Charge changing cross section of p-sd shell nuclei

Alfredo Estrade
St. Mary’s University and GSI

FRS users meeting, 28th November 2011.

Outline

- Motivation: equation of state of nuclear matter, structure of light unstable isotopes.

- Charge changing cross section (CCCS) experiments at the FRS.

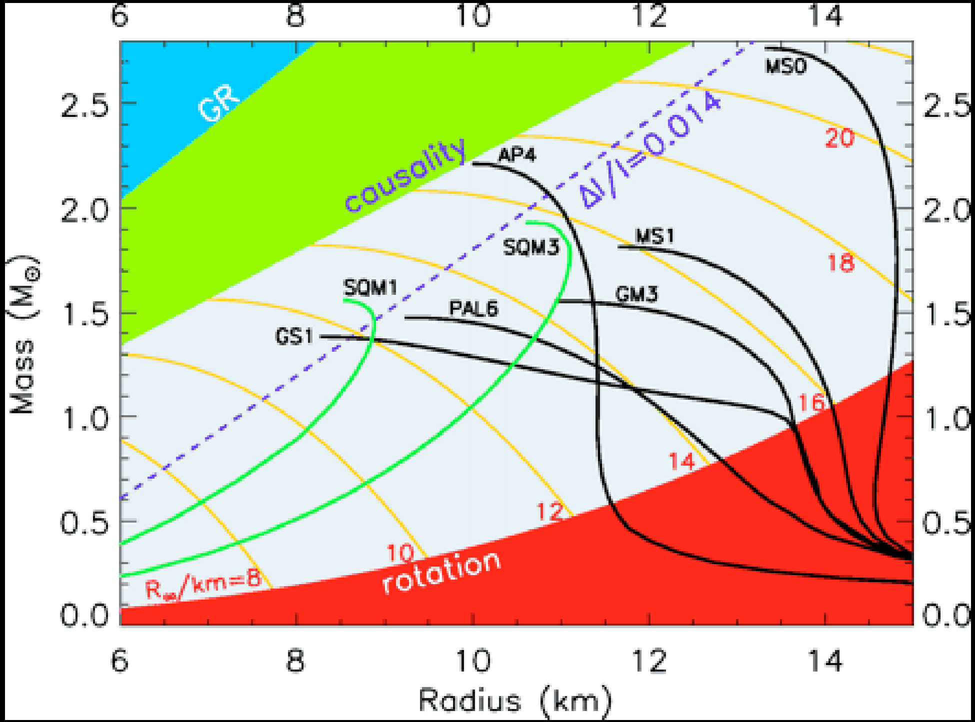
- Expriment S395: CCCS for neutron rich isotopes of Be, B, C, and O.

The neutron skin thickness and the equation of state of nuclear matter.

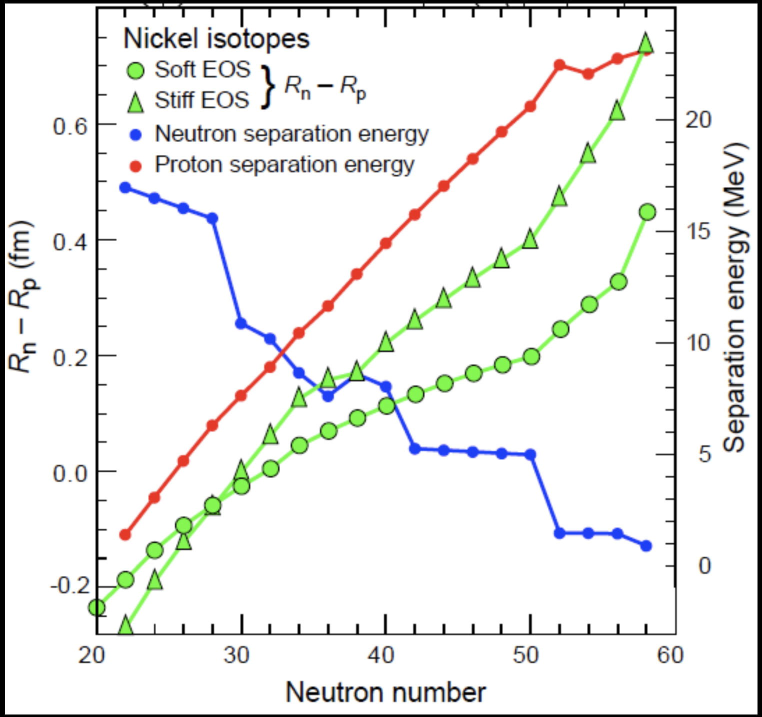
The equation of state provides P-ρ relation of neutron star matter.

$$E(n,x) = E(n,x=1/2) + S_\nu(n)(1-2x)^2$$

Symmetry energy (*Sv)* is its most uncertain term.



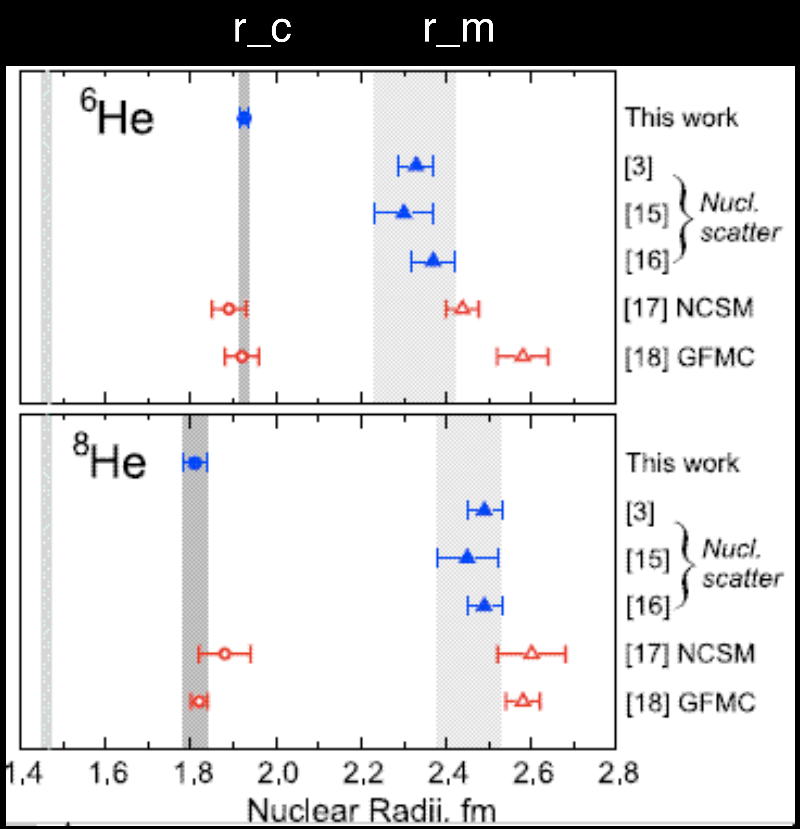
Lattimer and Prakash (2004)

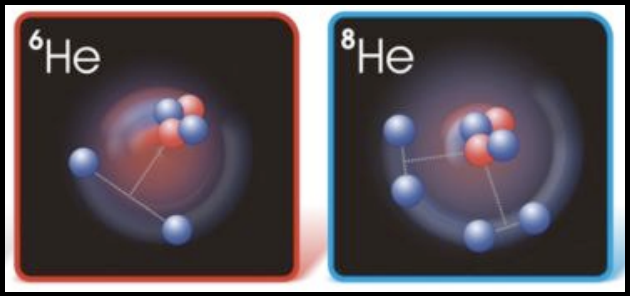


B. A. Brown (1998)

Neutron skin thickness is an observable sensitive to the EOS symmetry energy.

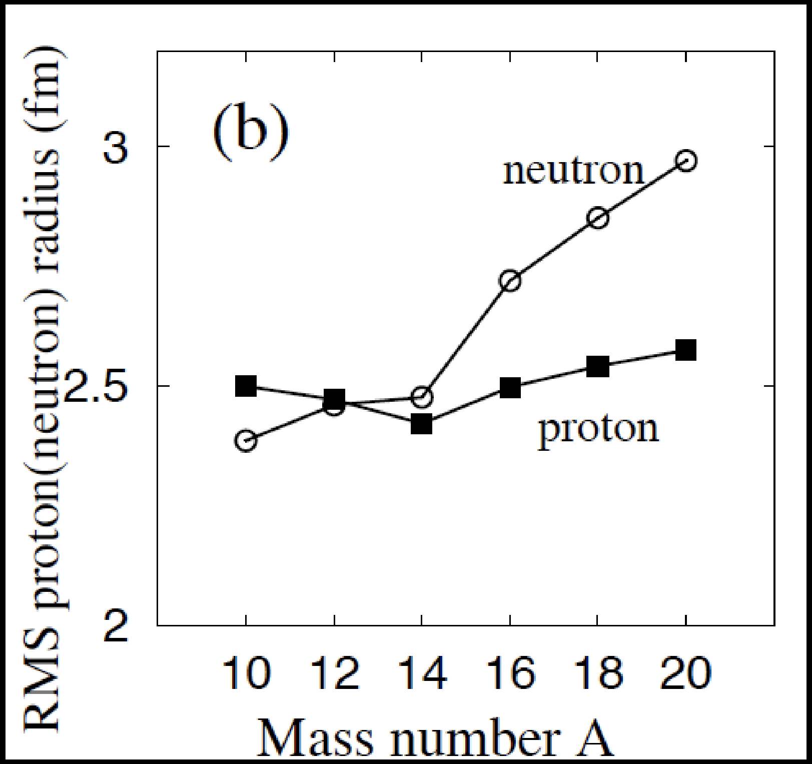
Nuclear ground state properties as a tool for nuclear structure studies.





P. Mueller et al (2007)

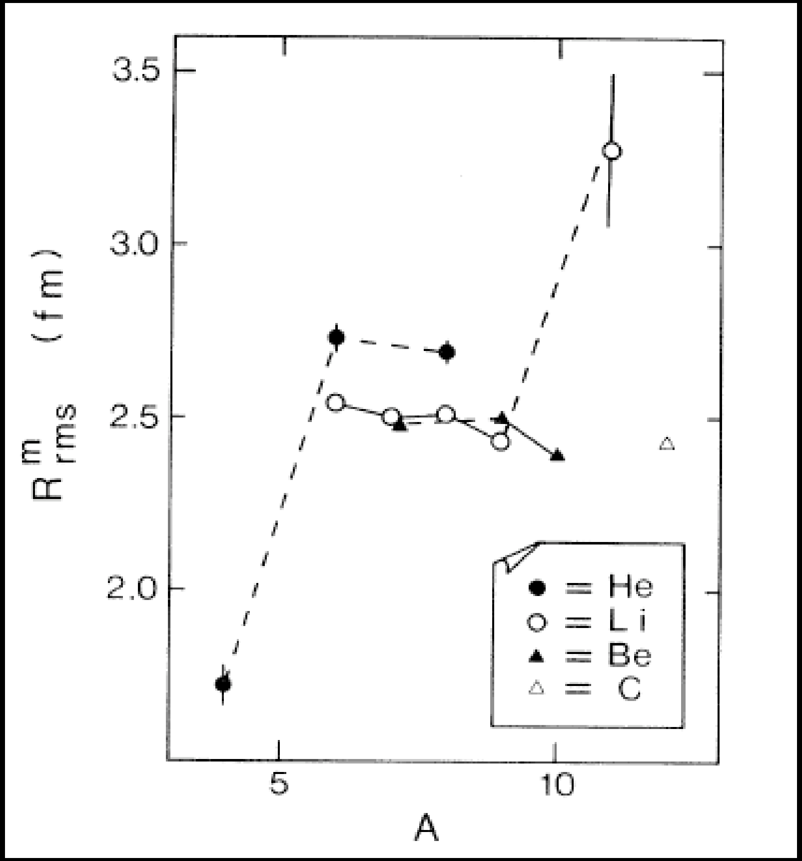
AMD calculations for deformation in C

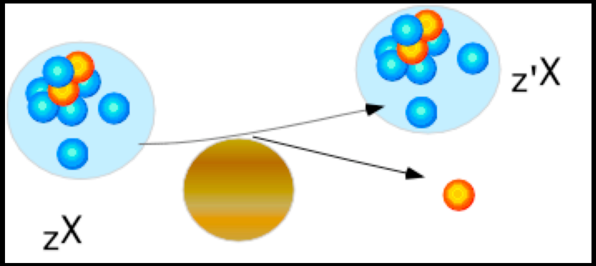


Y. Kanada-En'yo (2005).

Determination of nuclear matter distributions through reaction studies.

Discovery of halo structure in 11Li by interaction cross section measurement.





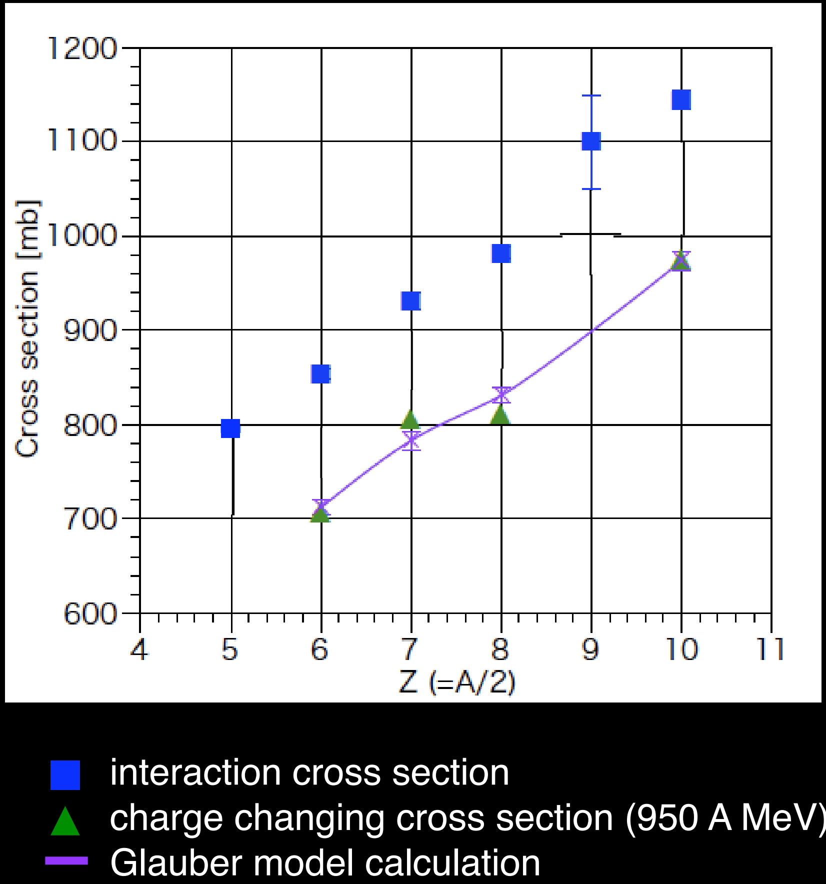
Glauber-type calculations can also correlate proton point radius with charge changing cross sections.

$$\sigma_{cc} = 2\pi \int b[1 - T^p(b)]\mathcal{E}(E)db,$$

$$T^p(b) = \exp\left[-\left(\sigma_{pp} \int \rho_p^{\text{targ}} \rho_p^{\text{proj}} + \sigma_{np} \int \rho_n^{\text{targ}} \rho_p^{\text{proj}}\right)\right],$$

I. Tanihata et. al (1985)

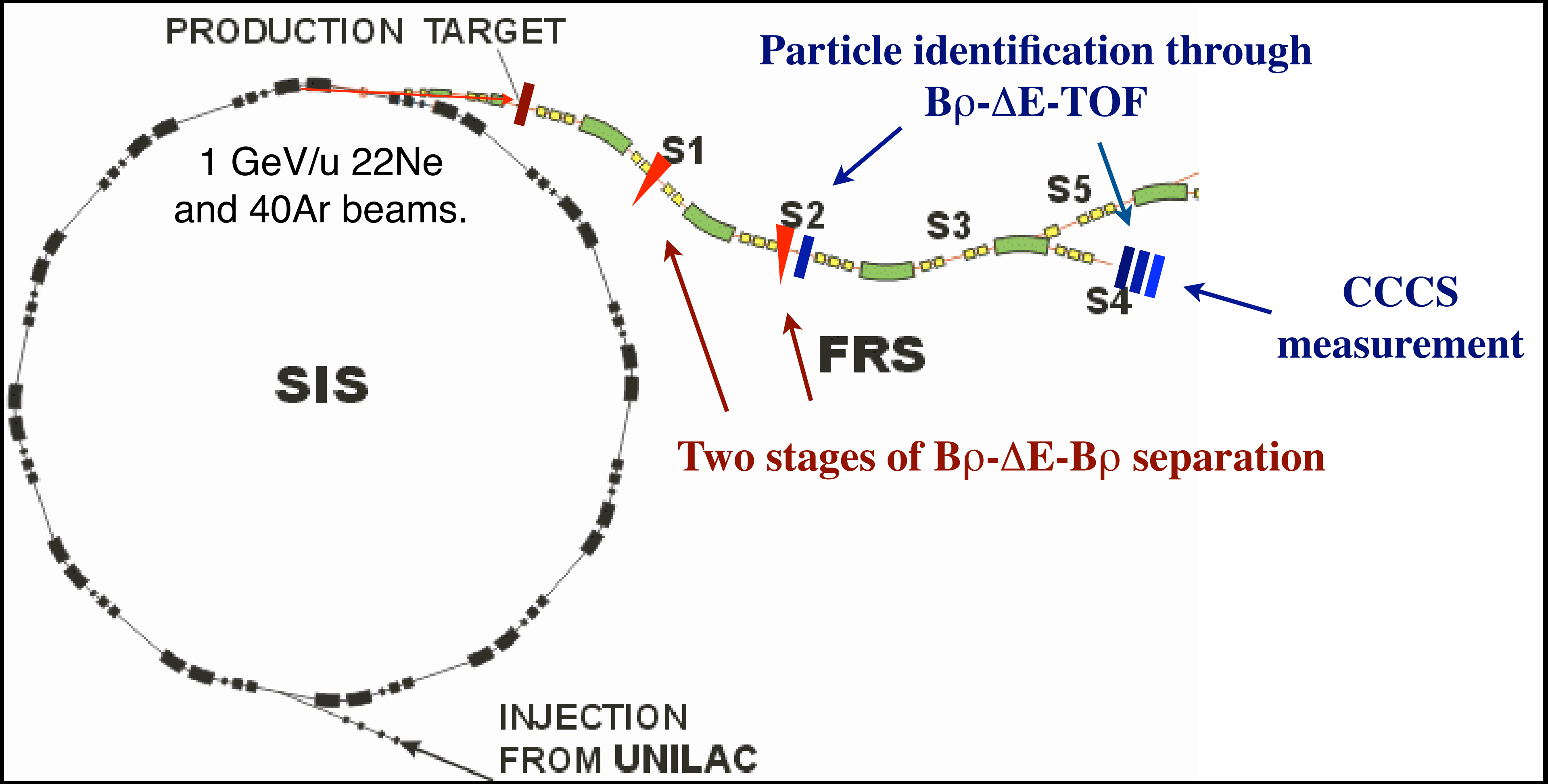
Test of Glauber model calculations of CCCS in stable nuclei.



Glauber model calculation reproduces well CCCS of stable light stable isotopes with known charge radii (12C, 14N, 16O, 20Ne).

See also T. Yamaguchi et al., PRC82 (2010) 014609 for study of energy dependence of CCCS.

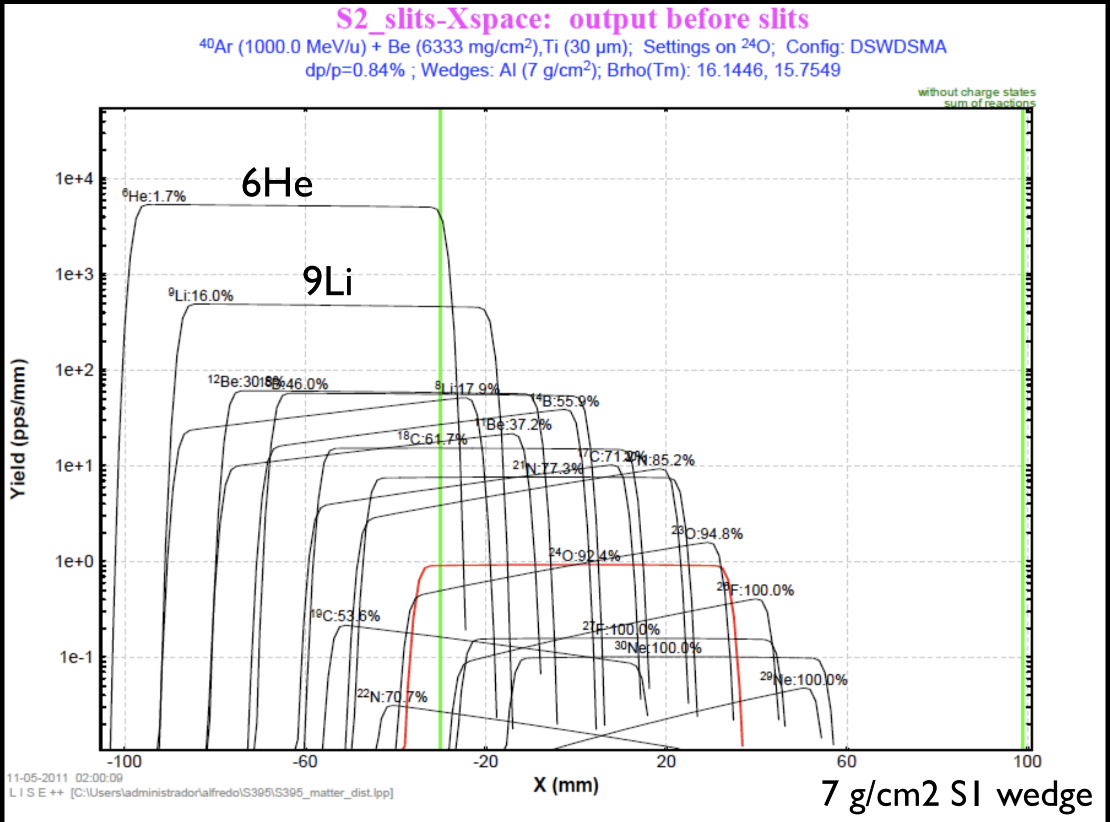
Charge changing cross section at the FRS fragment separator of GSI.

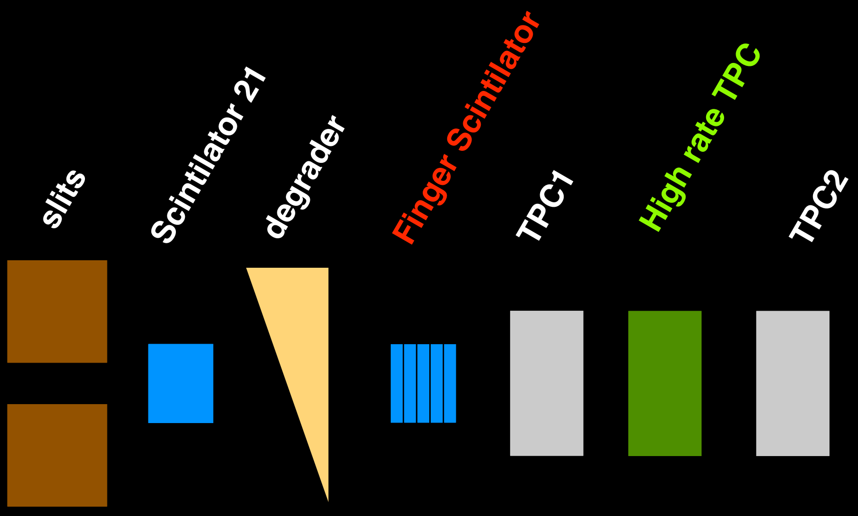


Experimental setup at FRS S2 focal plane

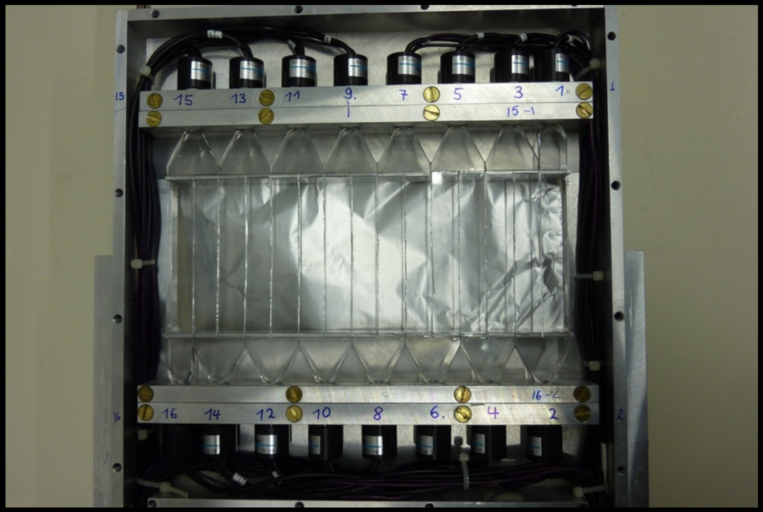
Low Z fragments at 1 GeV/u have large range in mater. S1 slits only effective method to control rate at S2.

Position distribution at S2 for A/Z=3 setting





Finger scintilator (F. Ameil)

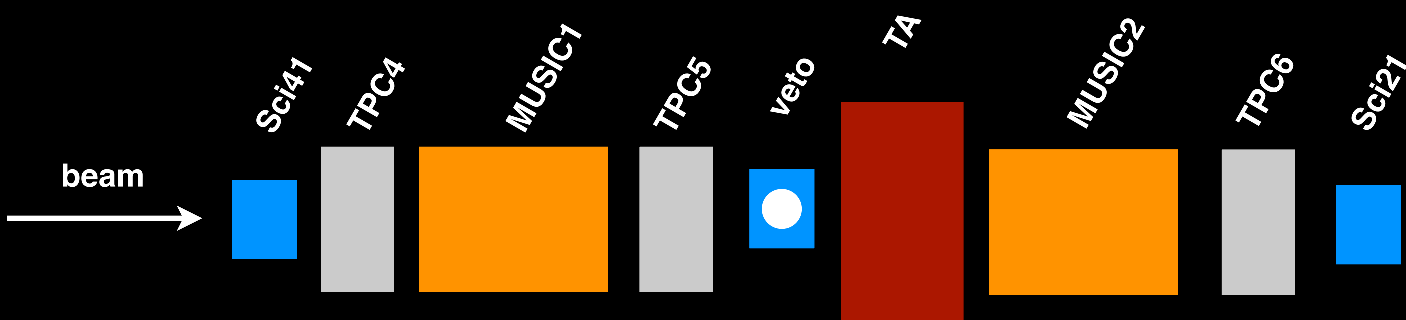


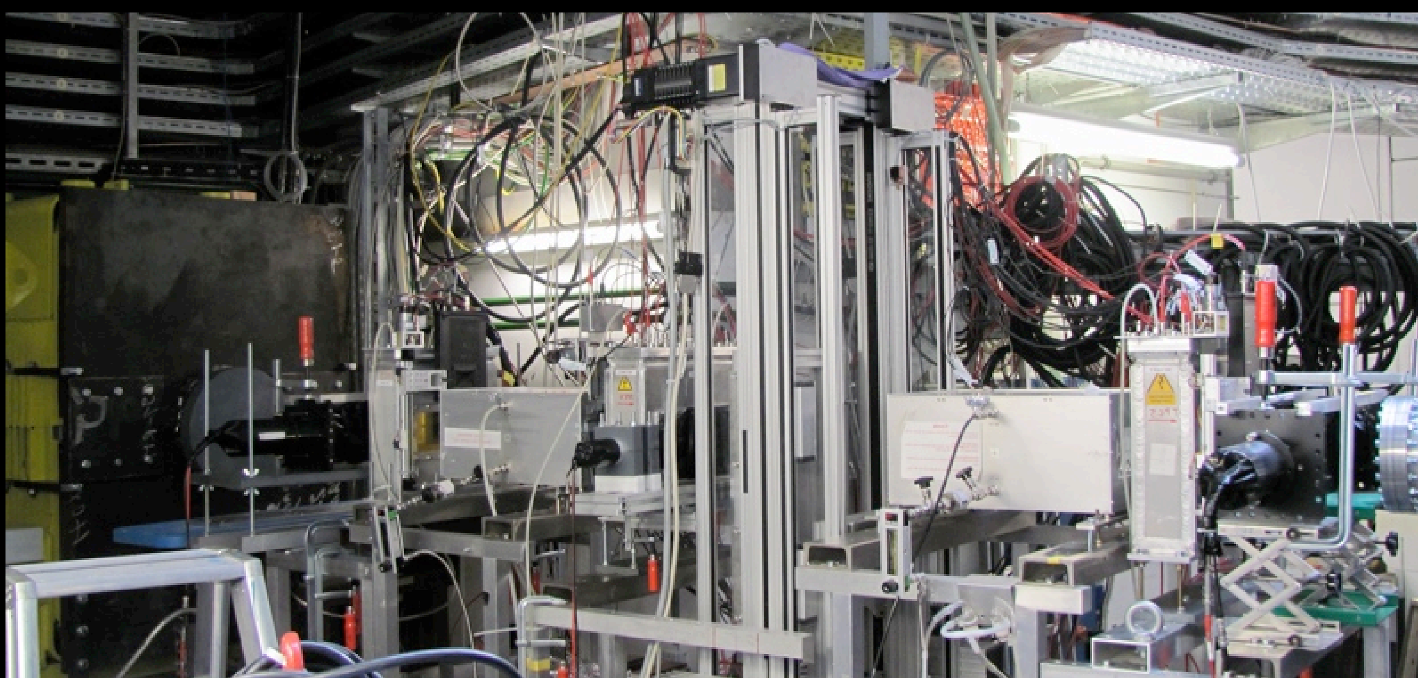
Experimental setup at FRS S4 focal point

- MUSIC(dE) for Z identification
- Beam tracking with TPC.
- 4 g/cm2 carbon reaction target

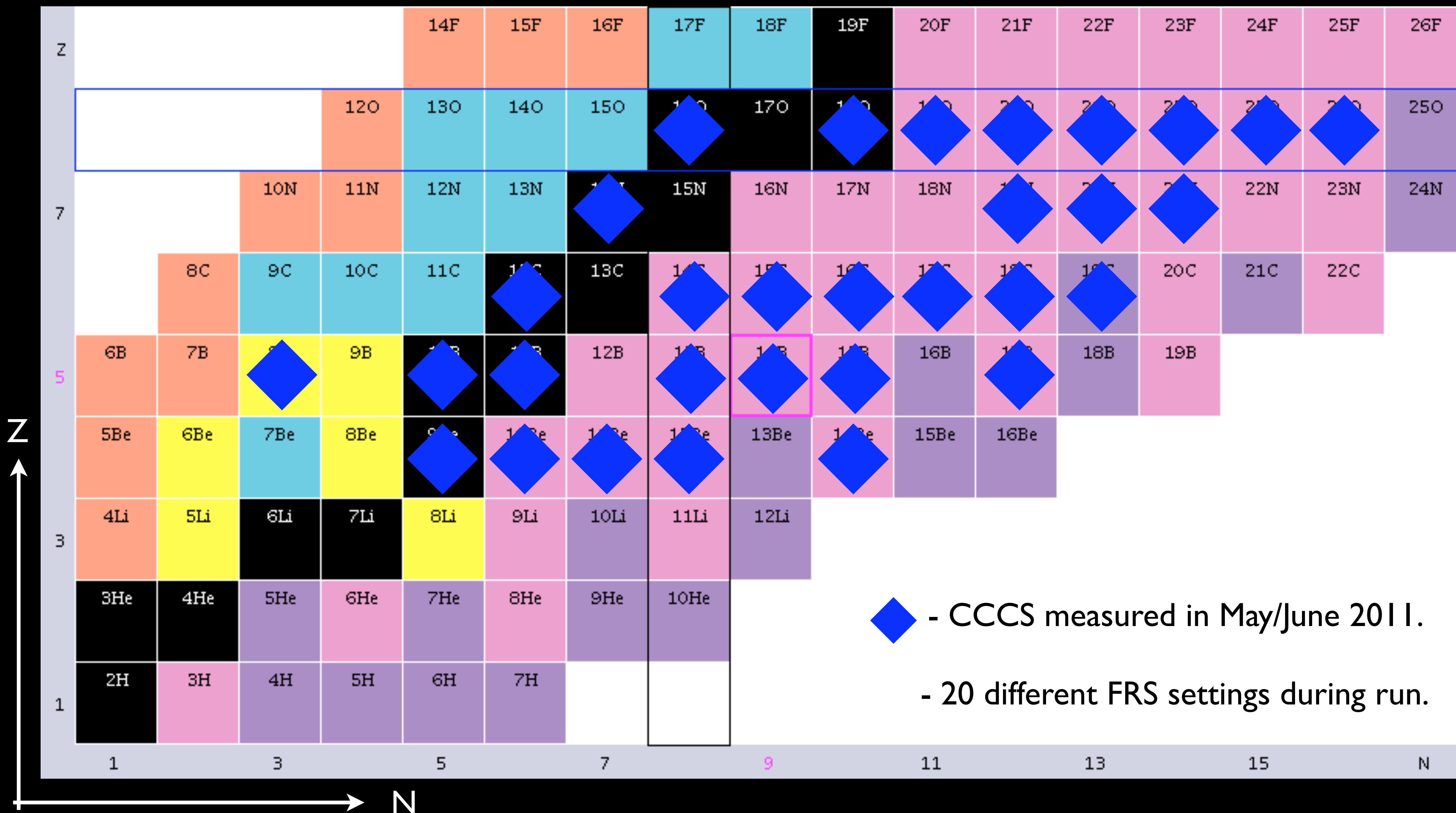
CCCS measured by counting particles that keep same Z after reaction target

$$\sigma_{cc} = \frac{1}{t}\ln\left[\frac{\left(\frac{N_{sameZ}}{N_{in}}\right)_{Tout}}{\left(\frac{N_{sameZ}}{N_{in}}\right)_{Tin}}\right]$$





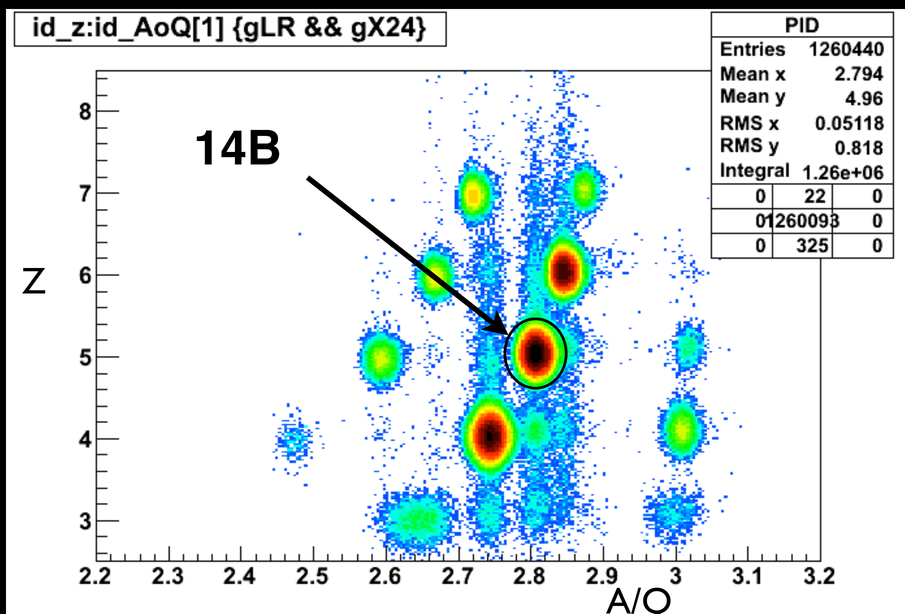
CCCS measurement at 1GeV/u at the FRS.



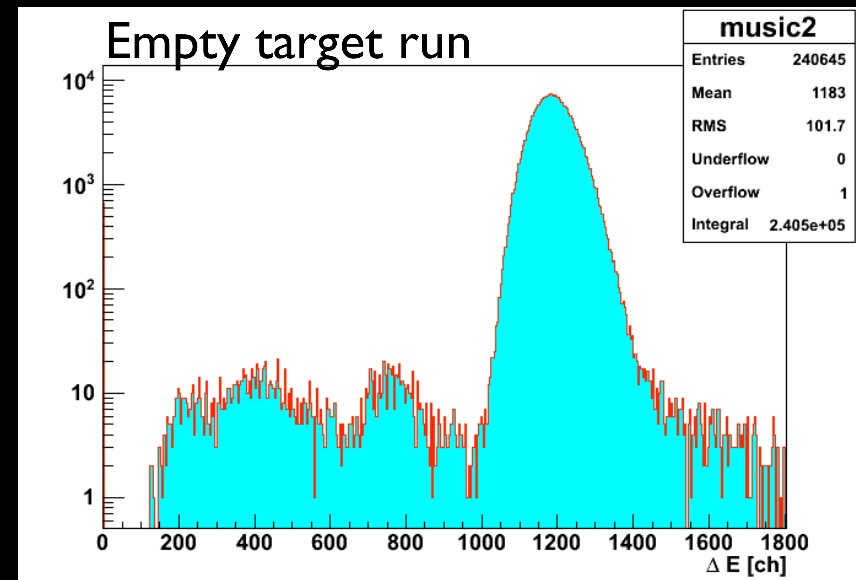
Goal: < 2% precision for CCCS measurement.

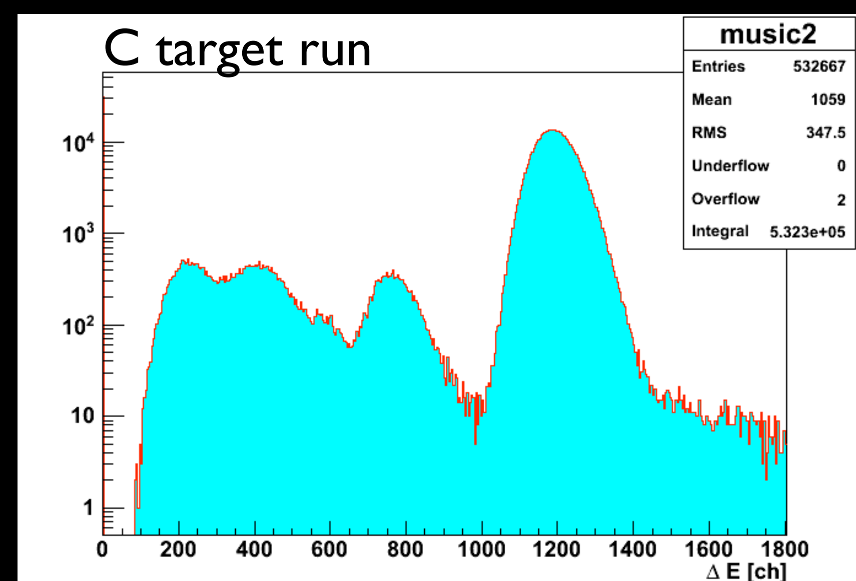
Sample data from 14B setting

Particle identification spectra



Energy loss in MUSIC2, gated on 14B



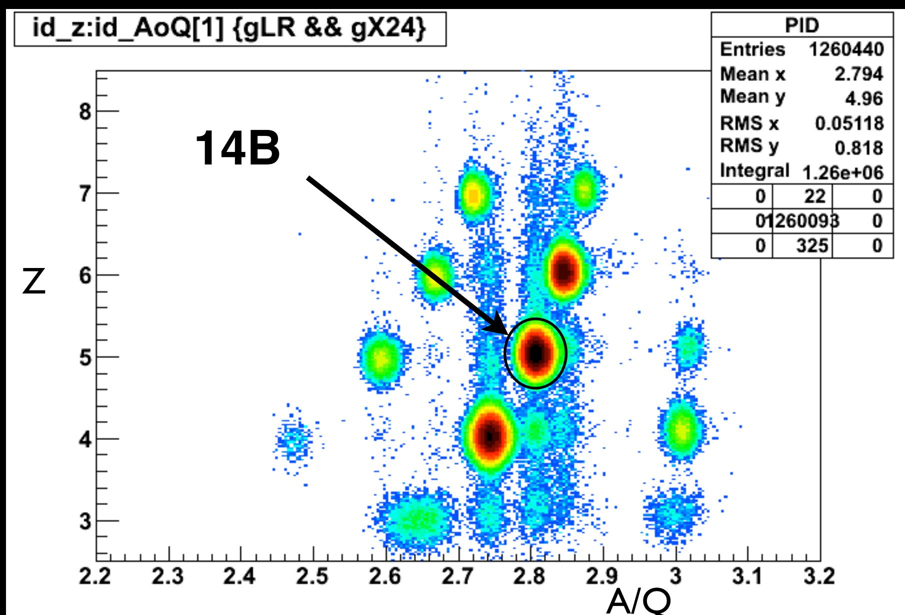


Energy loss resolution achieved:

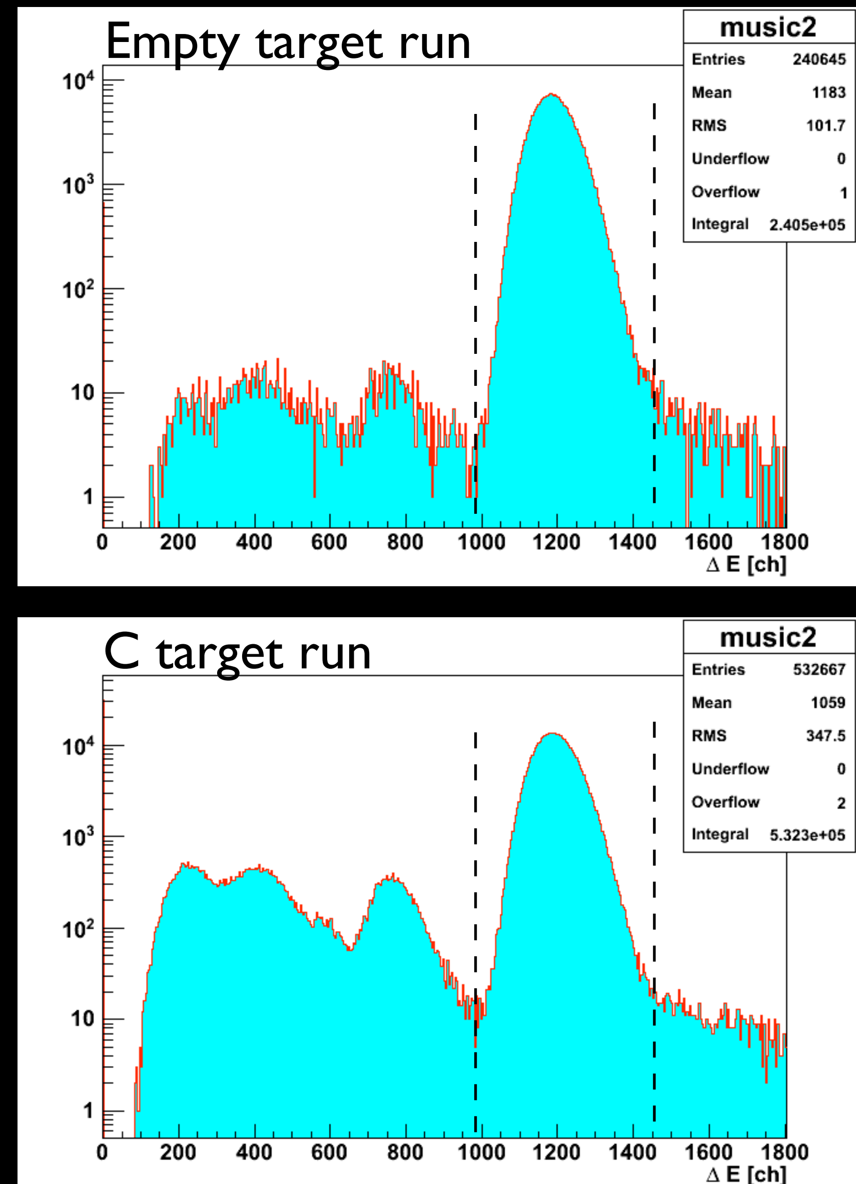
- B: 5.1 %
- C: 4.0 %
- N: 3.3 %

Sample data from 14B setting

Particle identification spectra



Energy loss in MUSIC2, gated on 14B

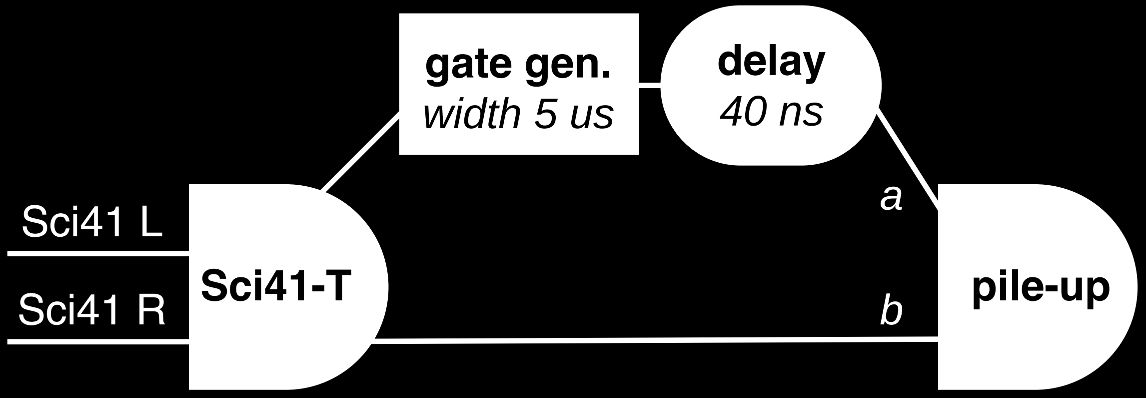


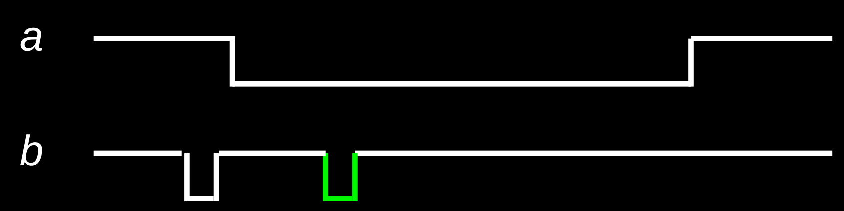
Energy loss resolution achieved:

- B: 5.1 %
- C: 4.0 %
- N: 3.3 %

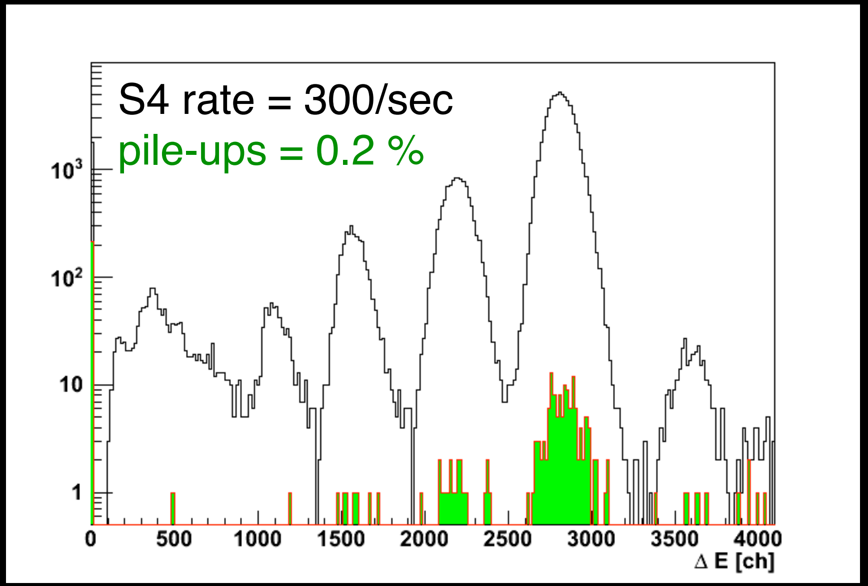
Rejection of pile-up events

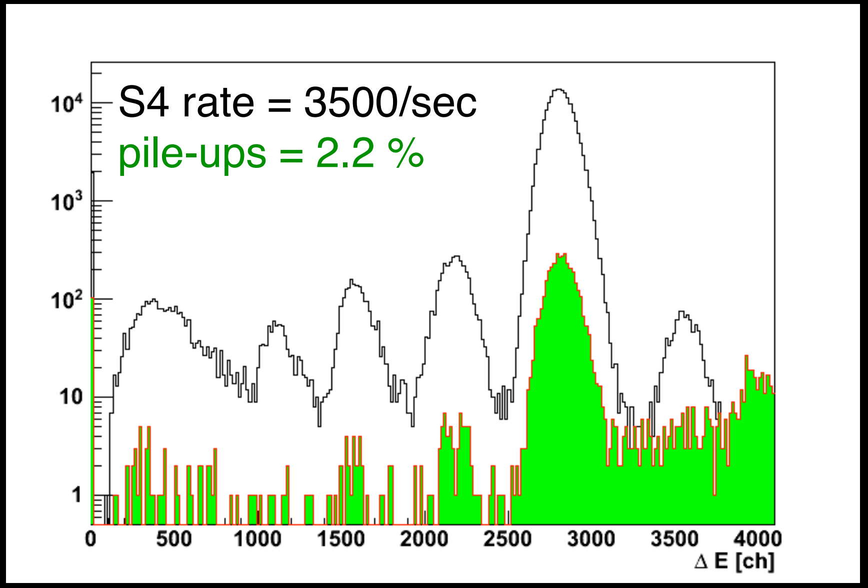
- Pile-up detection circuit.
- Multi-hit TDC.
- Veto scintillator.





MUSIC1 spectra for 16O settings





Conclusions and perspectives

- Charge changing cross section (CCCS) measurements allow the determination of proton radii of very unstable nuclei.

- Study of proton distribution important to place experimental constraints on the Equation of State of asymmetric nuclear matter, and to study the structure of light unstable isotopes.

- Measurement of CCCS for several neutron-rich Be, B, C, and O isotopes at 1 GeV/u performed successfully with the FRS in May 2011. Data analysis is in progress, and results are expected soon.

- Thanks to the GSI staff for their technical support to run the experiment, and to GSI for the alloted beamtime.

Collaboration

J. Atkinson, A. Estrade, **R. Kanungo** (St. Mary's University, Canada), H-J. Ong, **I. Tanihata**, J. Tanaka (RCNP Osaka University, Japan), F. Ameil, I. Dillman, A. Evdokimov, F. Farinon, H. Geissel, G. Guastalla, J. Kurcewicz, R. Knöbel, Y. Litvinov, M. Marta, I. Muhka, C. Nociforo, S. Pietri,, A. Prochazka C. Scheidenberger, M. Takechi, H. Weick, J. Winfield (GSI, Germany), S. Terashima (Beihang University, China) R. Janik, B. Sitar, P. Strmen (CUB, Slovakia), Y. Ayyad, D. Cortina-Gil, M. Mostazo, Y. Vargas (USC, Spain).