η-Physics at GEM

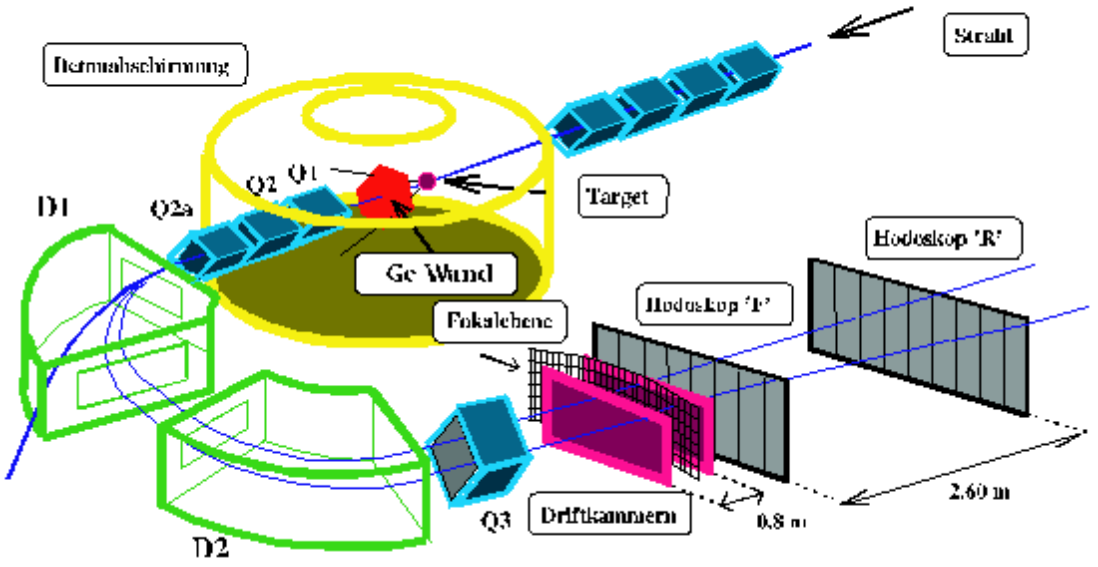
- $p + d \rightarrow \eta + {}^3He$
- $\vec{d} + d \rightarrow \eta + \alpha$ (talk by M.Lesiak)
- search for η-bound states
  - $p + {}^7Li \rightarrow \eta + {}^7Be$
  - $p + {}^{27}Al \rightarrow {}^3He + {}^{25}Mg_\eta$ (talk by V.Jha)
- precision measurement of the η mass

Piotr Hawranek
Jagiellonian University

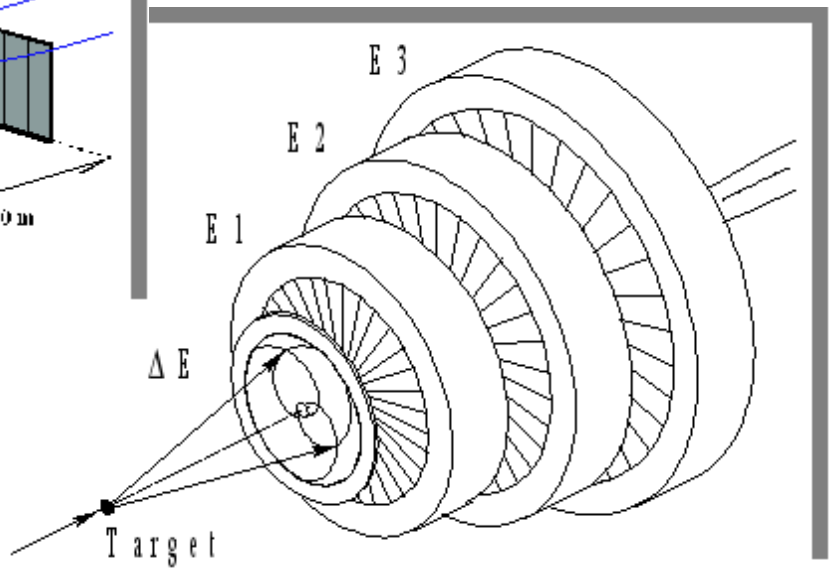
η Meson

- discovered in 1961 in $\pi^+ d \rightarrow pp\pi\pi\pi$ reaction
- existence was predicted before discovery
- ηN interaction → meson exchange model of strong interaction
- production mechanism not well known
- strong attractive interaction of η meson with nuclei → quasi bound states exists ?
- mixture of SU(3) states (η_0 η_8 π^0):
  - isospin symmetry breaking
  - u d quark mass difference
  - CP violation

GEM Detector

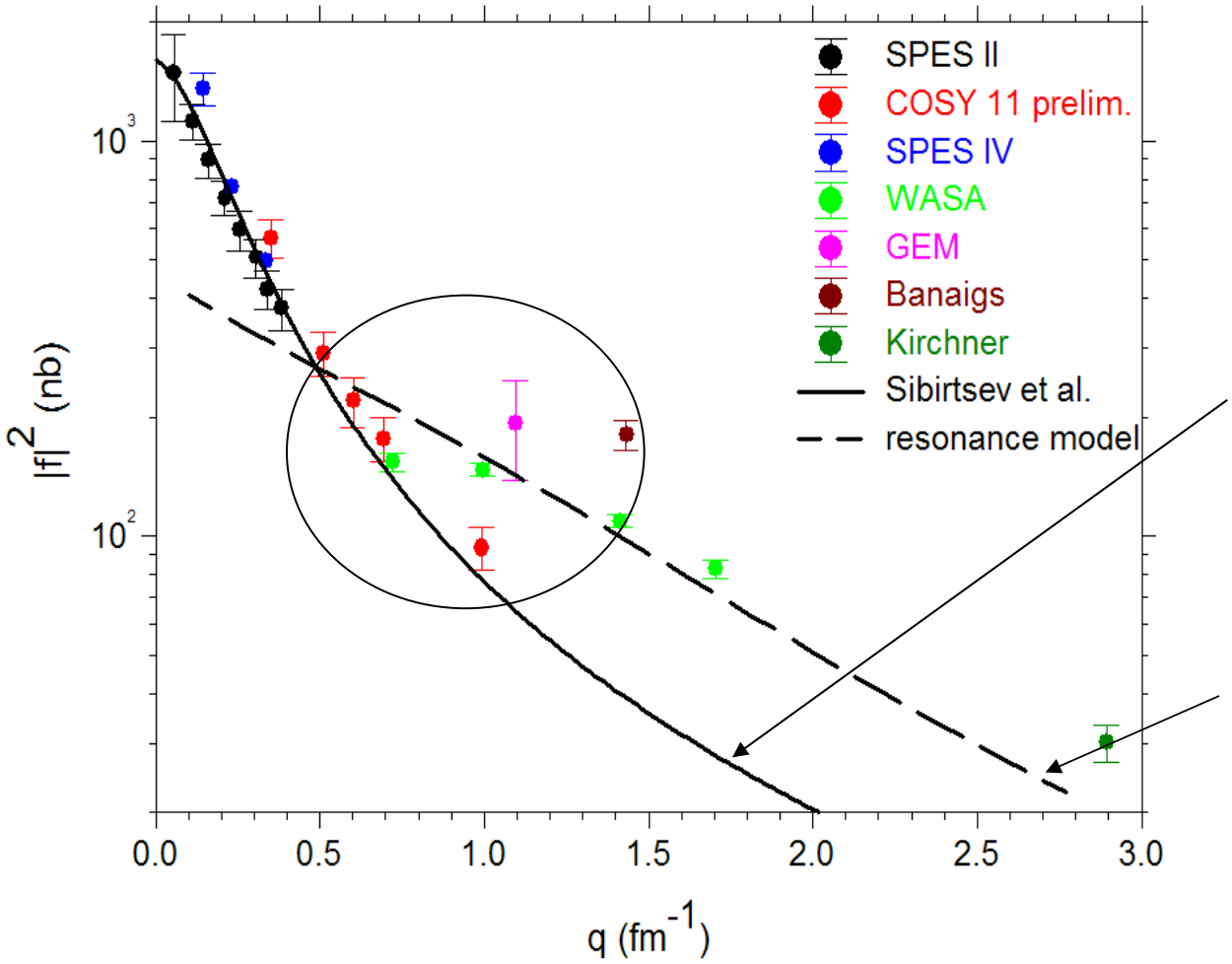


- GErmanium Wall



- Magnetic Spectrograph - Big Karl

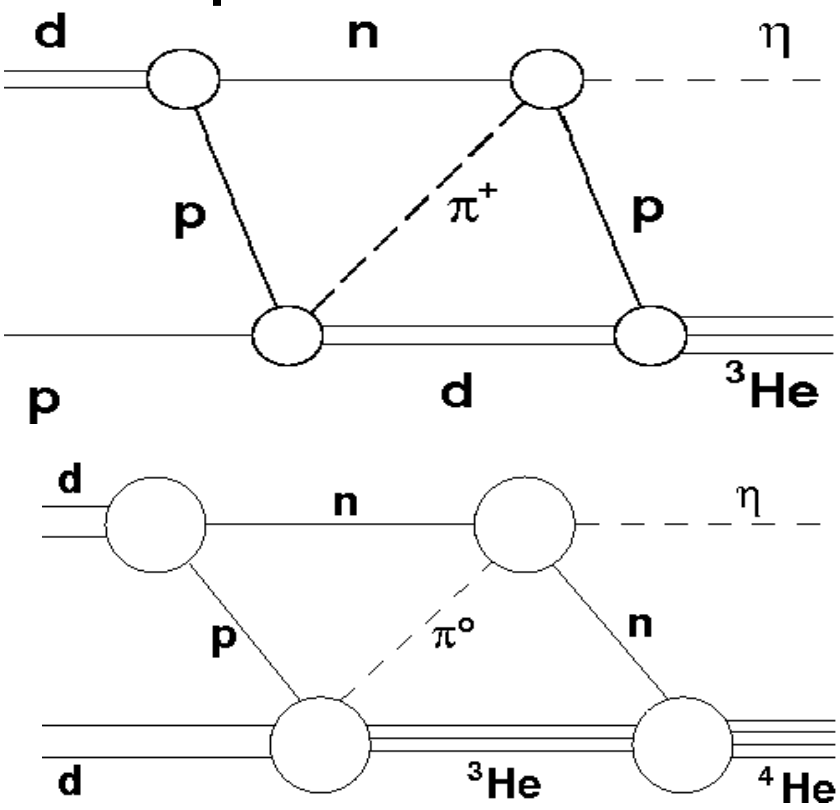
p + d → ^{3}He + η



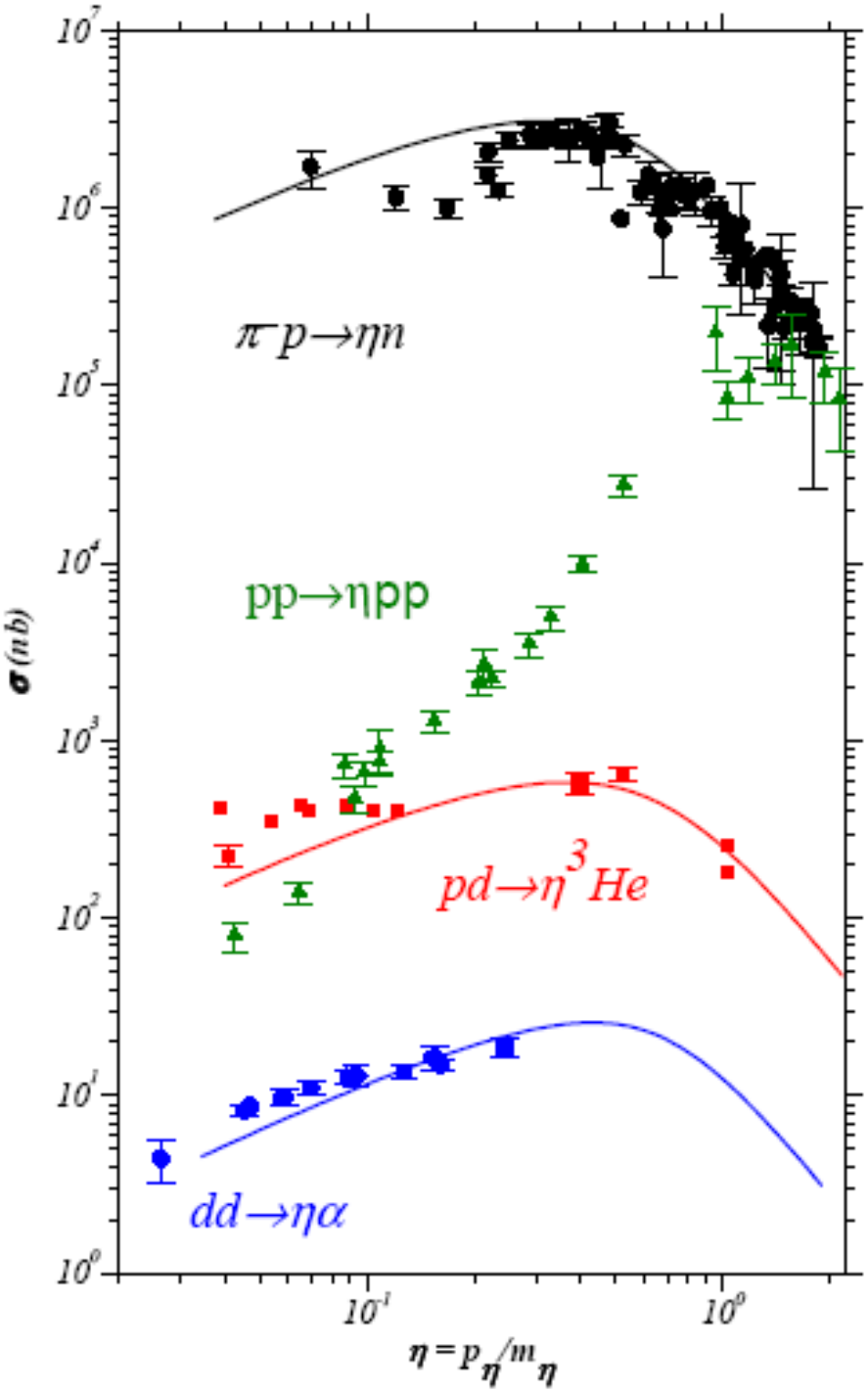
$$|f|^2 = \frac{\sigma_{tot}}{4\pi}\frac{p_p}{p_\eta}.$$

- fit to the data (*s*-wave + FSI)
- resonance model

2 Step Model

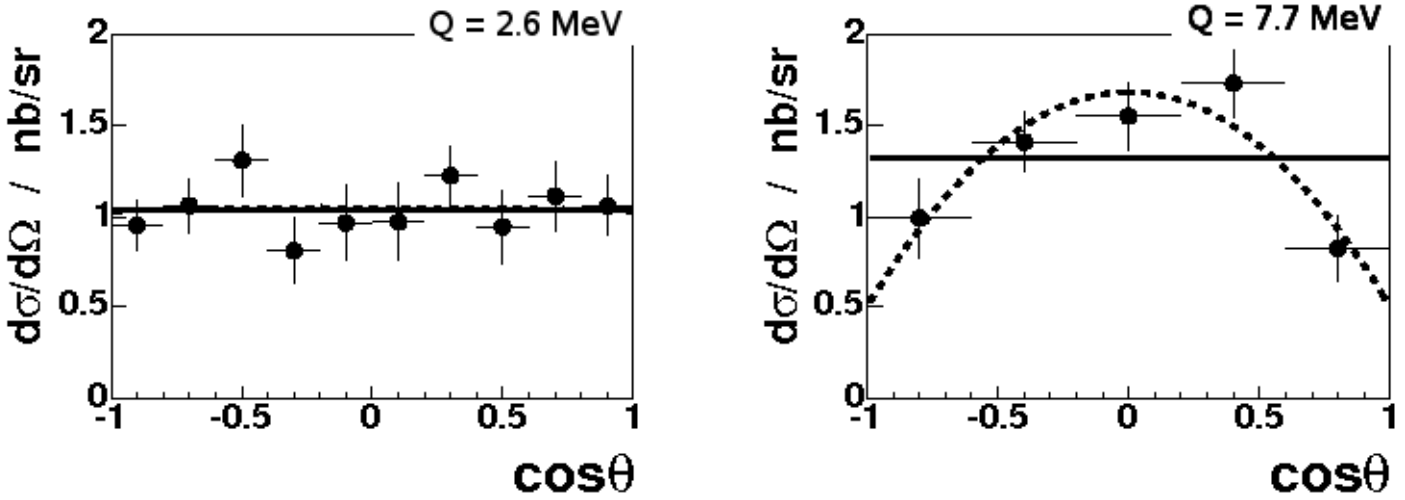


- energy dependence follow the one of the transmutual reaction



$\vec{d} + d \rightarrow {}^4He + \eta$

- total cross sections (SATURNE)
- recently the first angular distributions (ANKE)
  A. Wrońska et al., Eur. Phys. J. A 26, 421 (2005)



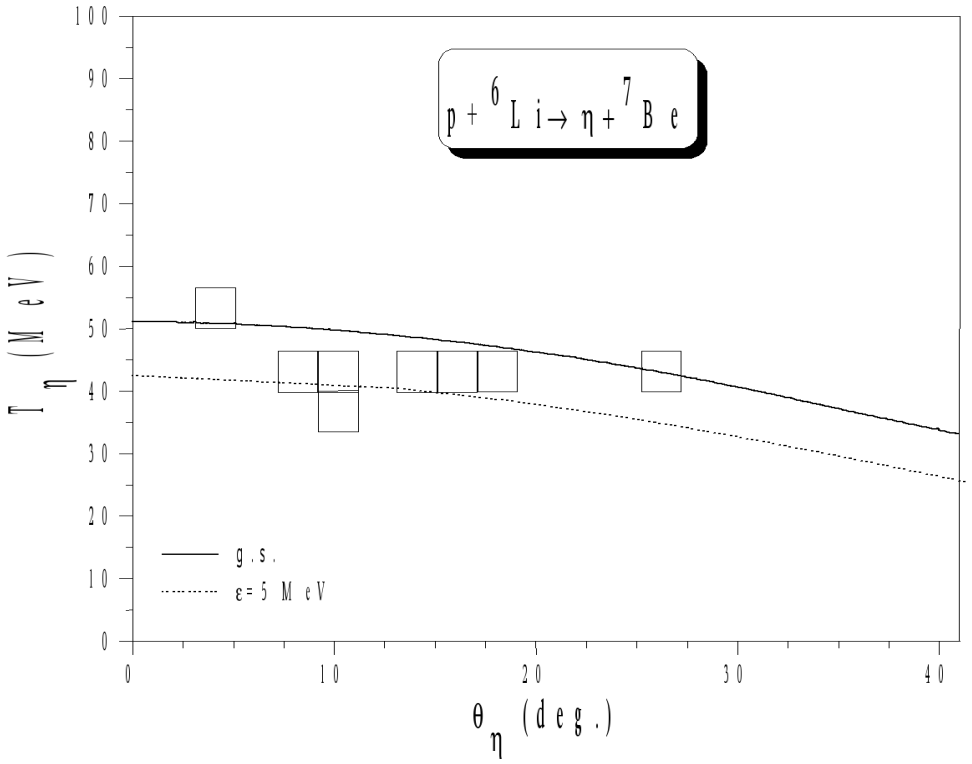
- polarization observables measured by GEM
  - possibility to extract the real and imaginary parts of the partial wave amplitudes
- see talk by M.Lesiak on parallel session !

Search for η-Bound State

- existence of η–mesic nuclei ?
- predicted binding energies and widths have large uncertainties
- practically no data exists on η–nucleus final state
- studying N*(1535) resonance in nuclear matter

$p + {}^{7}Li \rightarrow {}^{7}Be + \eta$

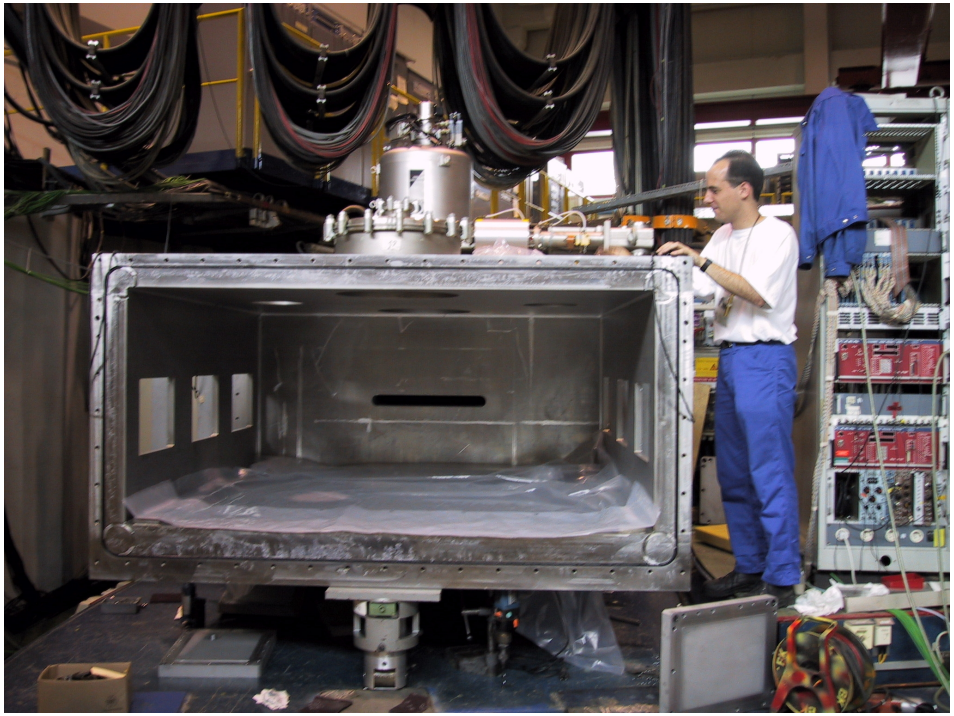
Scomparin et al. J Phys G19 (1993) L51

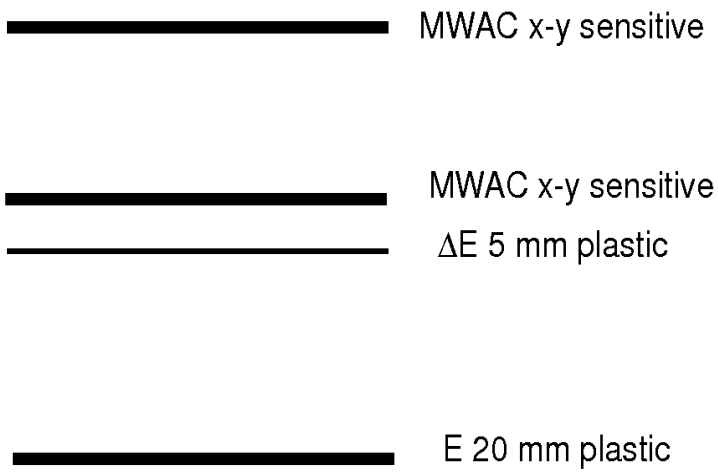


$$\frac{d\sigma}{d\Omega} = (4.6 \pm 3.8)\frac{nb}{sr}$$

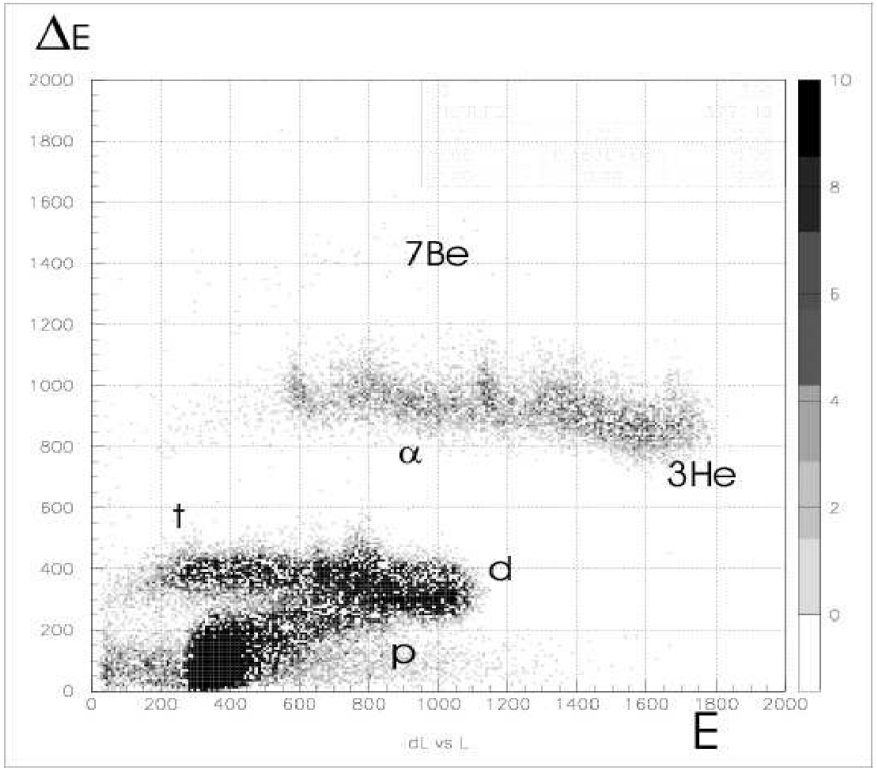
Idea

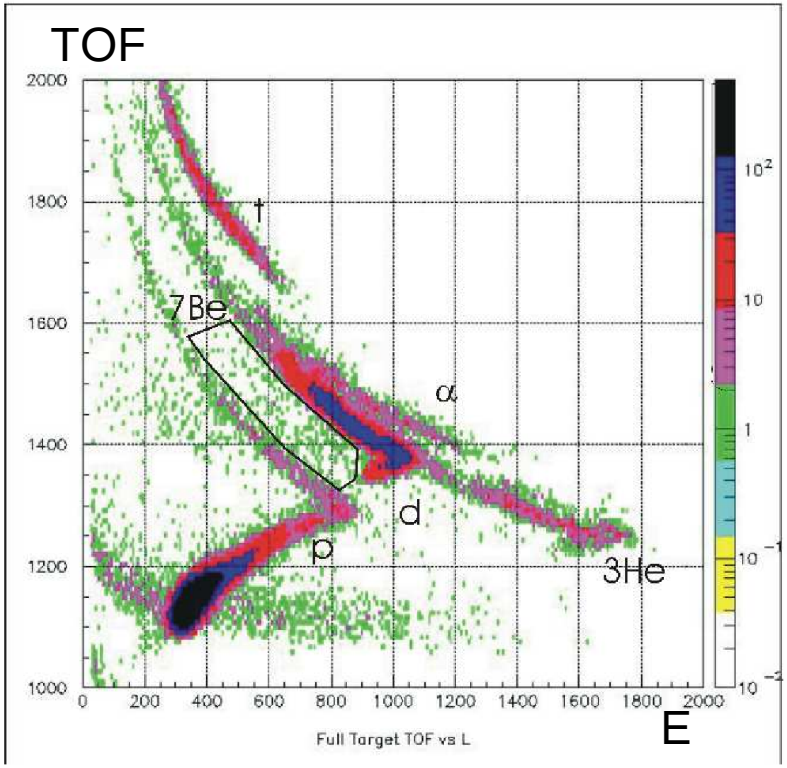
- ^{7}Be detected at Big Karl
  - high momentum resolution
  - low background
  - strong ionising particle detectors in vacuum





Test Run





- measurement scheduled in fall 2006

$p + {}^{27}Al \longrightarrow {}^{3}He + {}^{25}Mg_{\eta}$

measured with Big Karl

$p + {}^{27}Al \longrightarrow {}^{3}He + {}^{25}Mg_{\eta}$

η – nucleus decay products:

$\eta + N \longrightarrow N^*(1535) \longrightarrow$

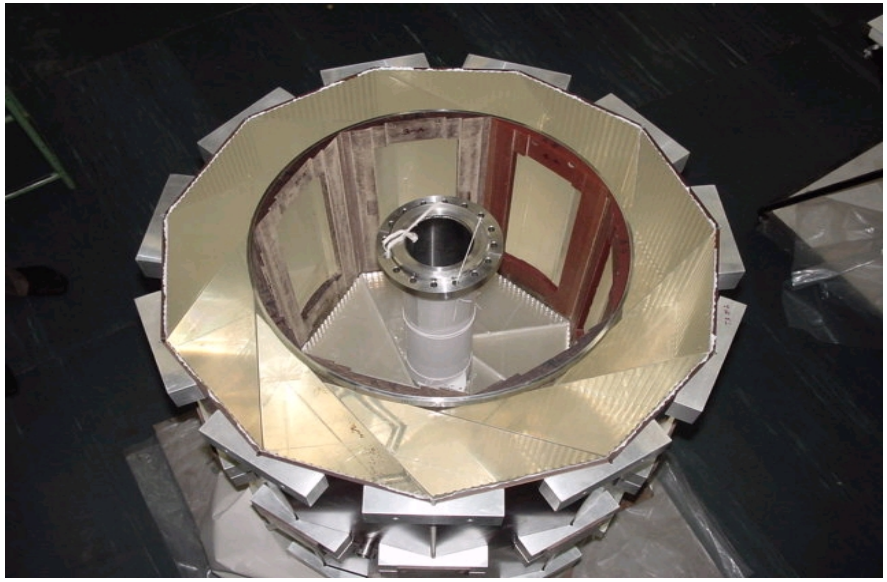
$\pi^- p$

$\pi^0 n$

$\pi^0 p$

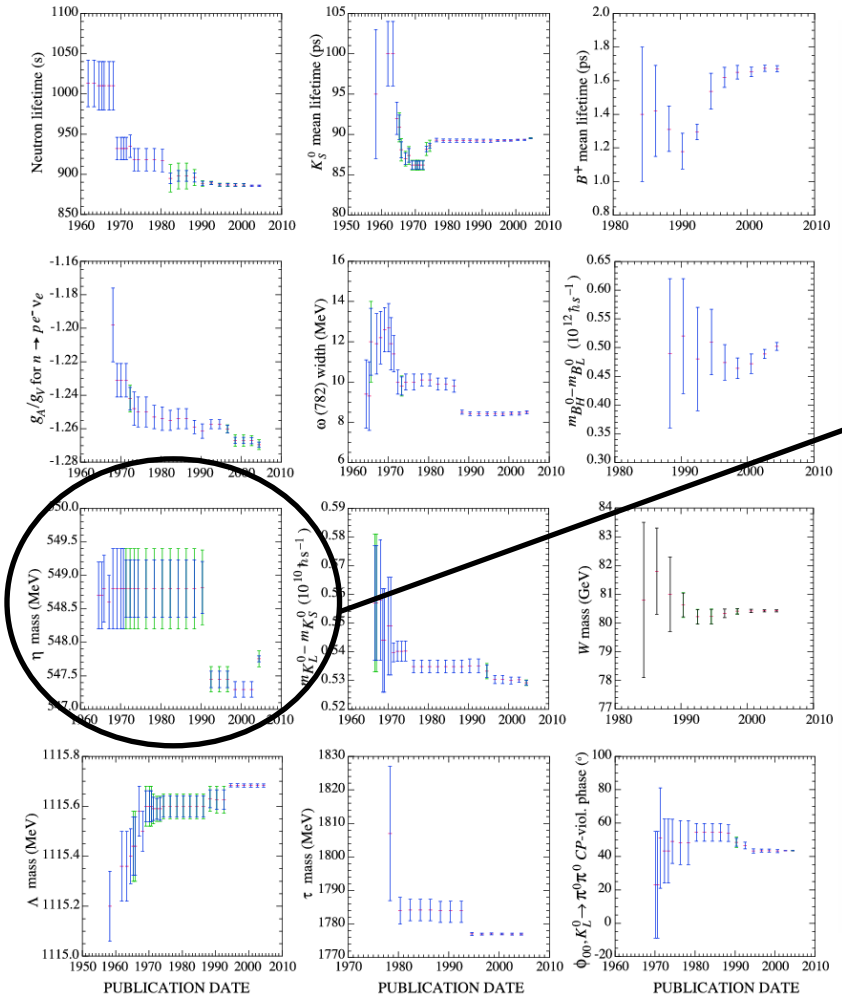
$\pi^+ n$

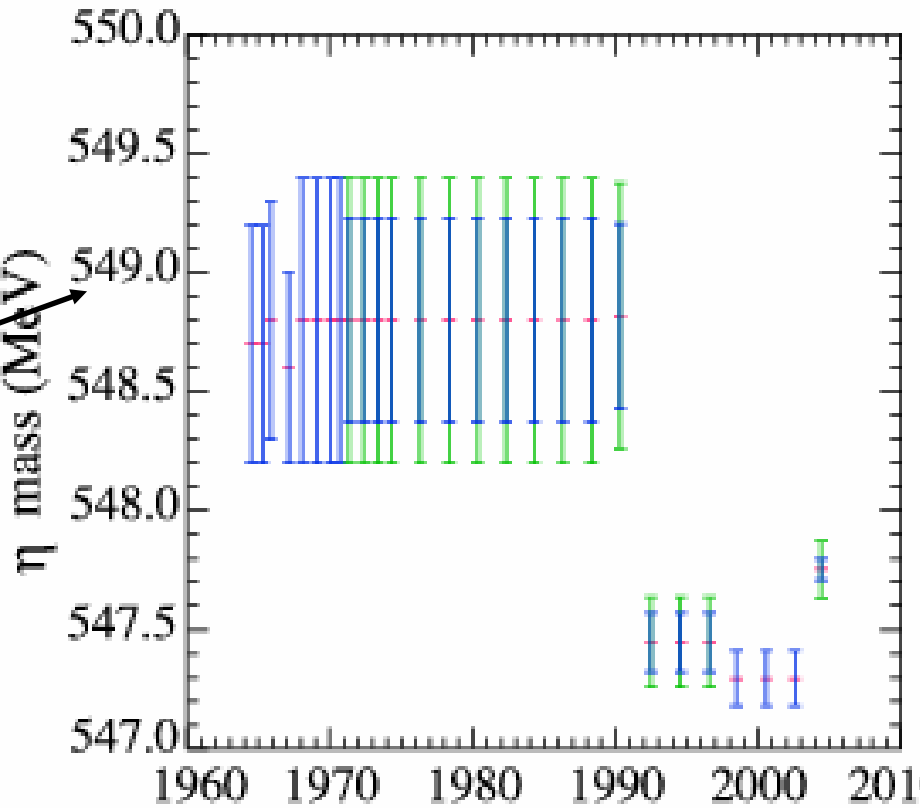
measured with ENSTAR



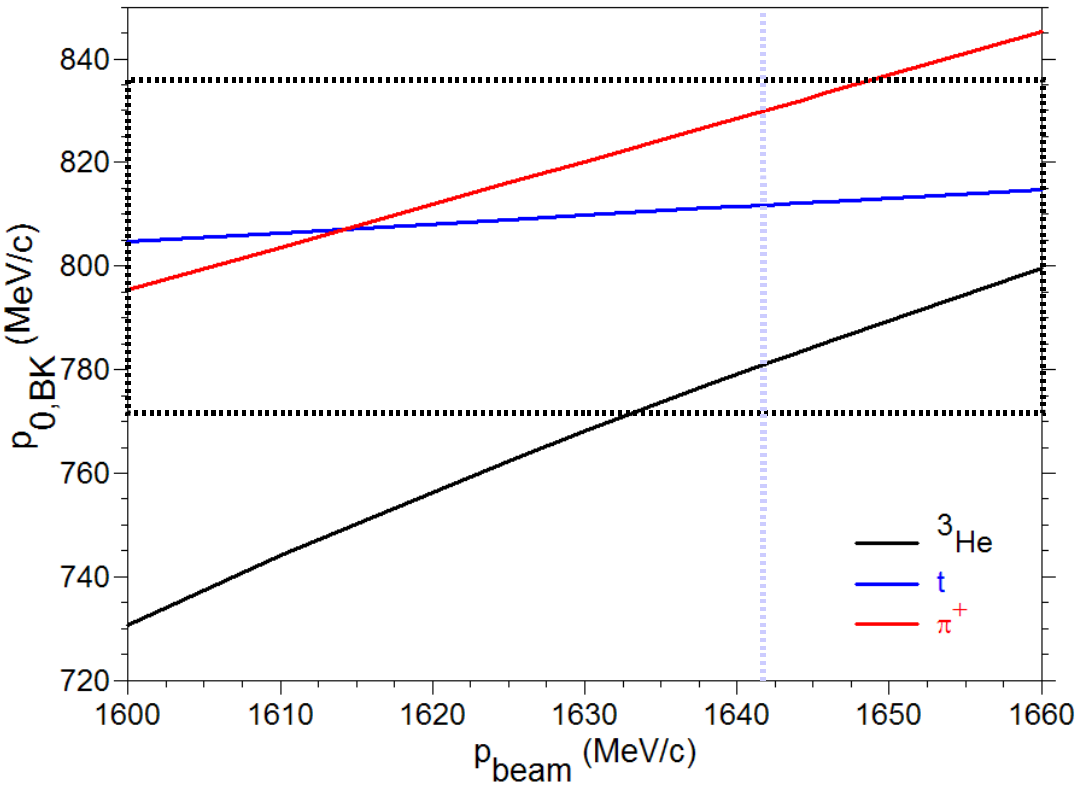
see talk by V.Jha on parallel session !

New determination of the η-mass (GEM): History





The method



three reactions simultaneously:

$^3H + \pi^+$

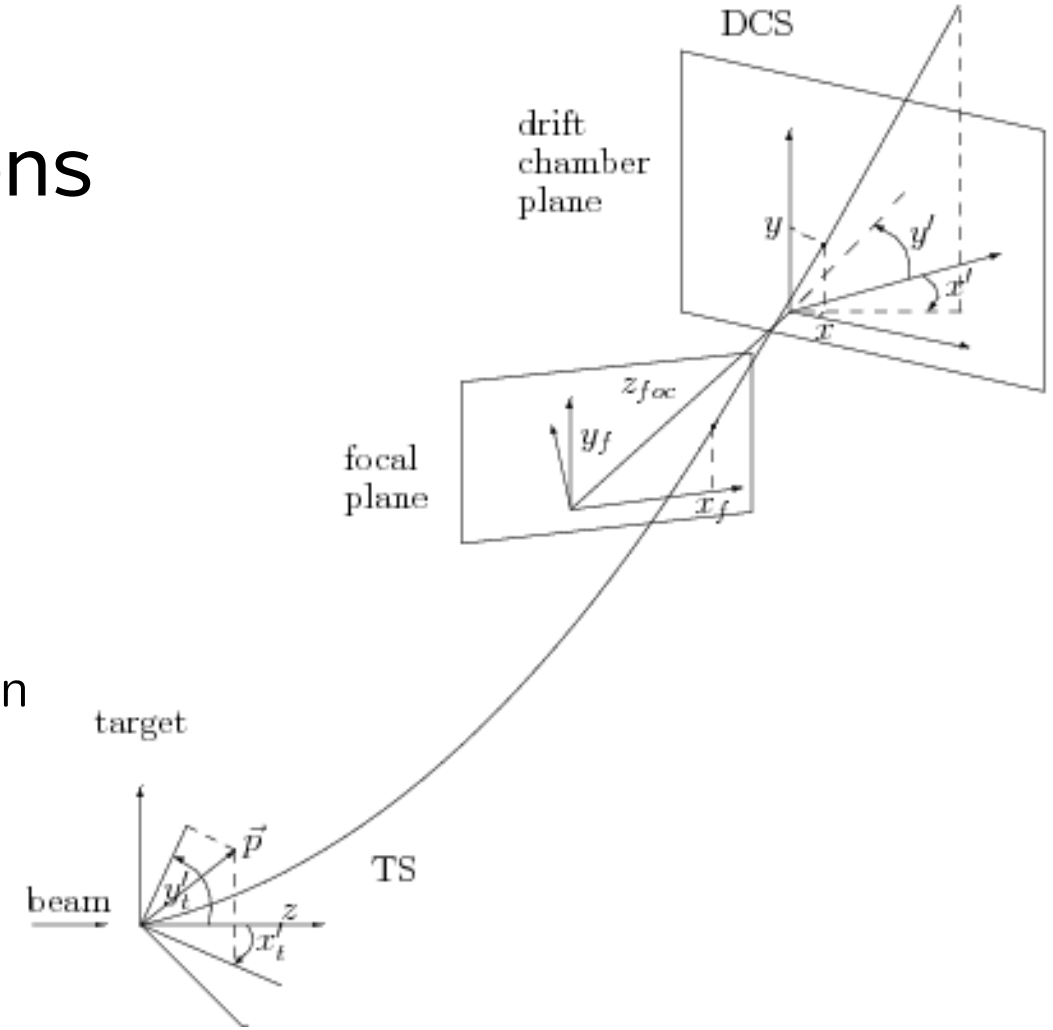
$p + d \rightarrow \pi^+ + {}^3H$

$^3He + \eta$

first two reactions calibrate magnetic spectrograph and beam momentum (self calibrating)

Transformations

x: horizontal position deviation
x': horizontal angle deviation
y: vertical position deviation
y': vertical angle deviation
l: longitudinal position deviation
δ: relative momentum



$$\begin{pmatrix} x_f \\ x'_f \\ y_f \\ y'_f \\ l_f \\ \delta \end{pmatrix} = \begin{pmatrix} R_{11} & R_{12} & 0 & 0 & 0 & R_{16} \\ R_{21} & R_{22} & 0 & 0 & 0 & R_{26} \\ R_{31} & 0 & R_{33} & R_{34} & 0 & 0 \\ 0 & 0 & R_{43} & R_{44} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_t \\ x'_t \\ y_t \\ y'_t \\ l_t \\ \delta \end{pmatrix},$$

Connection to observables

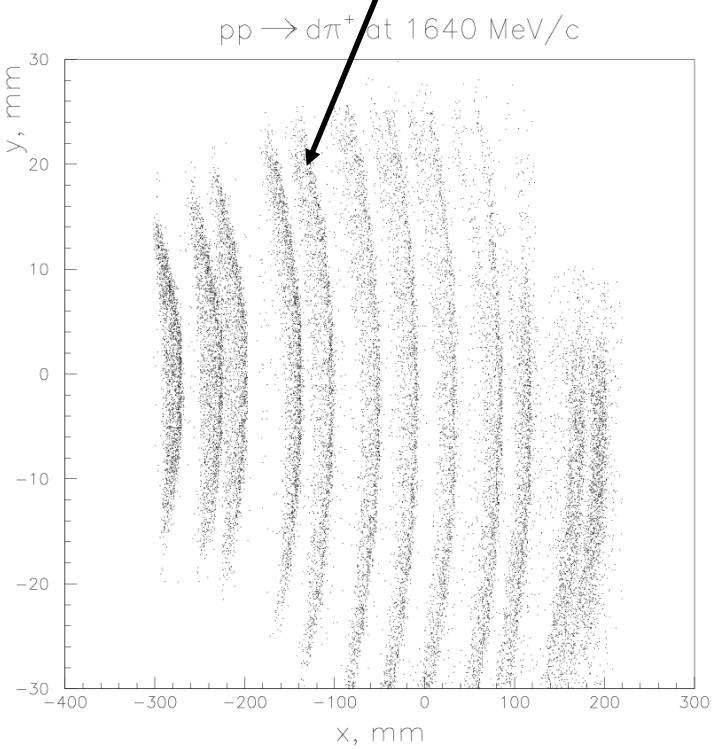
relative momentum difference:

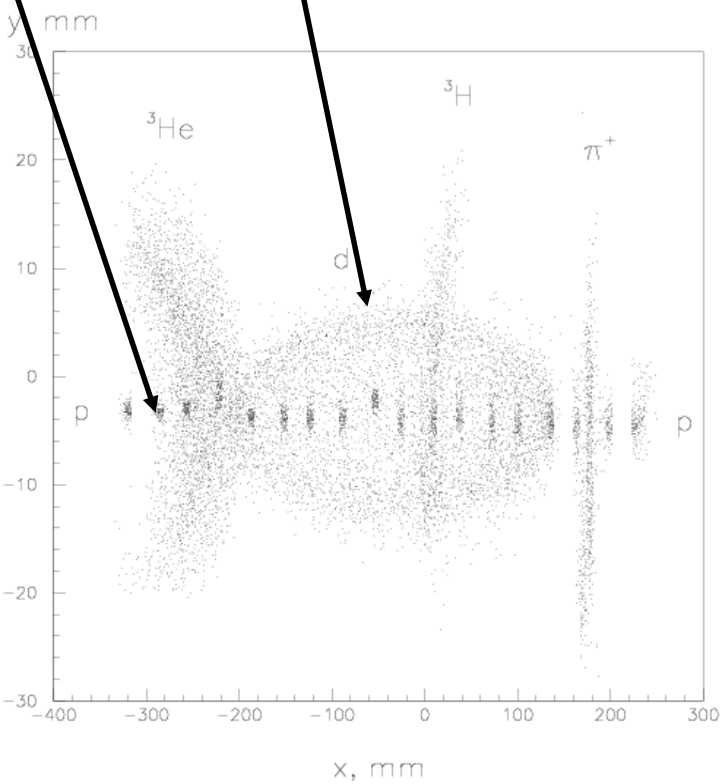
$$\delta = \frac{p - p_{BK}}{p_{BK}}$$

$$\begin{aligned} p &= Z p_{BK}(1+\delta) \\ p_z &= p/\sqrt{1 + x_t'^2 + y_t'^2} \\ p_x &= p_z x_t' \\ p_y &= p_z y_t' \end{aligned}$$

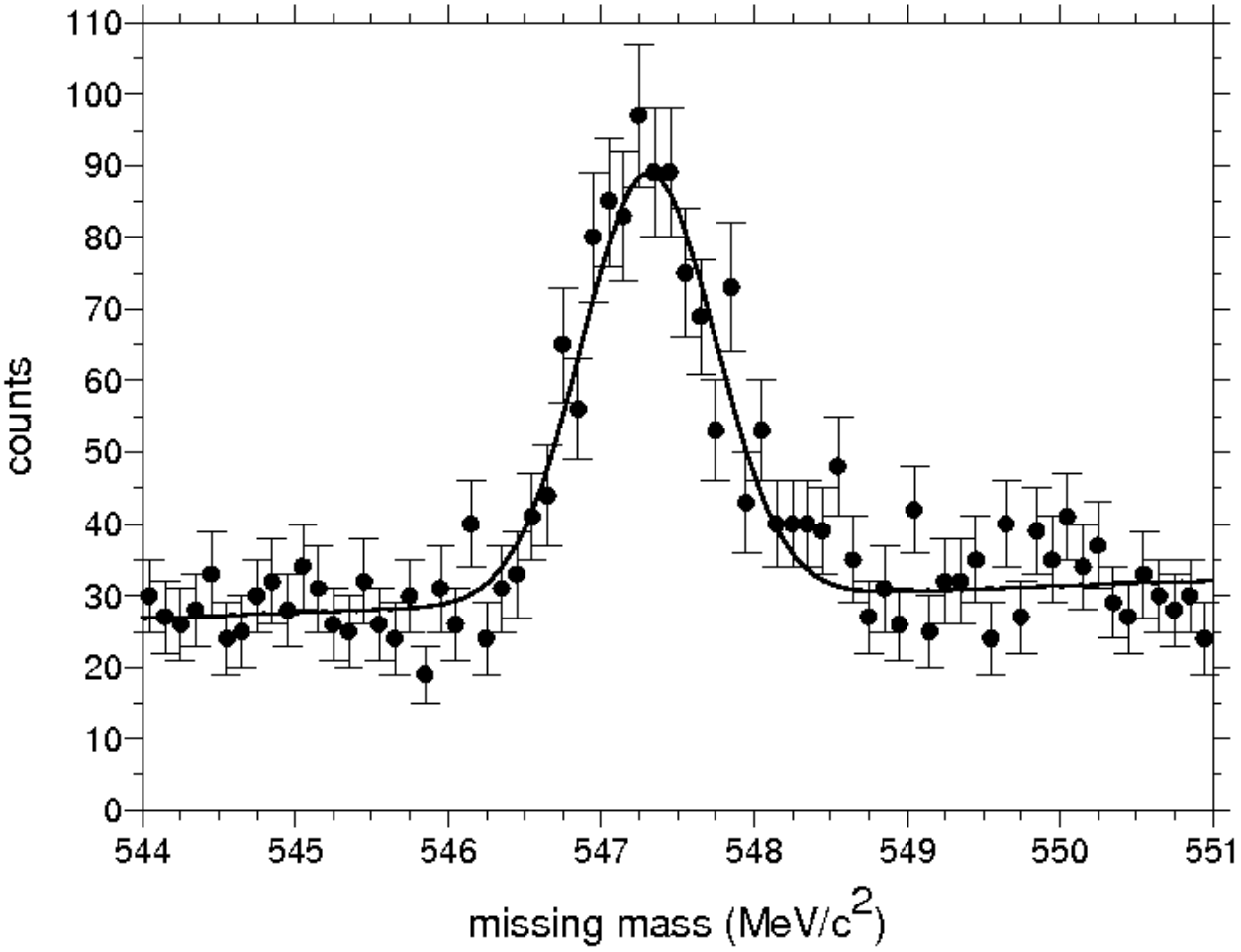
Calibrations

- sweeping the beam over the focal plane
- measure full ellipse (deuterons) from $pp \rightarrow d\pi^+$ at 793 MeV/c
- measure pions at various BK settings from $pp \rightarrow \pi^+ d$ at 1640 MeV/c





Missing Mass



P_{beam} from π^+

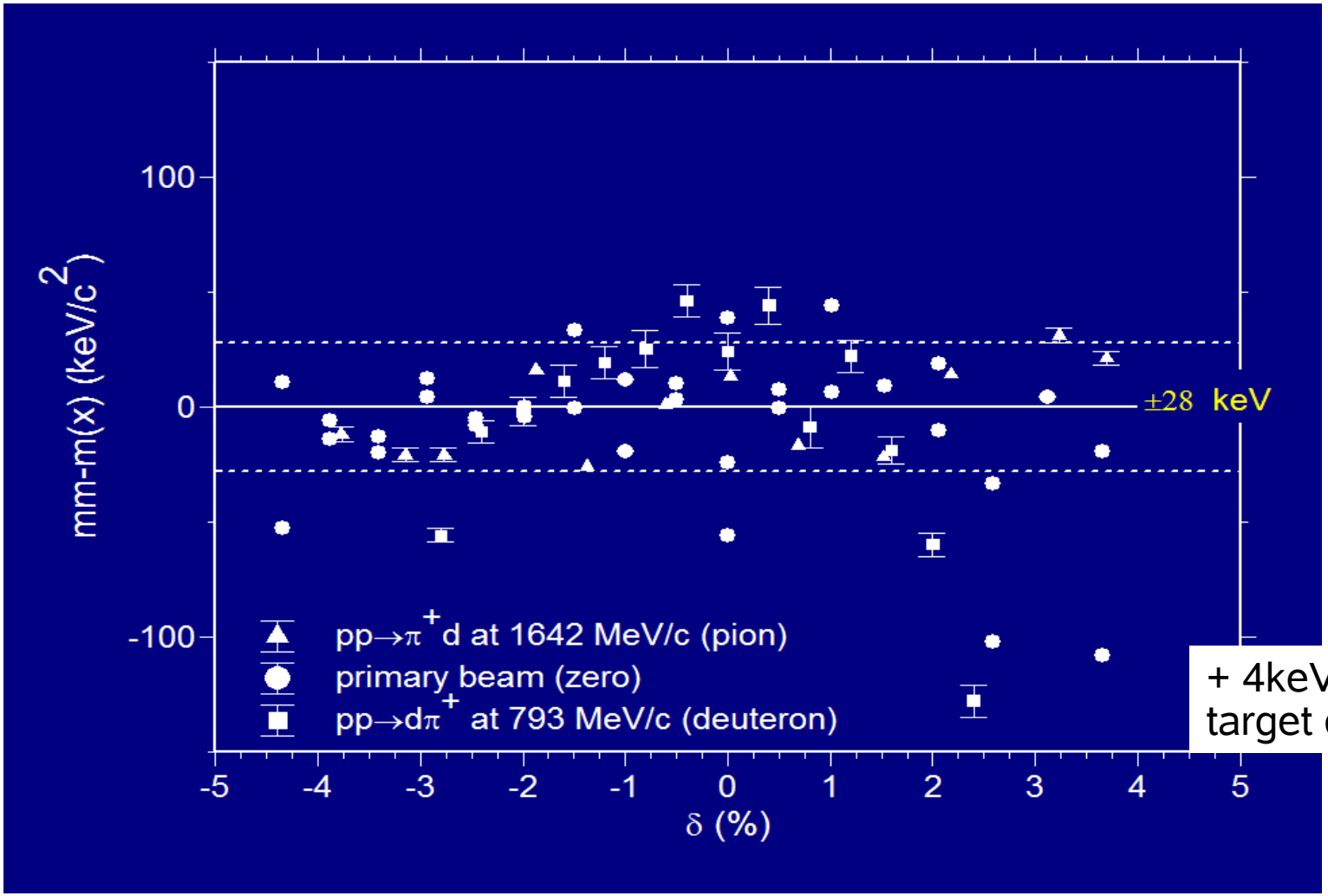
d_{target} from t

m_η from ^{3}He

centroid:

547.311 ± 0.028 MeV/c^2

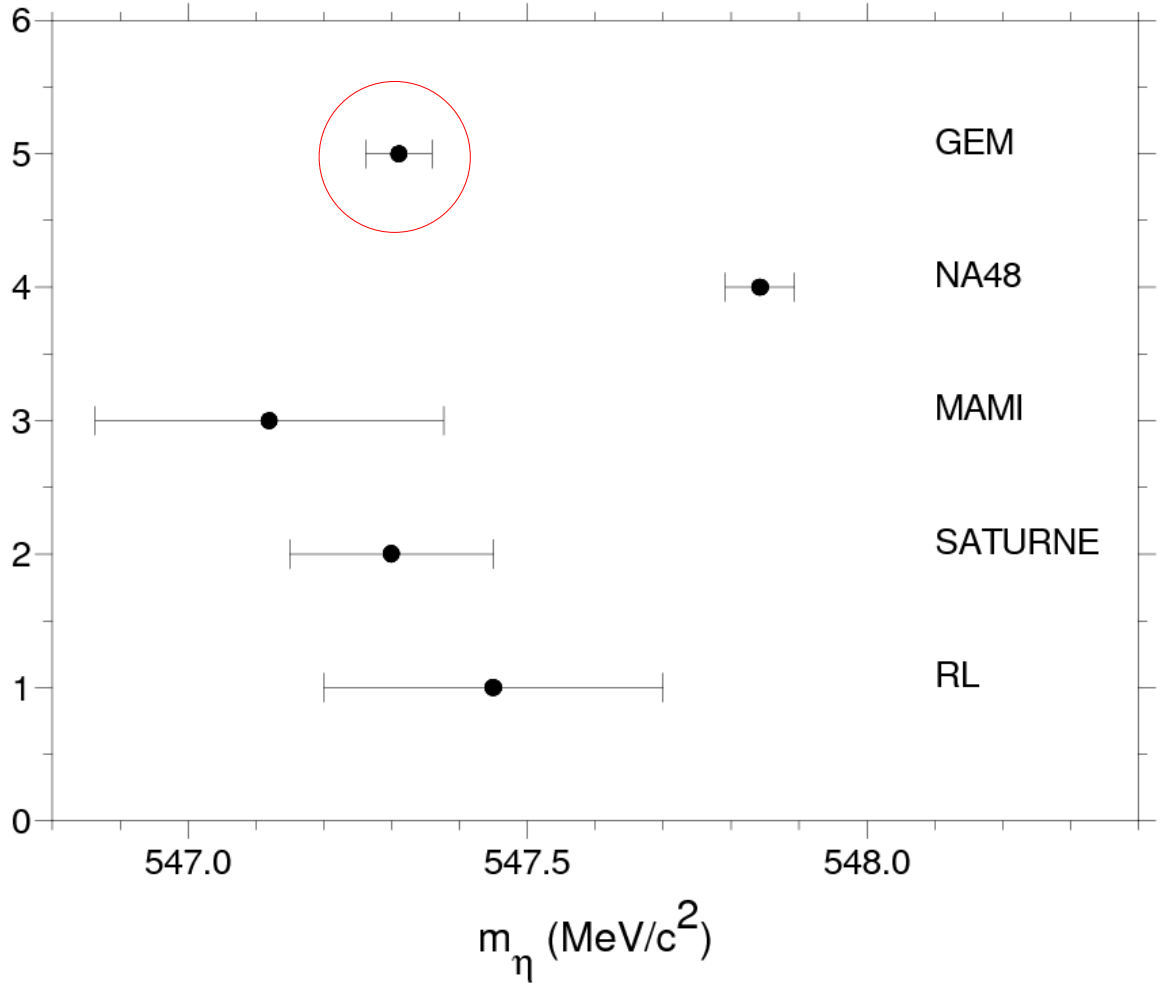
Systematic Error



+ 4keV from target density

Result:

m_η = [547.311 ± 0.028 (stat.)±0.032(syst.)] MeV/c^2



Summary

- GEM has measured a series of differential as well as total cross sections for η production with proton and deuteron projectiles and light nuclei as targets
- First polarization observables in $\vec{d} + \vec{d} \rightarrow \alpha + \eta$ allow to fix values (including signs) of the scattering length components
- A dedicated search for a possible bound η-nuclear state has started
- A new value for the η mass has been derived with extremely small error bars