Experiment S1227: Measurement of $^{3}He(\alpha,\gamma)^{7}Be$ with DRAGON

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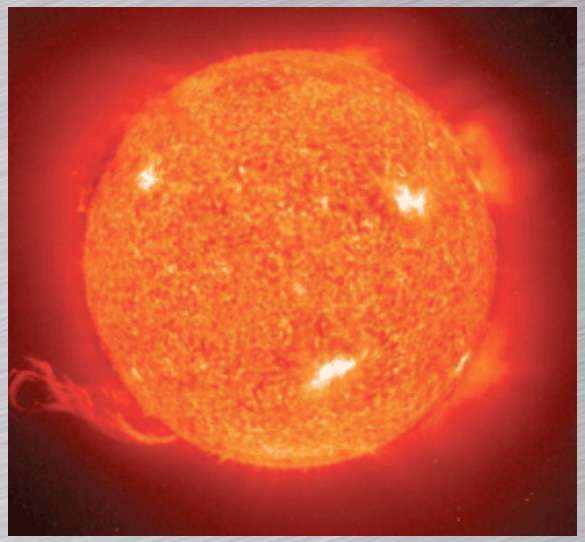
TRIUMF

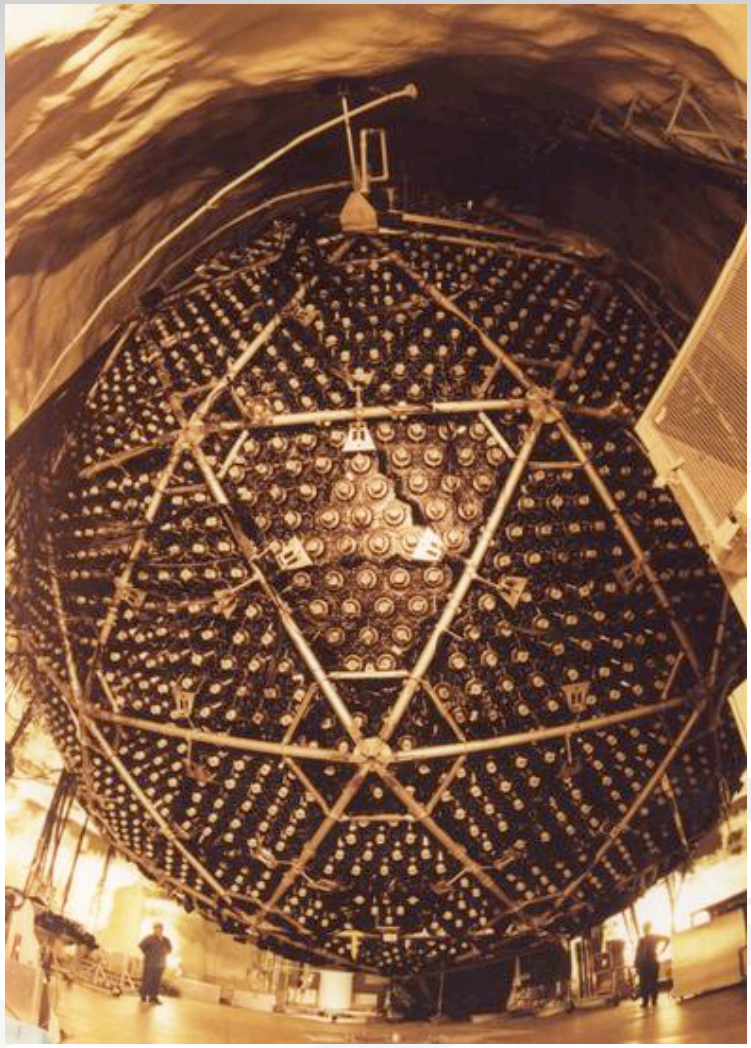
$^3He(\alpha,\gamma)^7Be$ in the Sun and Big Bang Nucleosynthesis

- Radiative capture reaction rates determine energy release, neutrino production, and nucleosynthesis in Sun and other stars
- $^3He + \alpha \rightarrow {}^7Be + \gamma$ ($\pm 5.1\%$)
  - Solar neutrinos
  - Big Bang nucleosynthesis



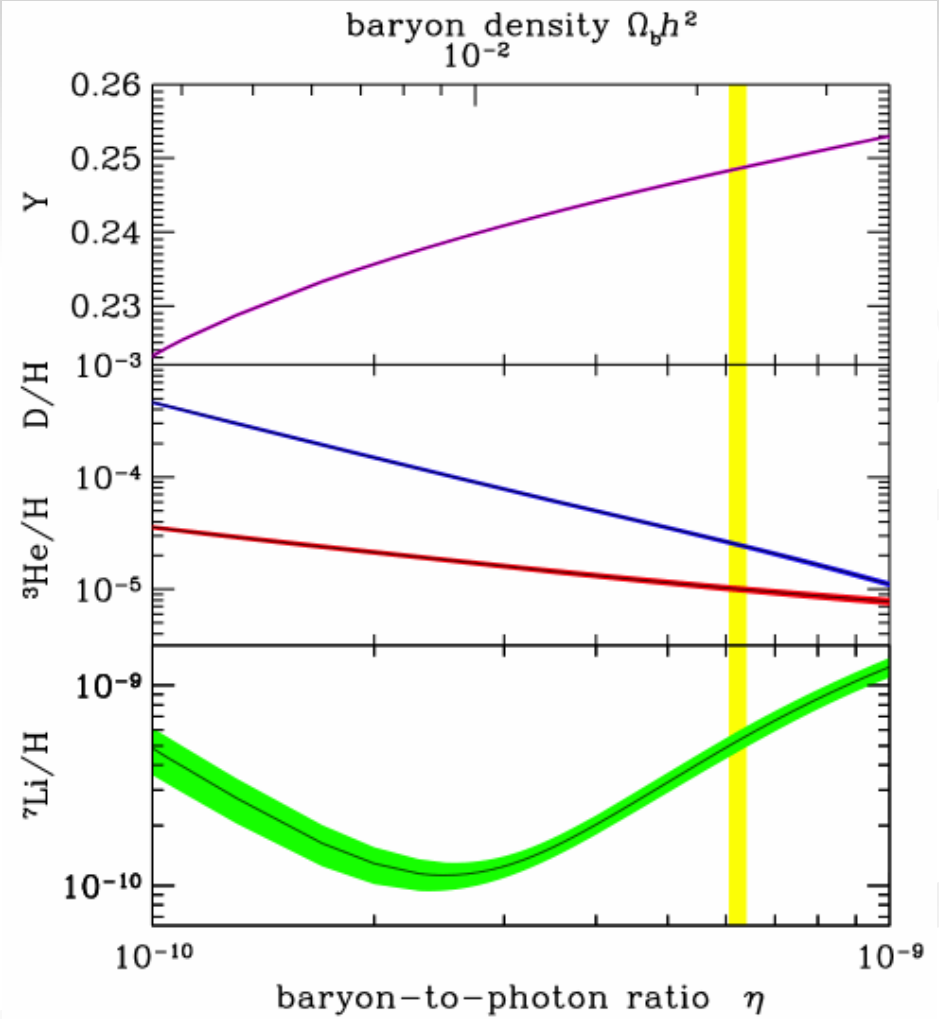
$^3He(\alpha,\gamma)^7Be$ in the Sun

- $^3He(\alpha,\gamma)^7Be$ cross section needed for predictions of solar neutrino flux
- ^8B solar ν flux now measured to ± 8.6% by SNO, ^7Be flux measured to ± 10% by Borexino
- $S_{34}(0)$ is the astrophysical S factor for the radiative capture $^3He + \alpha \rightarrow {}^7Be + \gamma$ at zero energy; most probable energy for reaction is 23 keV
- ^8B flux $\propto S_{34}(0)^{0.81}$
- ^7Be flux $\propto S_{34}(0)^{0.86}$



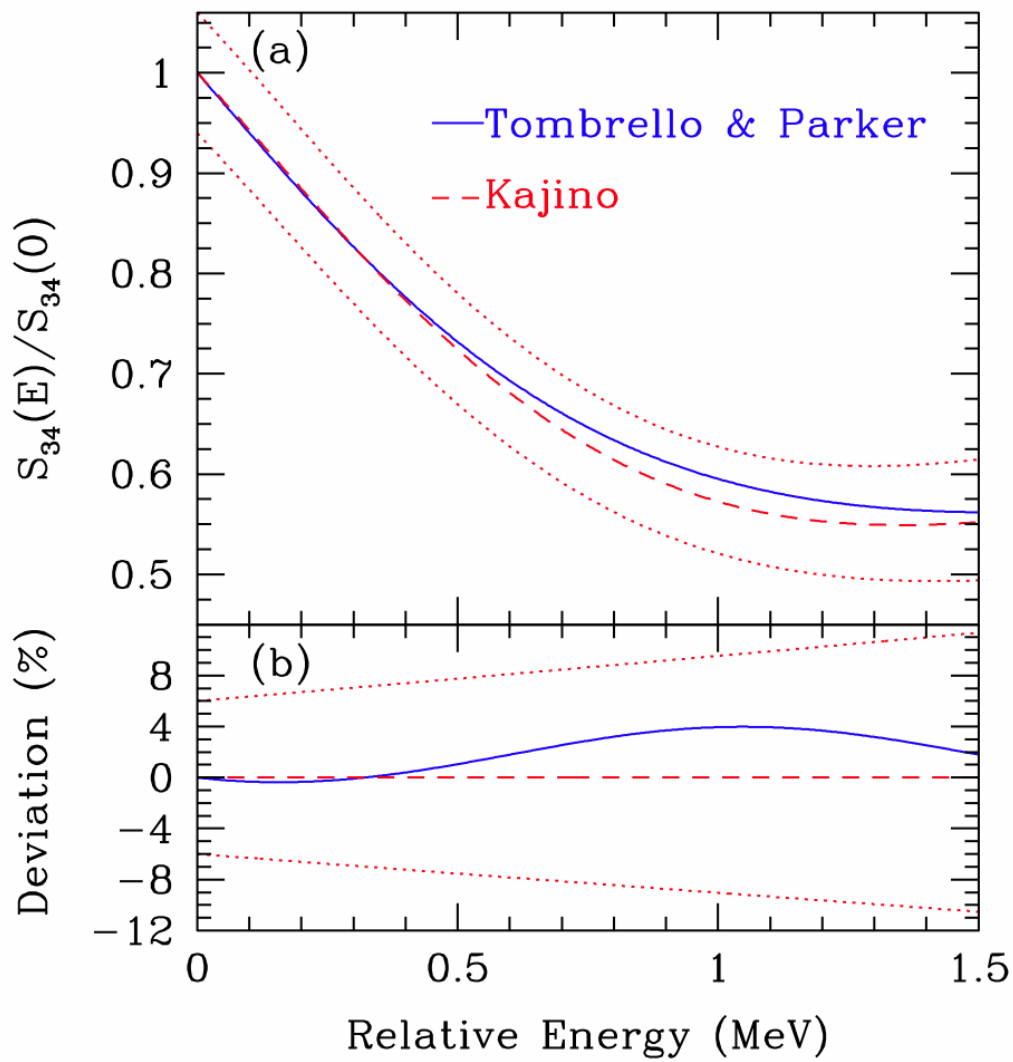
$^3He(\alpha,\gamma)^7Be$ in Big Bang Nucleosynthesis

- BBN a robust prediction of hot big bang cosmology for > 40 yr
- Explains origin of large universal He abundance, trace quantities of D, ^3He, & ^7Li
- Given general relativity, cosmological principle, abundance predictions depend only on mean lifetime of neutron, number of active, light neutrino flavours, universal baryon density, and nuclear reaction rates
- ^7Li produced via $^3He(\alpha,\gamma)^7Be$
- Primordial ^7Li abundance proportional to $S_{34}(300\ keV)^{0.96}$

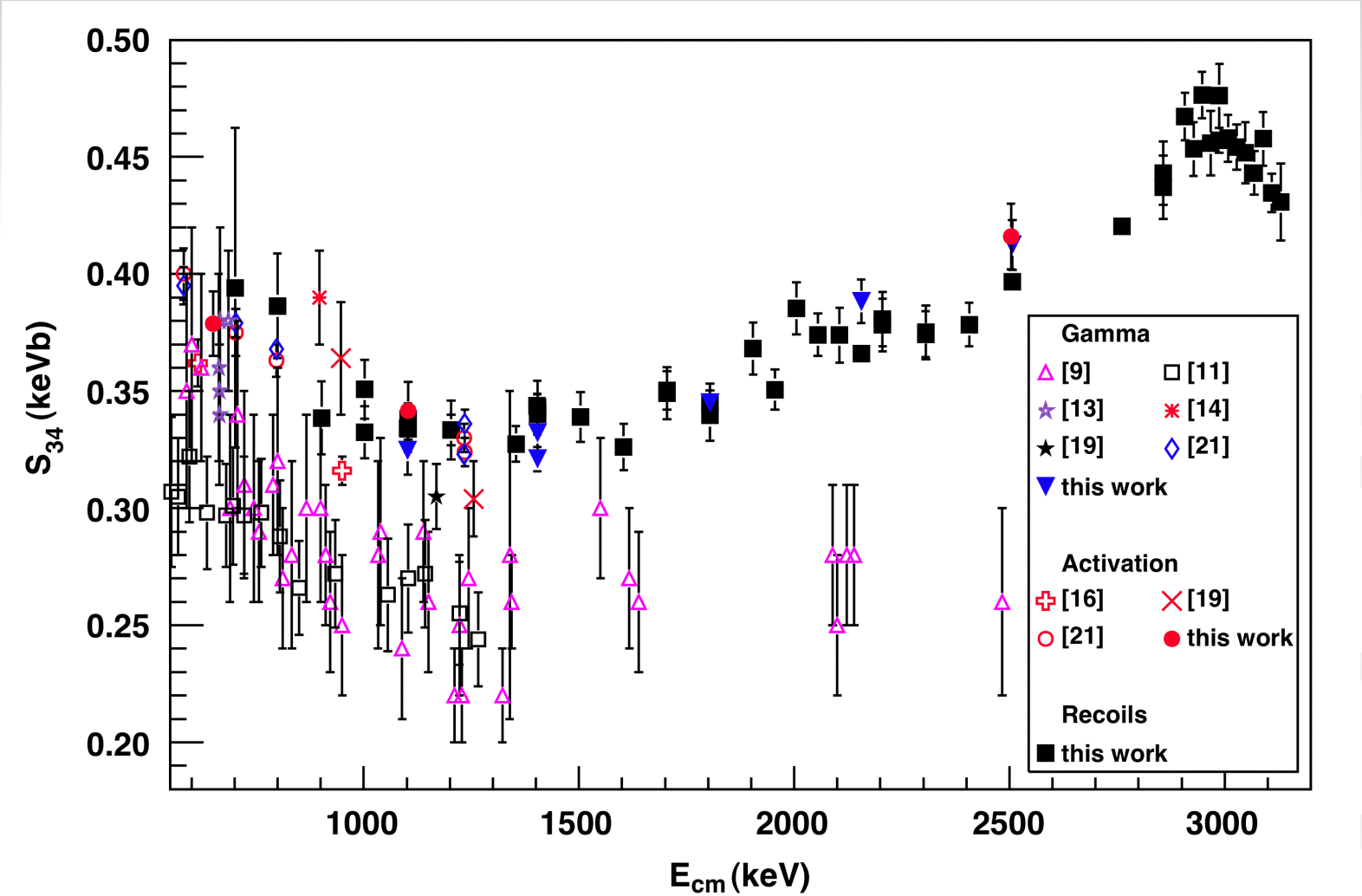


Theoretical S_{34} Models

- Potential model and RGM cluster model of Kajino [NPA 460, 559 (1986)] shapes agree below 500 keV, but is it fortuitous? Absolute values of calculations significantly underestimate data
- Uncertainty in cluster model $S_{34}(E)$ derived from theoretical estimates of uncertainty in $S_{34}(0)$ and its logarithmic derivative, shown by dotted lines

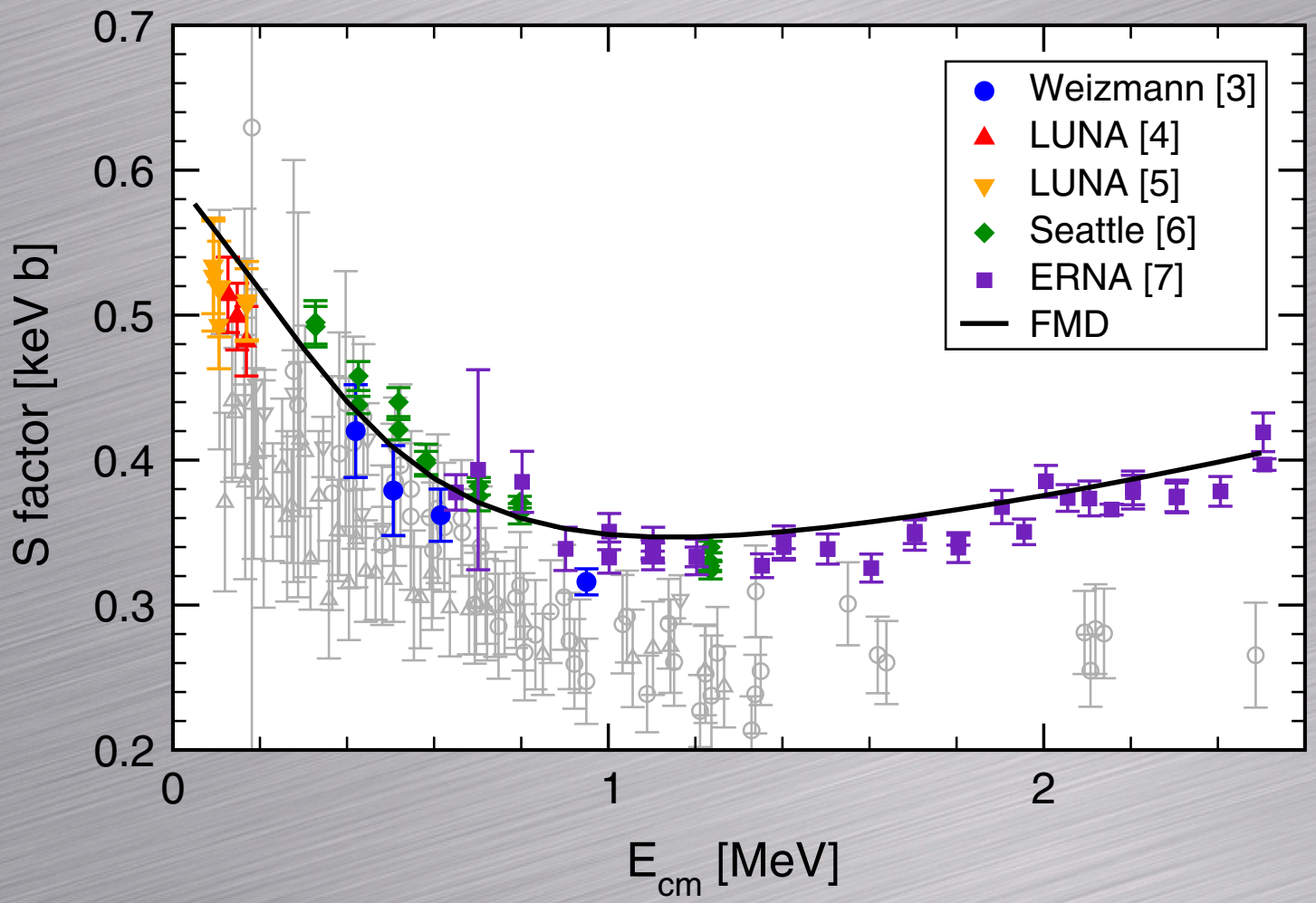


1st Measurement with a Recoil Separator, ERNA



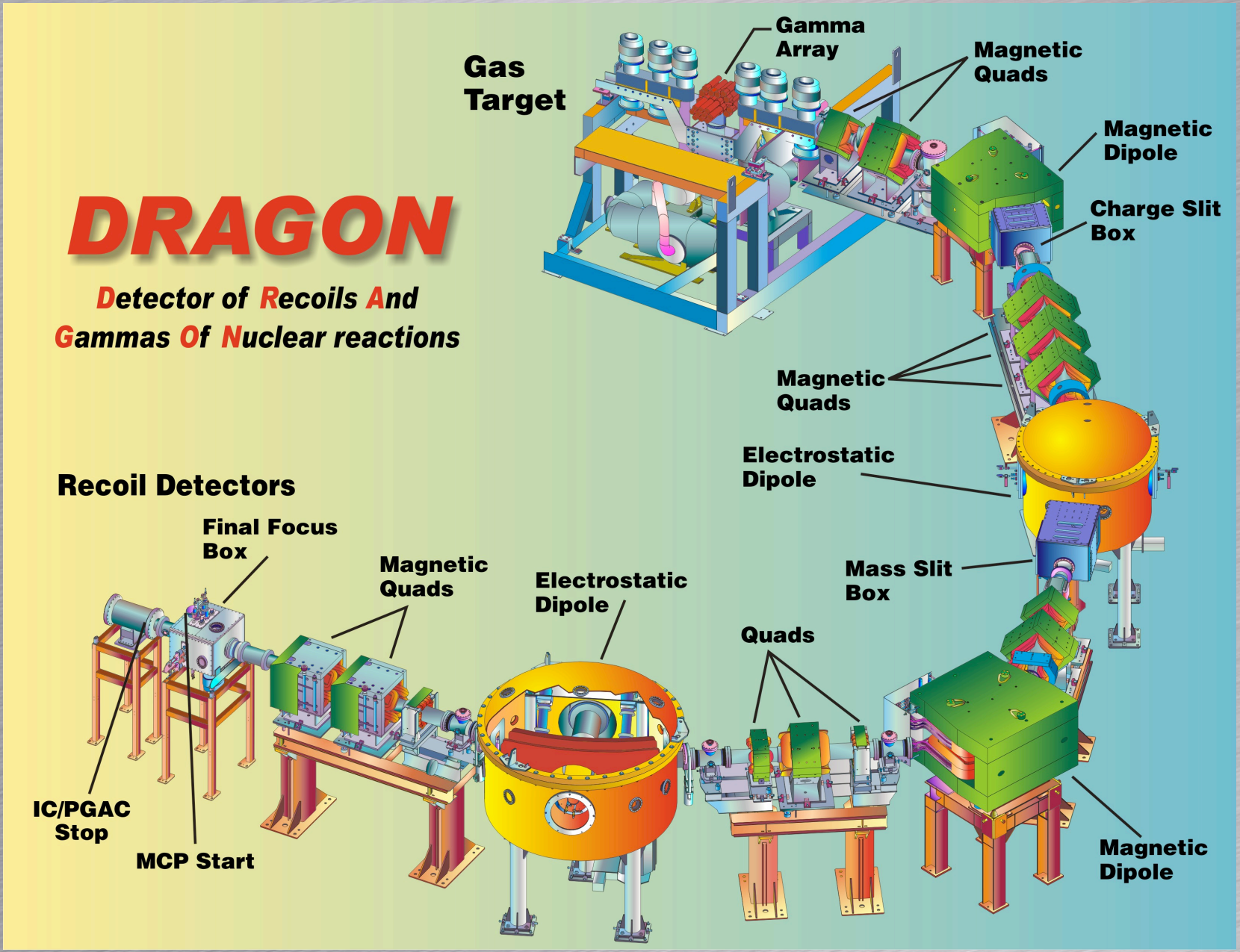
Di Leva *et al*. PRL **102** 232502 (2009)

New FMD Calculation

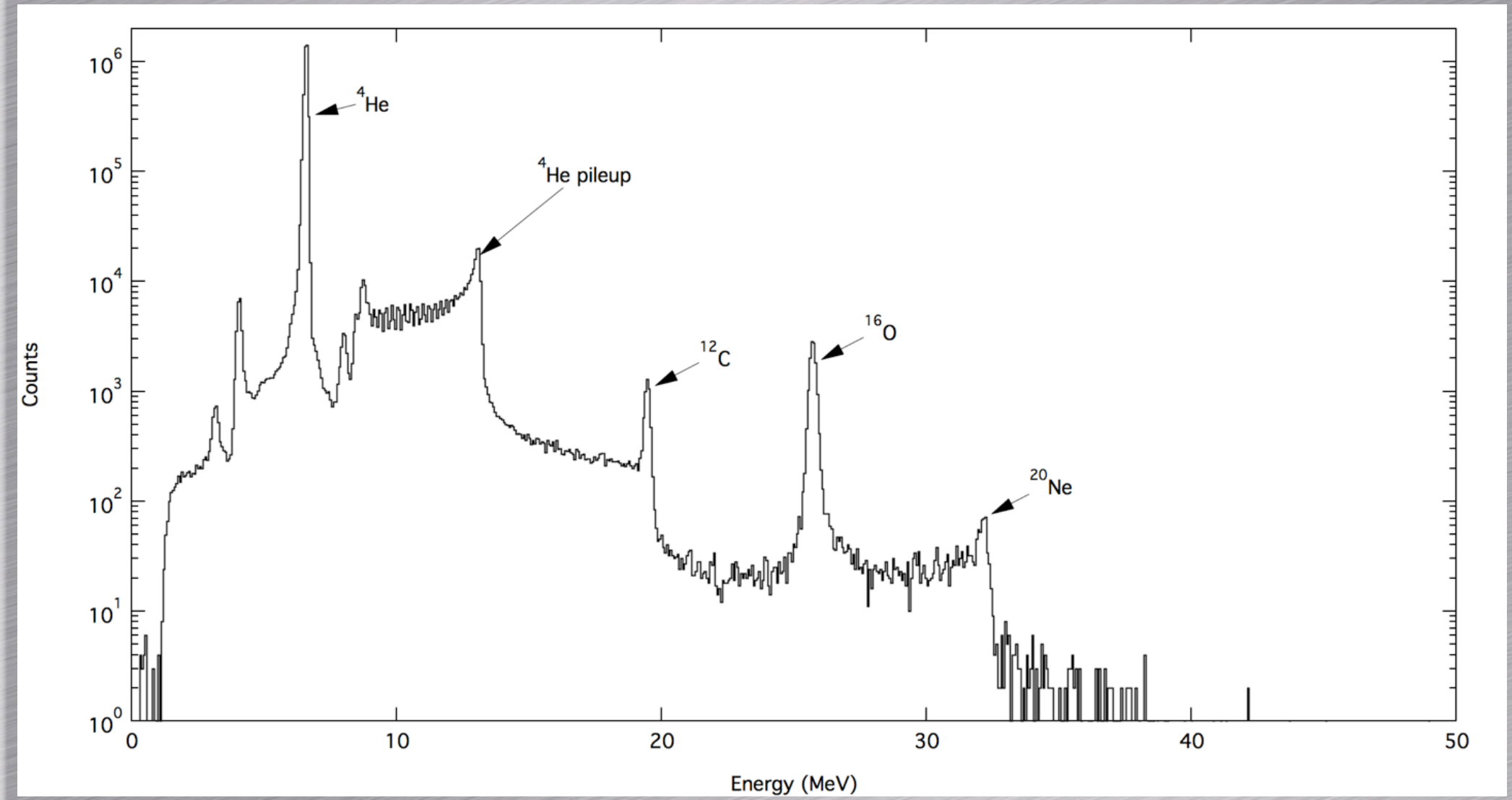


FMD calculation by Neff in good agreement with ERNA data, disagrees with Parker & Kavanagh, Weizmann data

TRIUMF's Recoil Separator

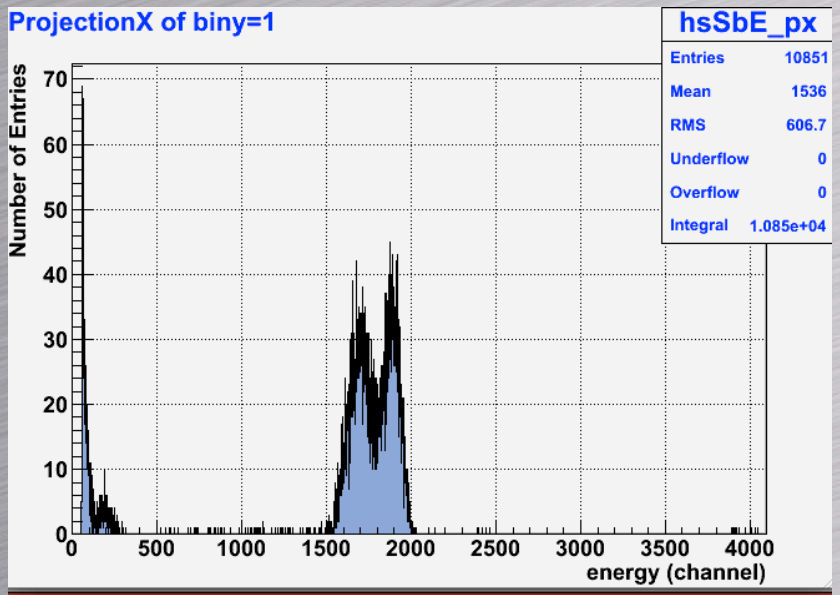


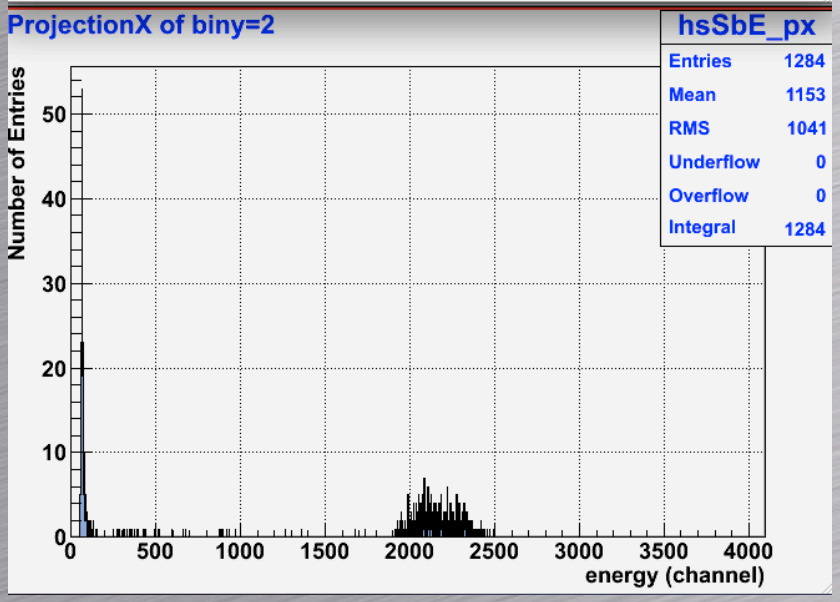
^{4}He Beam Purity

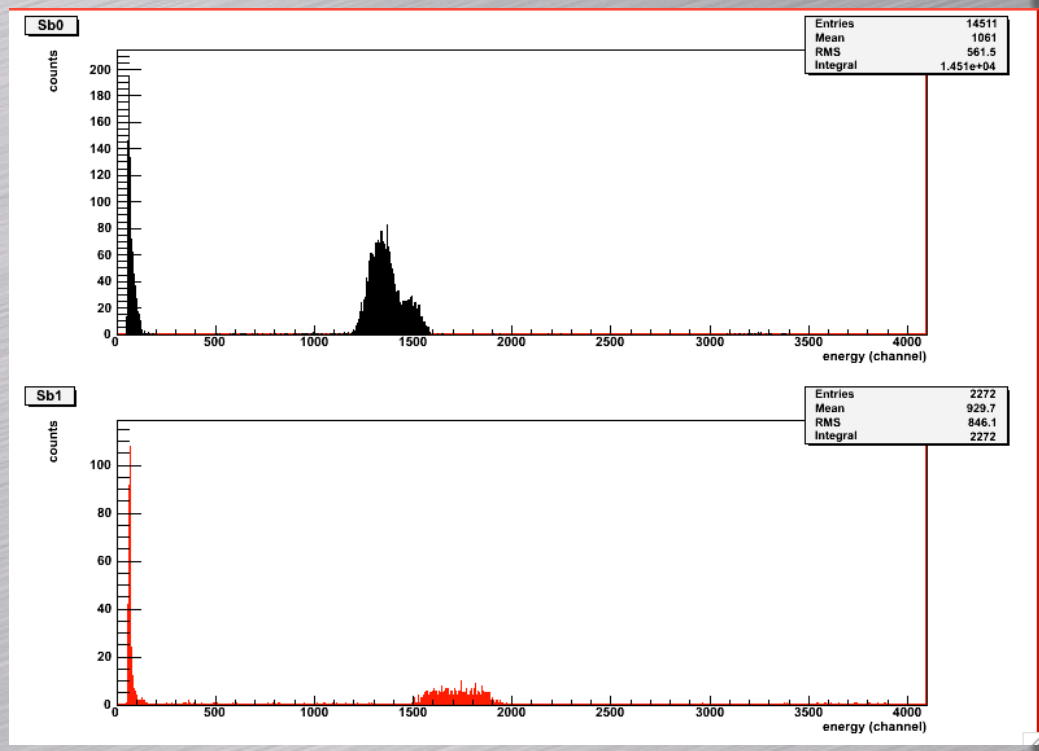


Si detector viewing Au foil at 30 degree angle just downstream of drift tube linac

Beam Current Monitors

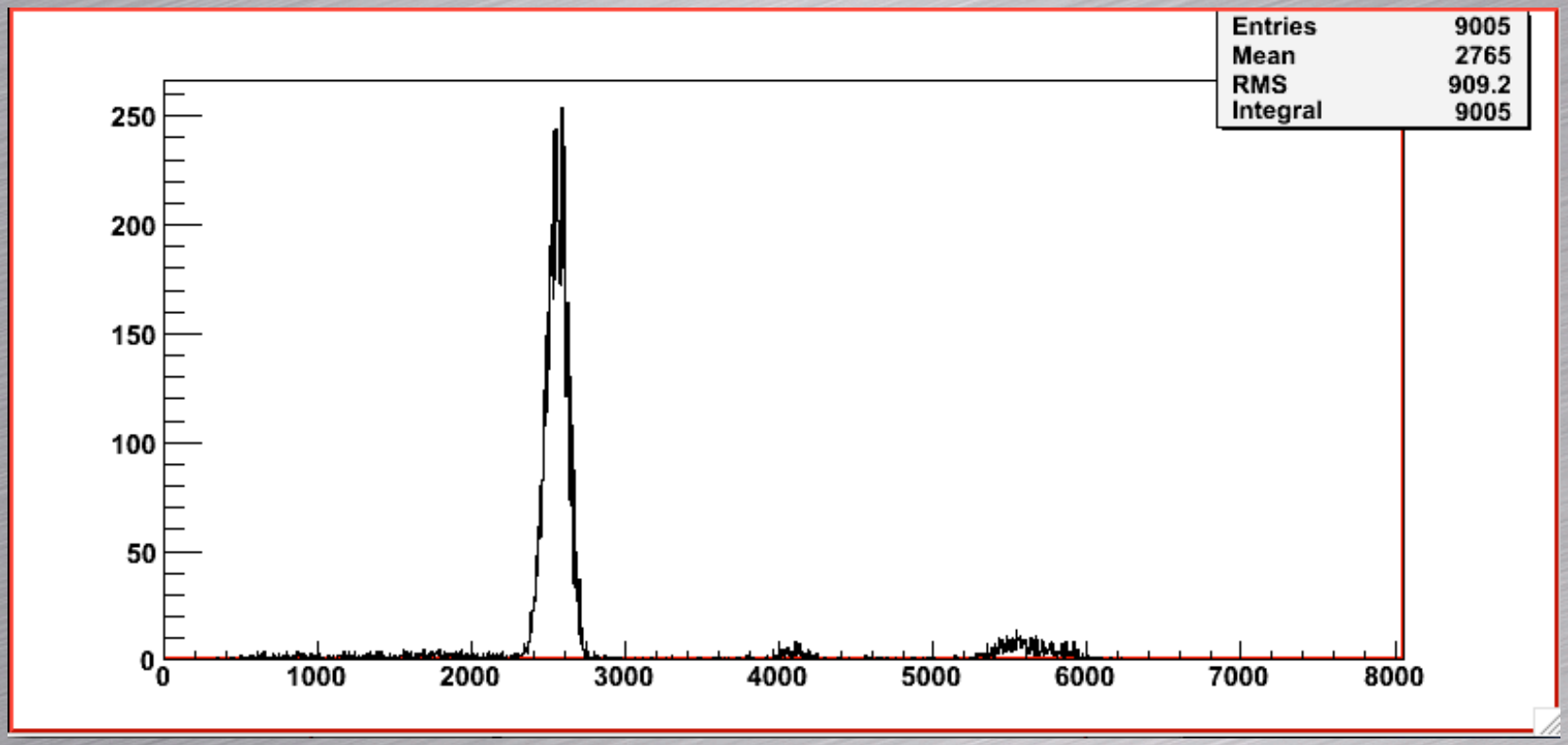






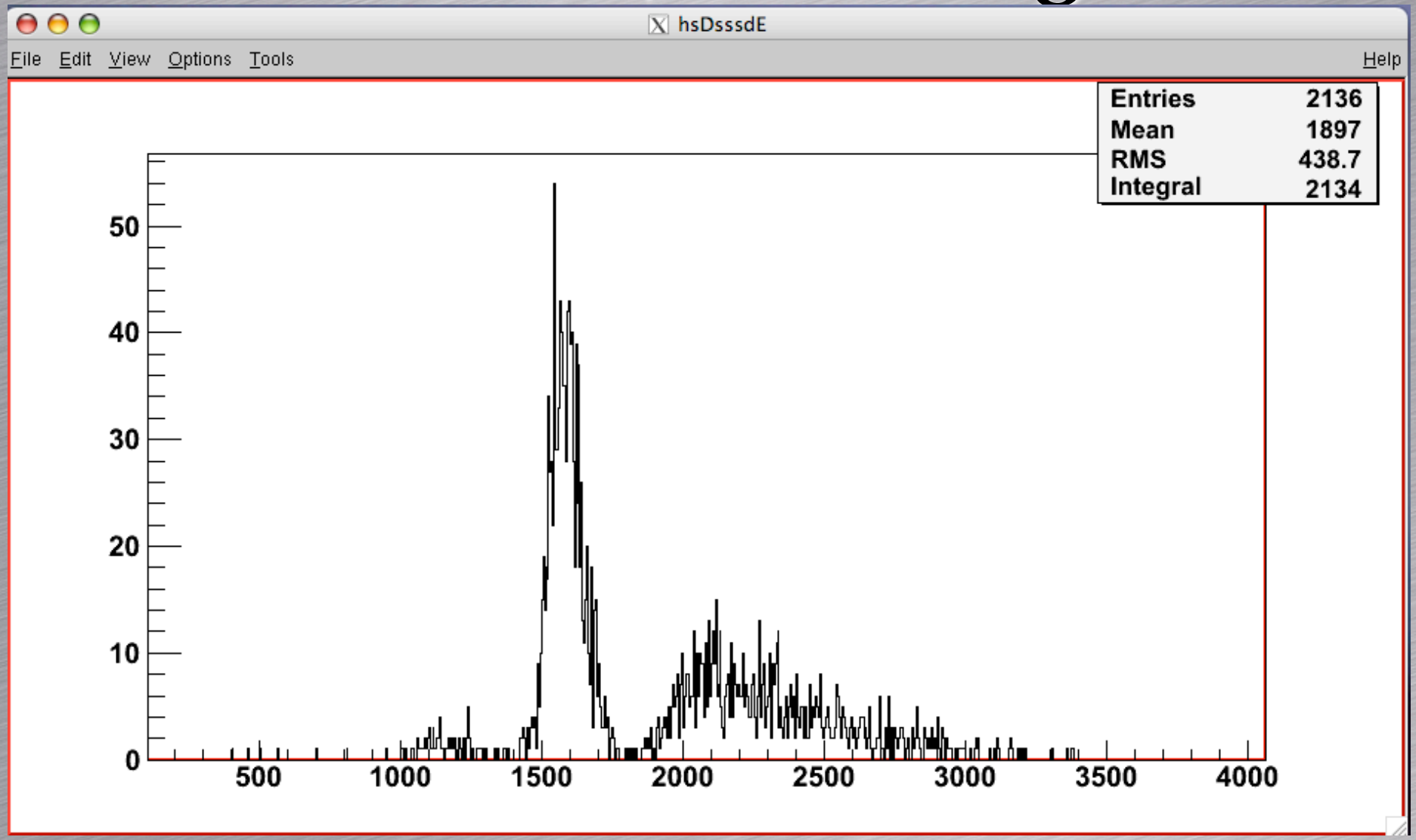
Si detectors viewing gas target at 30 and 57 degrees count ^{3,4}He continuously, Faraday cup measurements hourly

^{7}Be Recoil Energy Spectrum: E_{rel} = 2.2 MeV, 3^{+} Charge State



Recoil peak at focal plane DSSD easily separated from scattered higher mass beam components

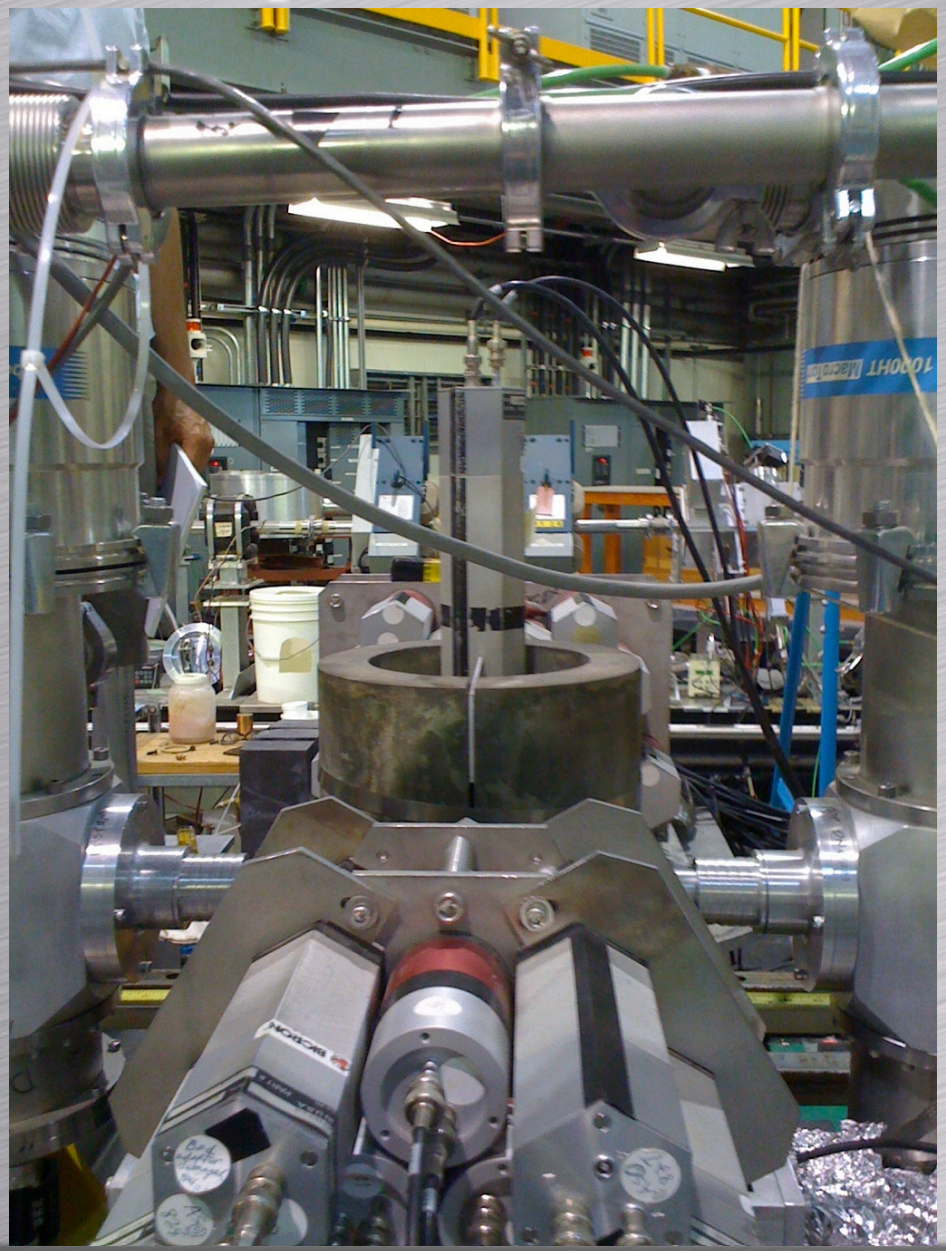
^{7}Be Recoil Energy Spectrum: E_{rel} = 1.5 MeV, 2^{+} Charge State



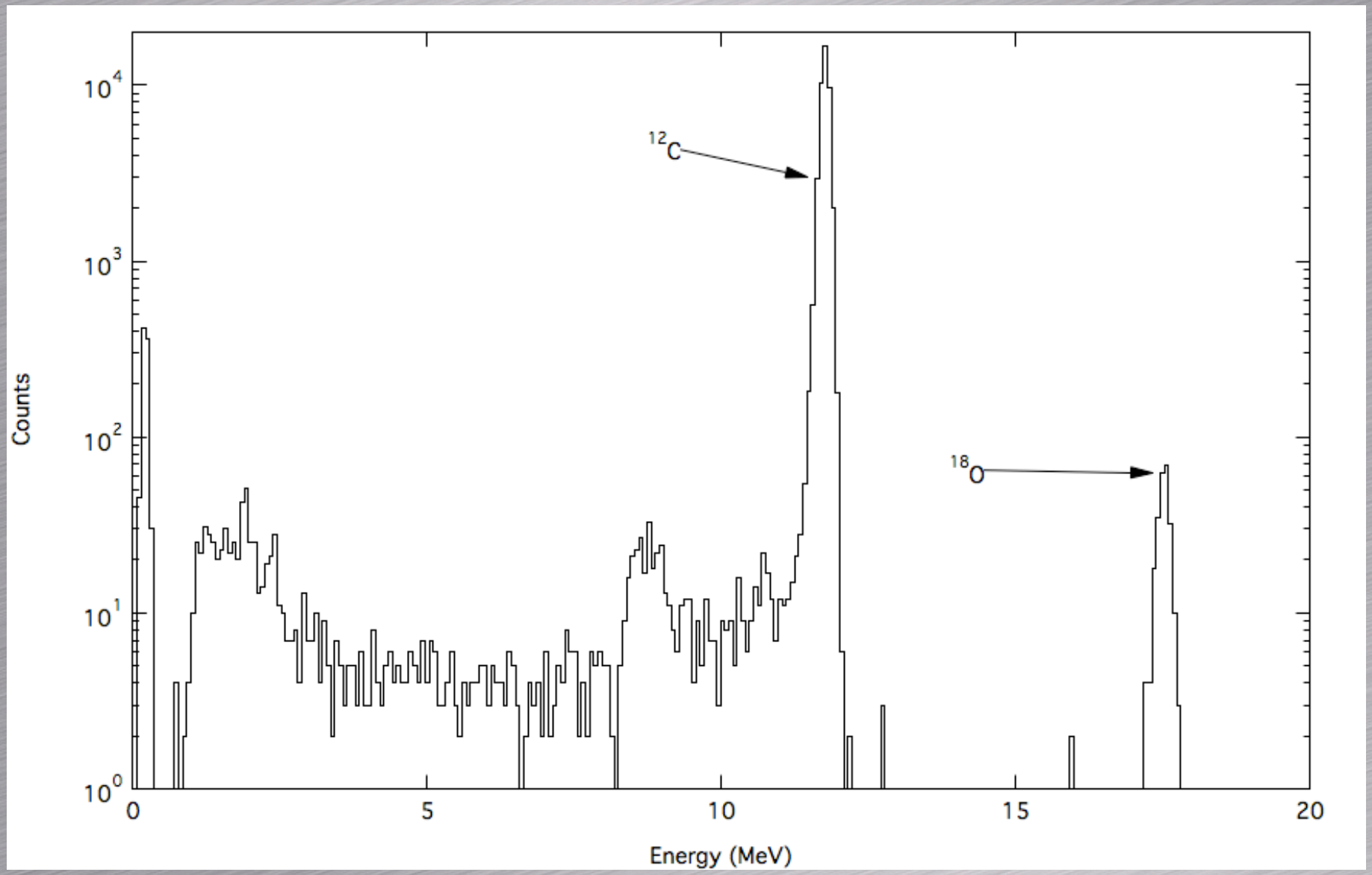
Much more scattered beam in 2^{+} setting, but separation OK

Target Density Measurement:

$^{3}He + ^{12}C \rightarrow p + ^{14}N^{*}(6.446\ MeV)$

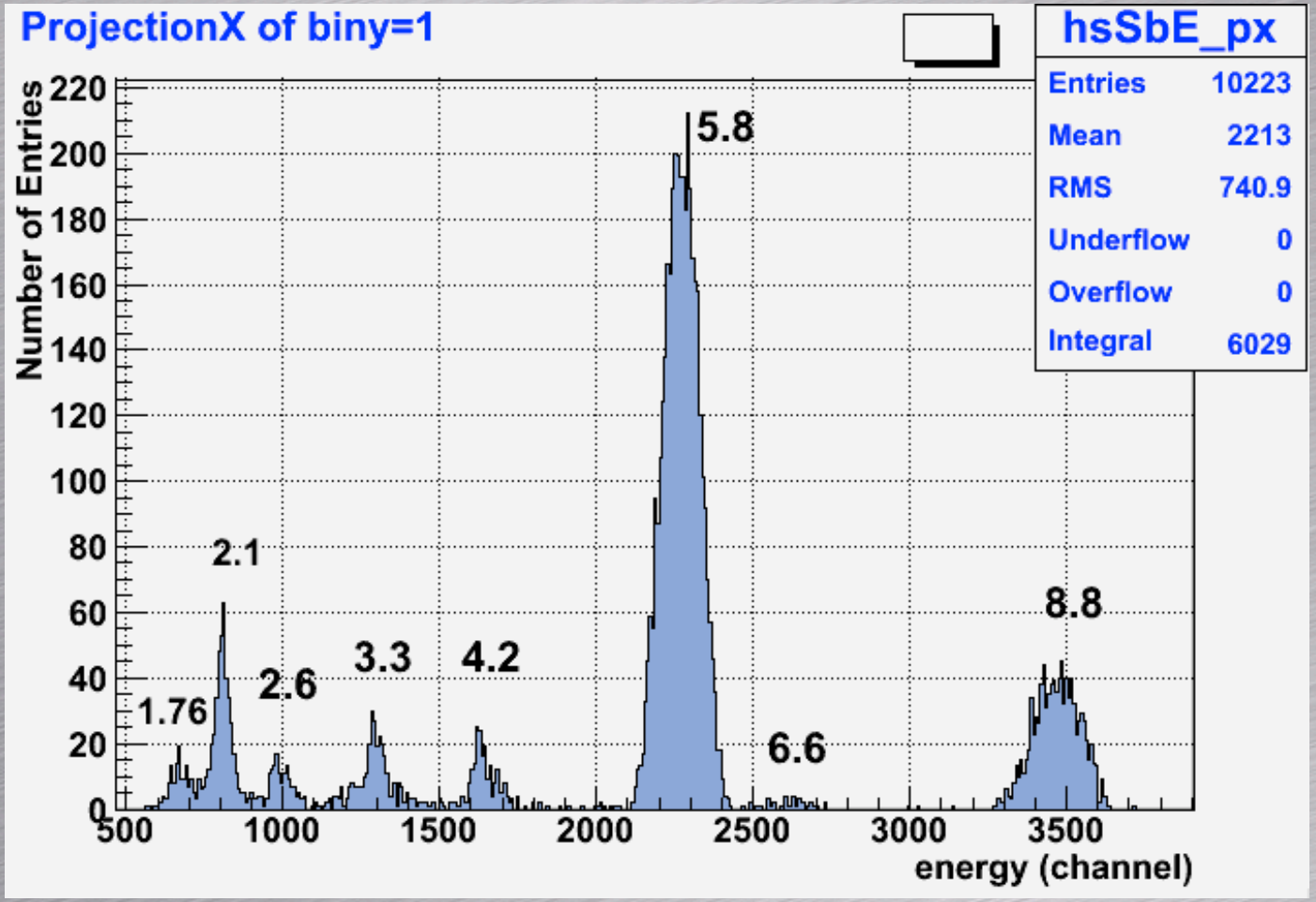


^{12}C Beam Purity



Si detector viewing Au foil at 30 degree angle just downstream of drift tube linac

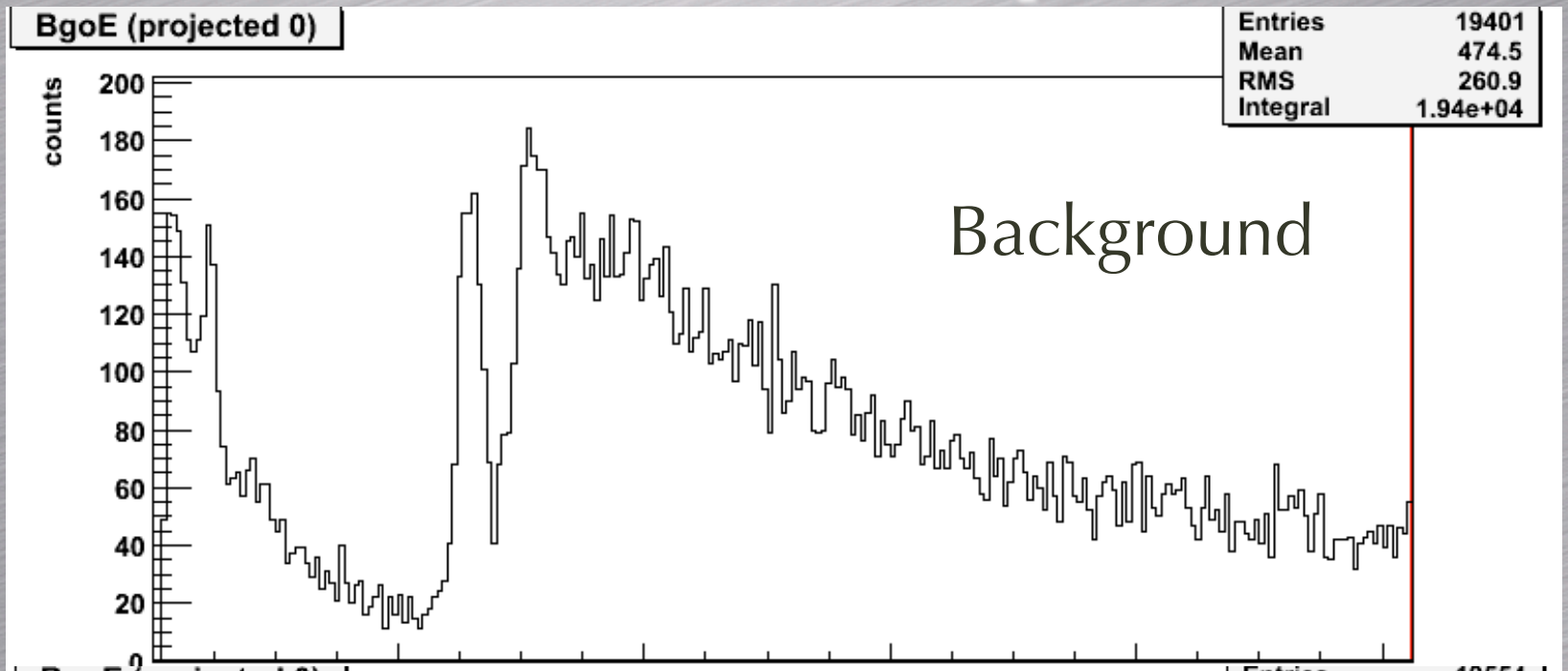
Beam Current Monitoring

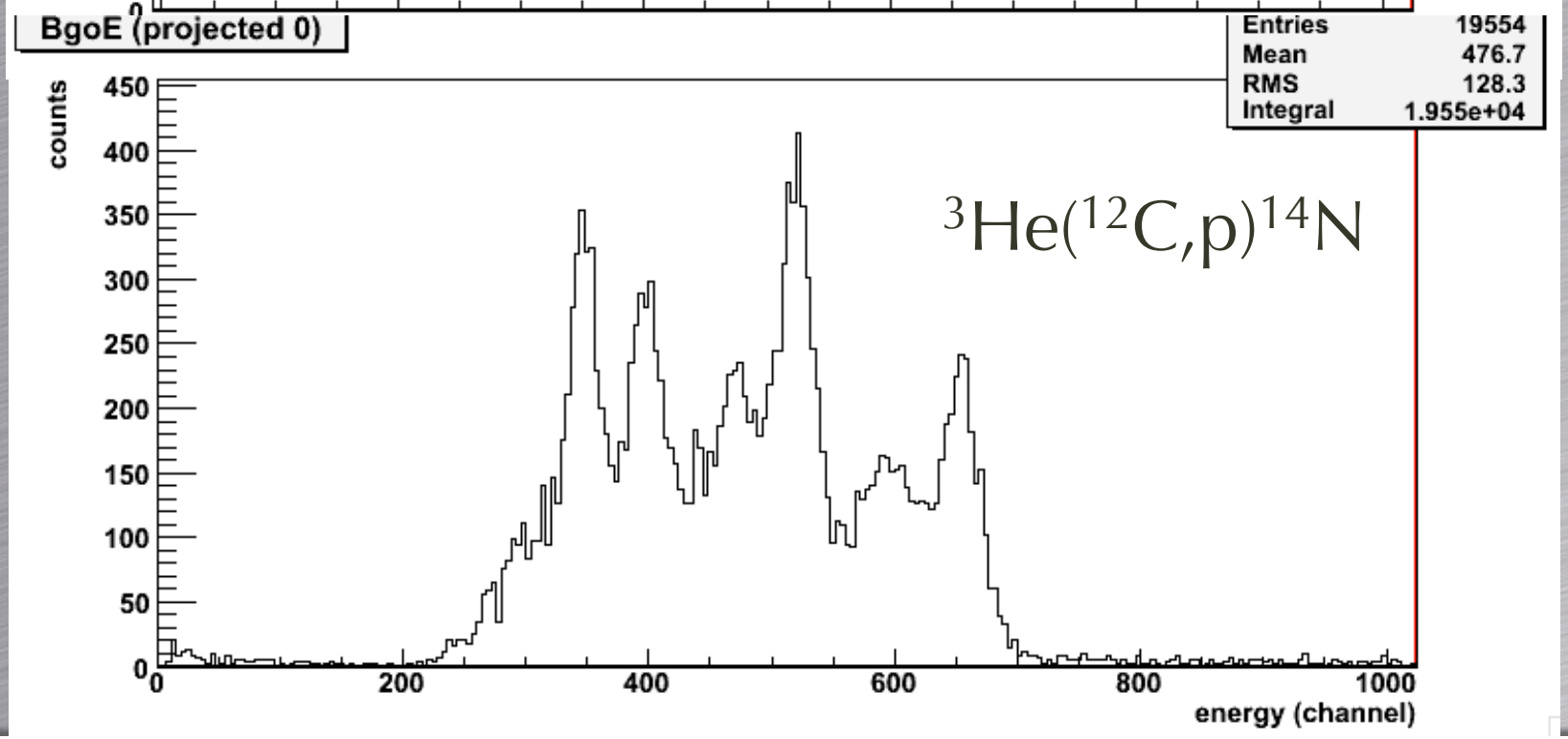


Continuous monitoring of surface barrier detector at 30 degrees, and Faraday cup just after gas target

Main peak is elastic ^{3}He; other peaks are (^{3}He,p) and (^{3}He,α)

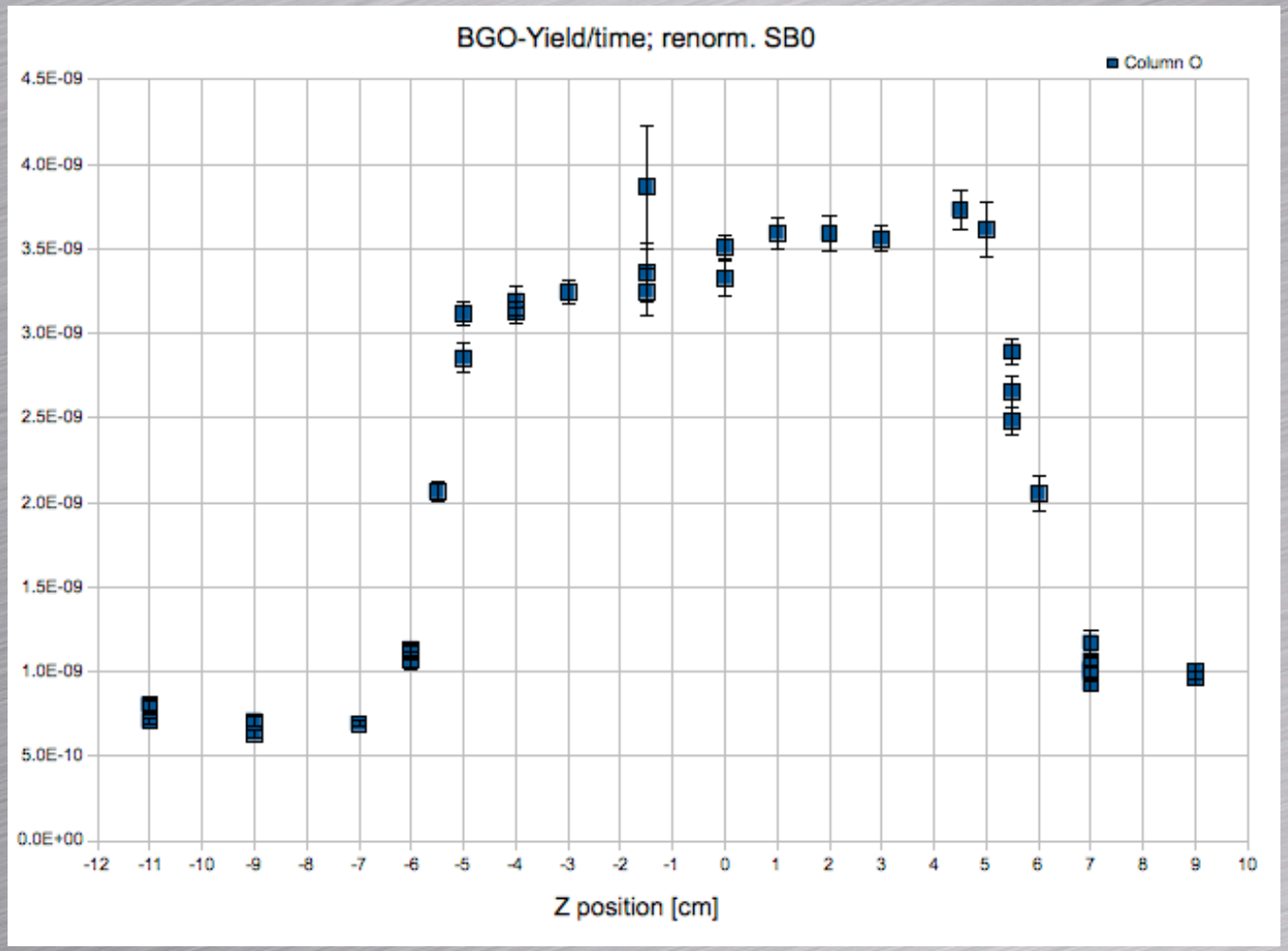
BGO Gamma Spectra





Beam Instability

Yield vs. Position



Asymmetry presumed due to resonance excitation function

Major Remaining Tasks

- Be charge state distribution measurement at three energies, varying target pressures planned for 2012
- Reduce/analyse target density and radiative capture data (Alex Rojas and Mariano Gallardo)
- Complete Monte Carlo simulations of electromagnetic separator angular and energy acceptance (Sarah Reeve)

Credits

Sarah Reeve, Simon Fraser University and TRIUMF
Alex Rojas, TRIUMF
Mariano Gallardo, CSIC Madrid
Sky Sjue, Los Alamos National Lab
(and the stalwart DRAGON team)

B. S. Nara Singh, University of York
Michael Hass, Weizmann Institute