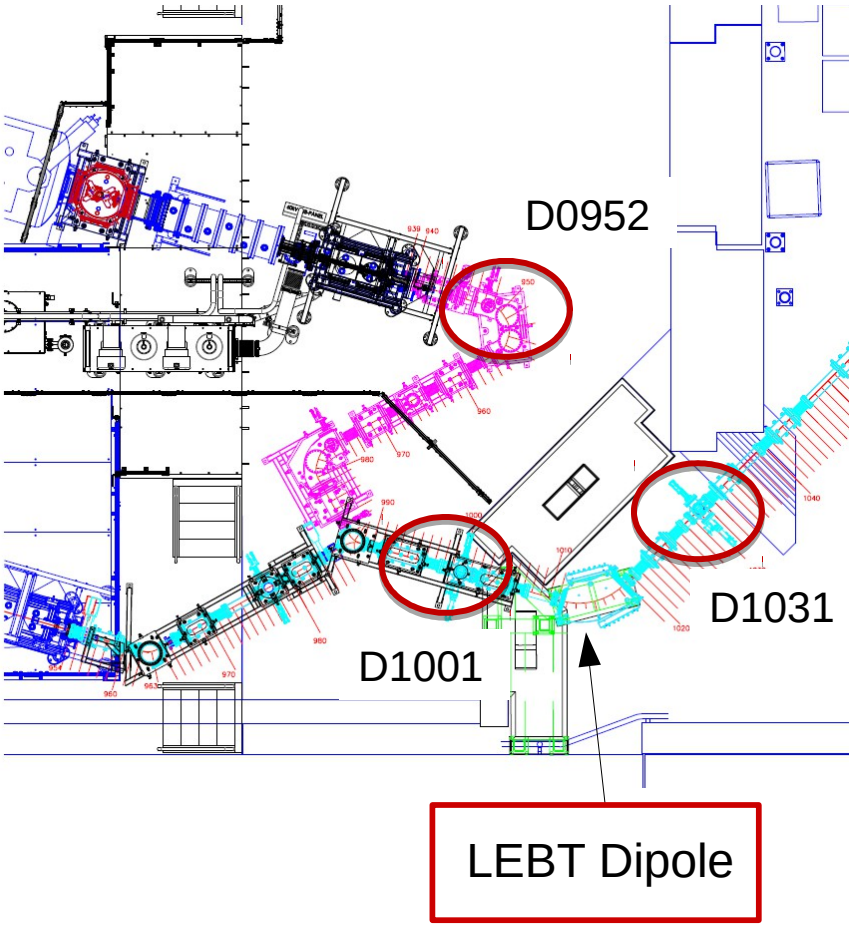




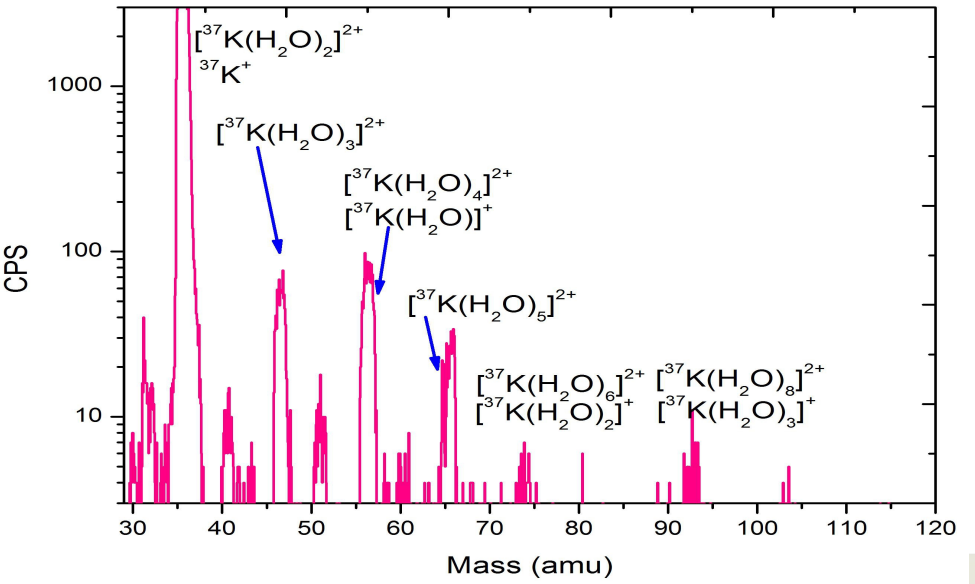
Production rate ~1.3E5 PPS/pnA
Purity for K-37 ~ 50%
dp/p = 0.5%

- Silicon PIN detector gives energy loss (dE)
- Scintillator gives time-of-flight with respect to cyclotron RF

^{37}K Commissioning Experiment



- Decay counters at D0952 and D1031 give total activity and mass-selected activity
- Scan the magnet field and plot activity as a function of time – activity as a function of mass
- An analysis of the chemistry



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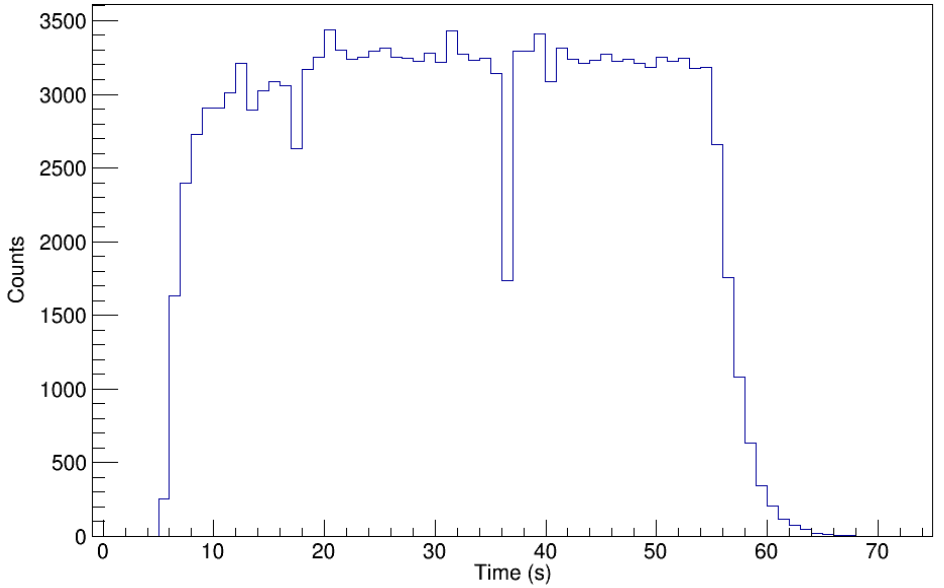
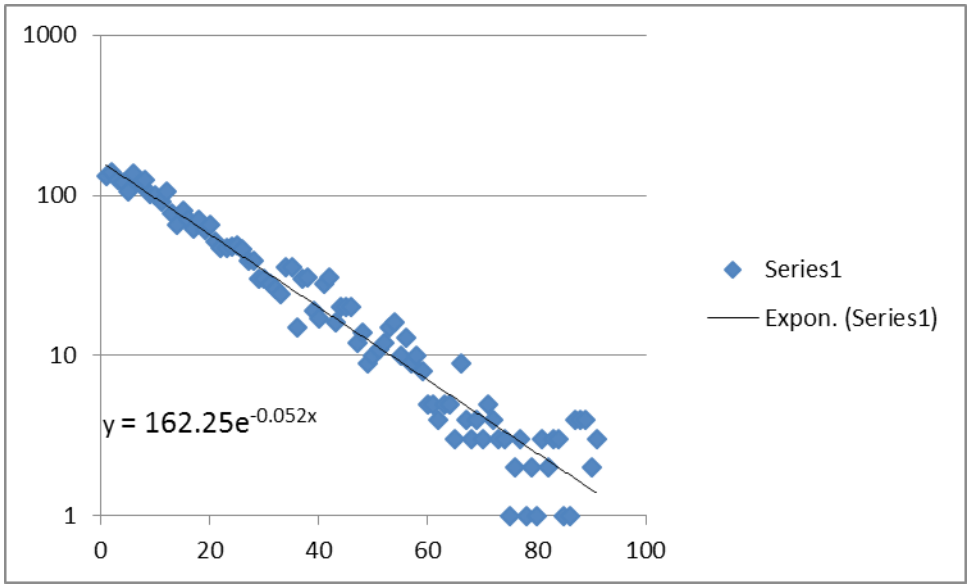


- Select one mass, measure activity as a function of time cycling beam on and off
- Grow-in and decay curve after mass selection

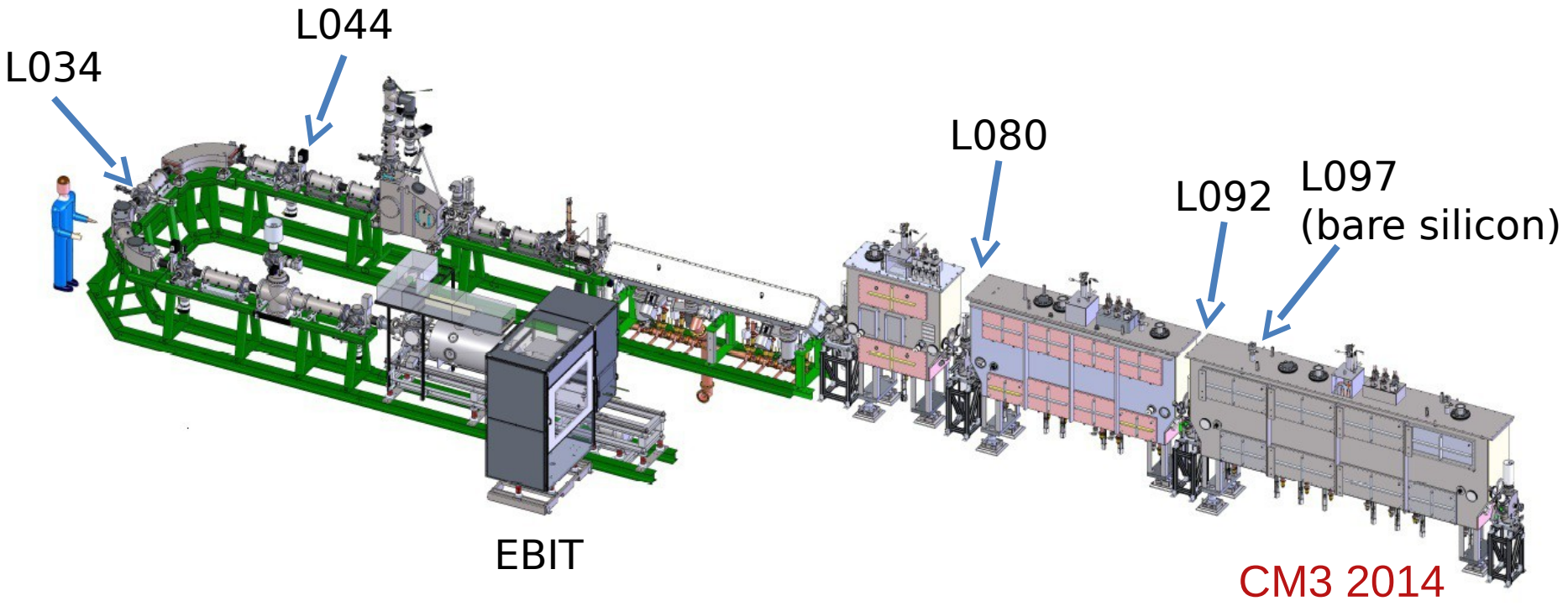


λ	T1/2
0.052	1.33

- Data with finer time resolution (100ms per bin) gives $T_{1/2}$ of 1.33s, consistent with 1.23s in the literature
- ^{37}K identified

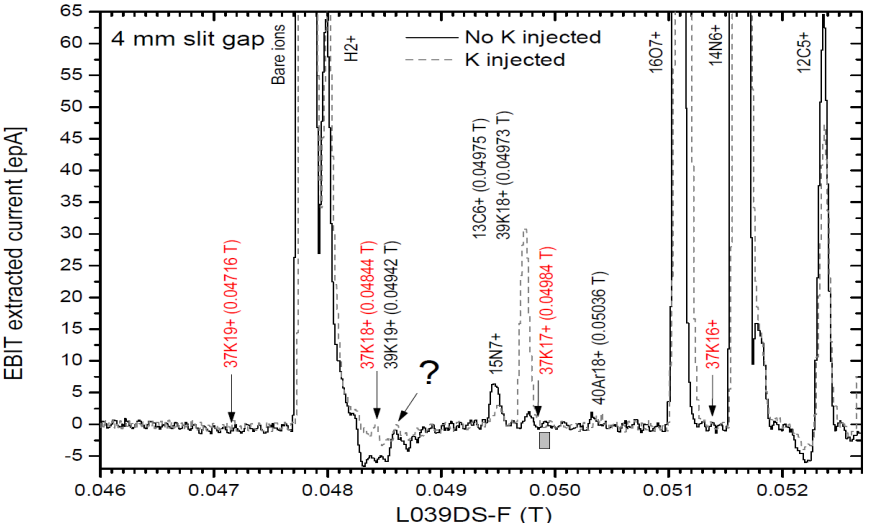
^{37}K Commissioning Experiment

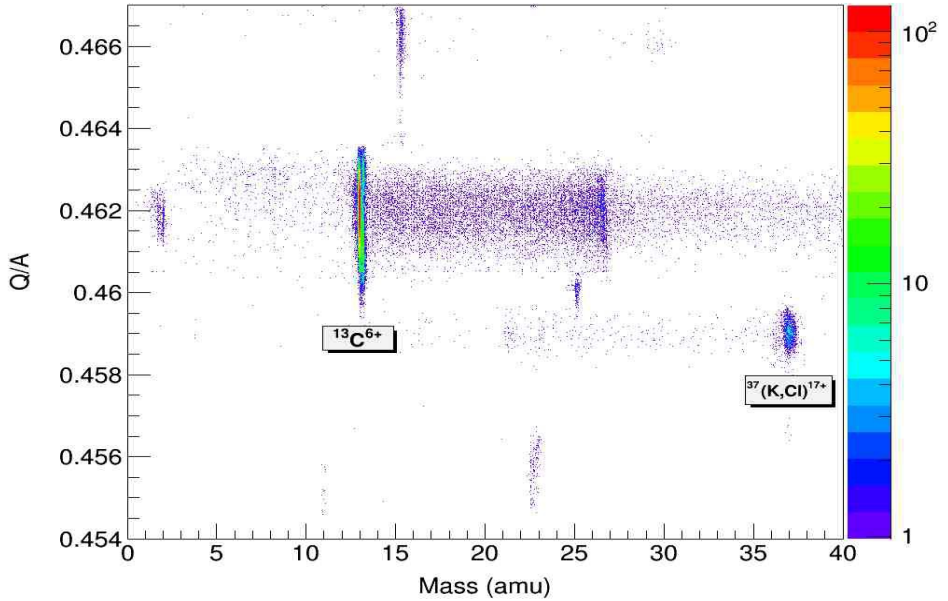
- Decay counters in place in Q/A section and ReA
- Detectors sensitive to beta radiation and total energy

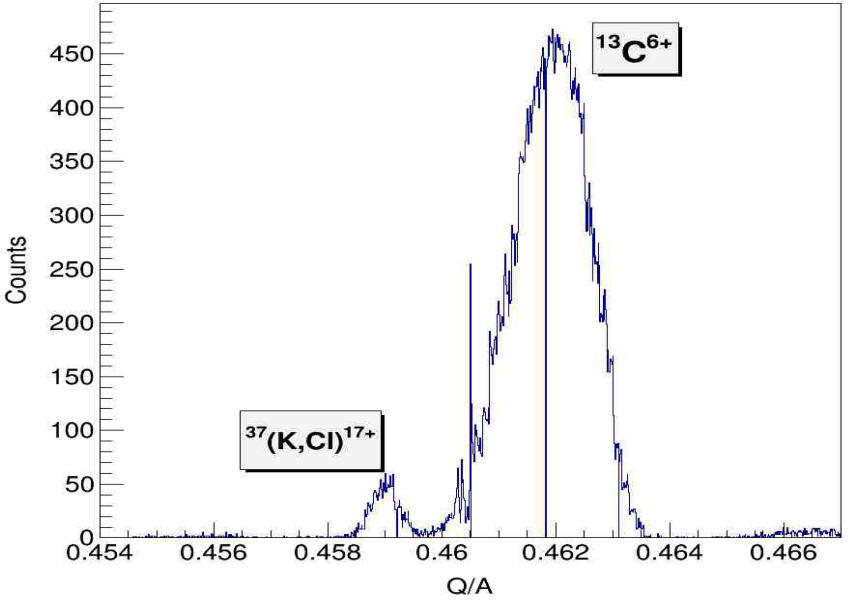


^{37}K Commissioning Experiment

- Scan the field in the magnetic dipole of the Q/A section
- Measure SIB current in Faraday cup of decay counter
- Suitable ^{37}K charge states shown in red – 17+ chosen
- $^{13}C^{6+}$ close by – need single ion level of sensitivity







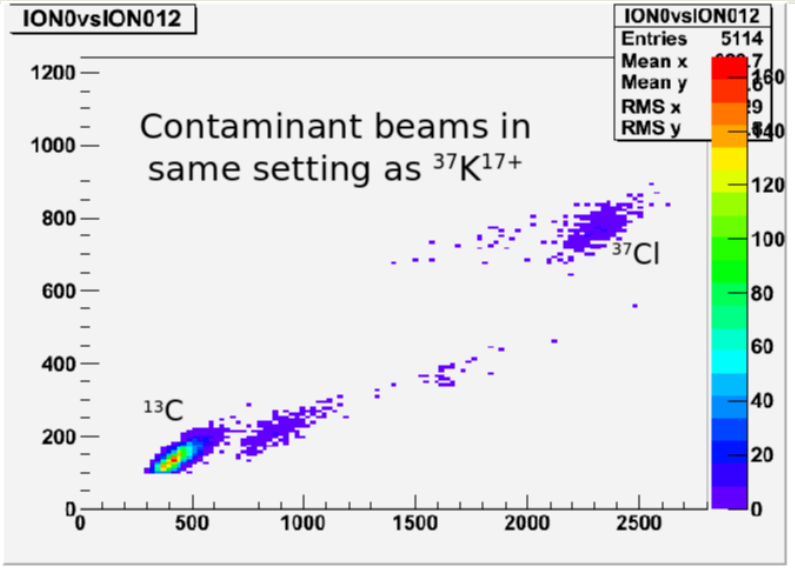
^{37}K Commissioning Experiment

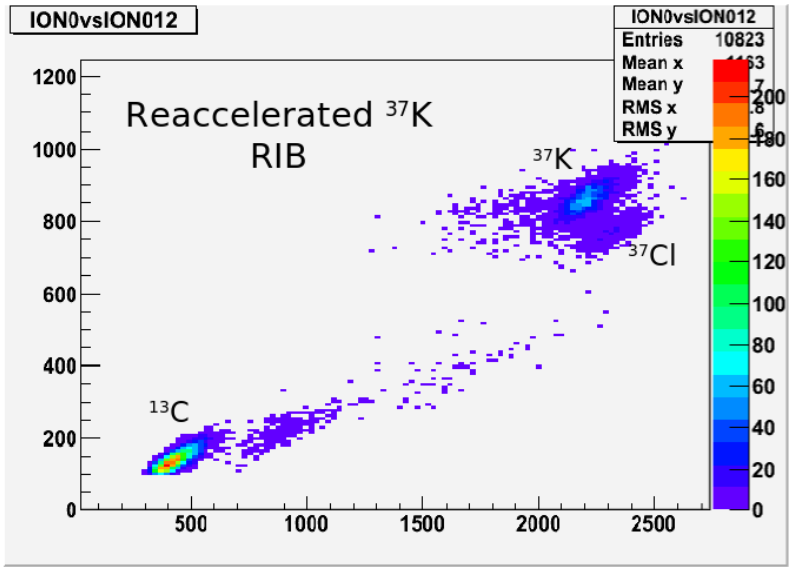
- $^{37}K^{17+}$ delivered to ANASEN detector (Array for Nuclear Astrophysics Studies with Exotic Nuclei)

- Ionization chamber at zero degrees
- Split anode allows E – delta E telescope measurement

- 3mm slits in Q/A section gives transport of full RIB intensity with some contamination from SIB close by

- Successful commissioning experiment – beam delivered to users





Conclusions/Outlook

- Bare silicon detectors and decay counters solve the largest majority of the diagnostics challenges
- DAQ gives the opportunity to measure:
  - Chemistry of the thermalized beam (given a favourable half life)
  - Single-ion-counting survey of Q/A landscape
- Bare silicon detectors have rate restrictions – attenuation needed
- Decay counters provide the functionality of a Faraday cup sensitive only to the activity (given a favourable half life)

Thank you for your attention.