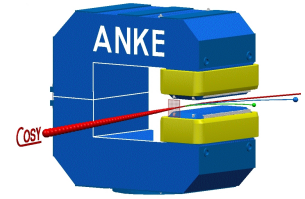
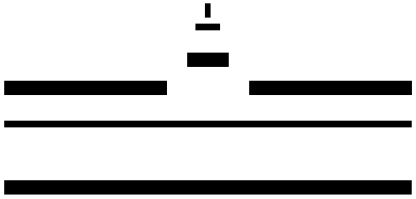


Investigation of the quasi-free reaction $\mathrm{p} + \mathrm{d} \to \mathrm{d} + \eta + \mathrm{p}_{\mathrm{sp}}$ close to threshold at ANKE

Daniel Schröer

Westfälische Wilhelms-Universität Münster
for the ANKE collaboration



Westfälische
Wilhelms-Universität
Münster

March 21, 2014
DPG Spring Meeting

Motivation

(Quasi-)bound η-mesic nuclei

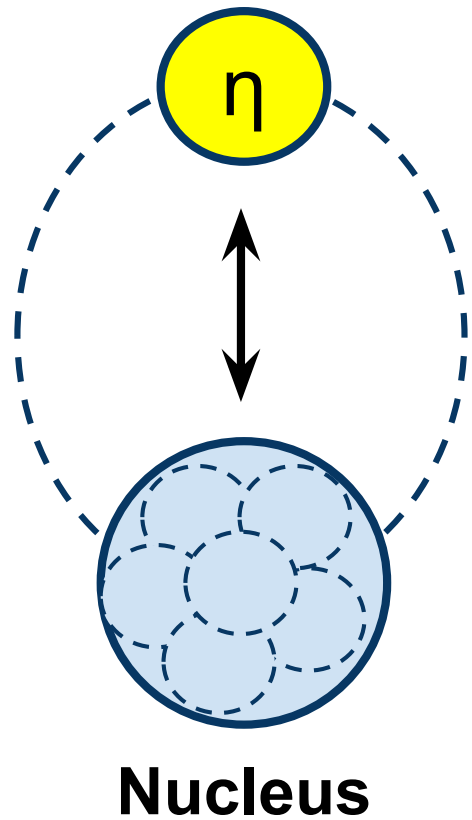
- Attractice S-wave ηN interaction

  R.S. Bhalerao and L.C. Liu, Phys. Rev. Lett. 54 (1985) 685

- Possible formation of η-nucleus bound states

  Q. Haider and L.C. Liu, Phys. Lett. B172 (1986) 257

  C. Wilkin, Phys. Rev. C47 (1993) 938



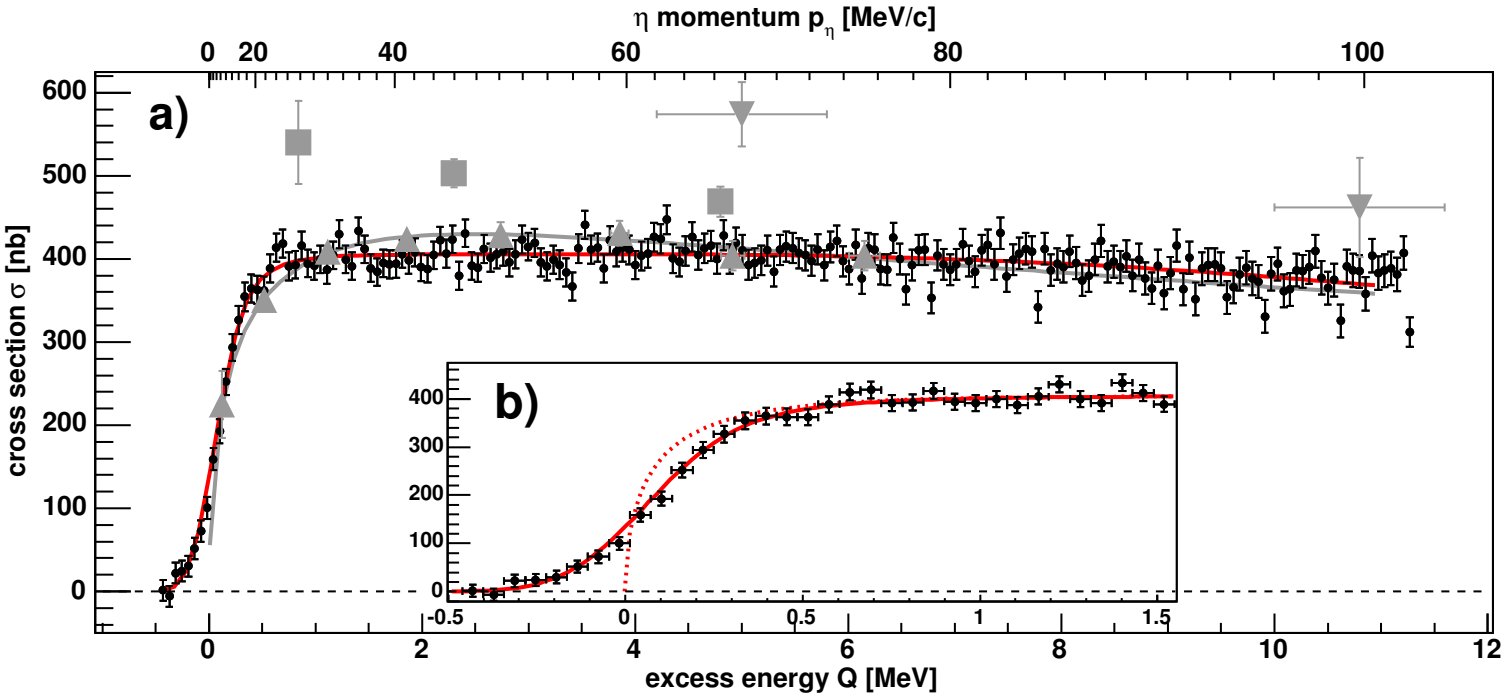
η-mesic nuclei program at COSY

- $A > 4$: GEM(η^6Li and η^{25}Mg)
- η^4He: ANKE, GEM, WASA@COSY
- η^3He: ANKE, COSY-11, GEM, WASA@COSY
- ηd: ANKE

Motivation

Good candidate: $^3\mathrm{He}\eta$ system

- Precisely measured at ANKE
- Strong FSI observed
- Evidence for pole at $|Q_0| \approx 0.37\,\mathrm{MeV}$



Motivation

Two ways to search for signals from η-mesic nuclei

- No clear signal from such a state below the ηA threshold
- Pole near threshold should influence the ηA production above threshold → described by a FSI-ansatz

S-wave FSI-ansatz:

$$\frac{p_i}{p_f} \cdot \frac{d\sigma}{d\Omega} = |f|^2 = |f_s \cdot FSI|^2 \quad \text{with}$$

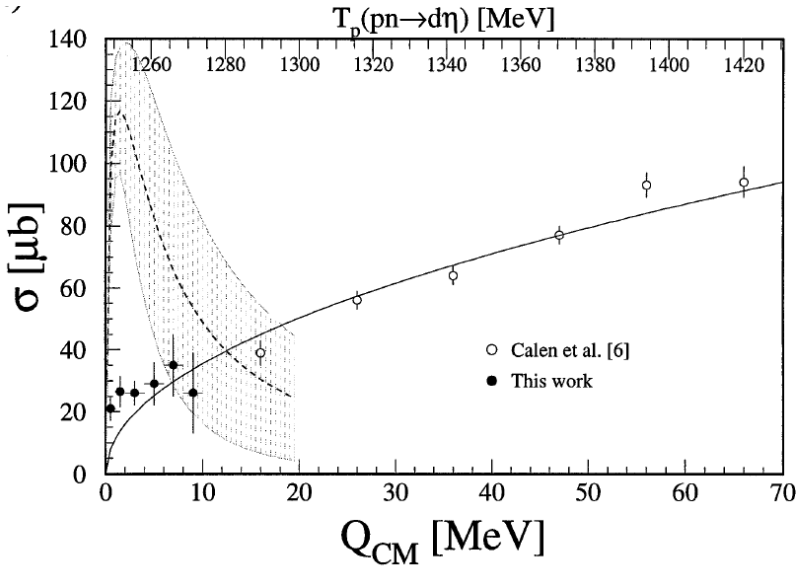
$$\text{FSI} = \frac{1}{1 - i \cdot a \cdot p_f + \frac{1}{2} r_0 a p_f^2} = \frac{1}{(1 - p_f/p_1)(1 - p_f/p2)}$$

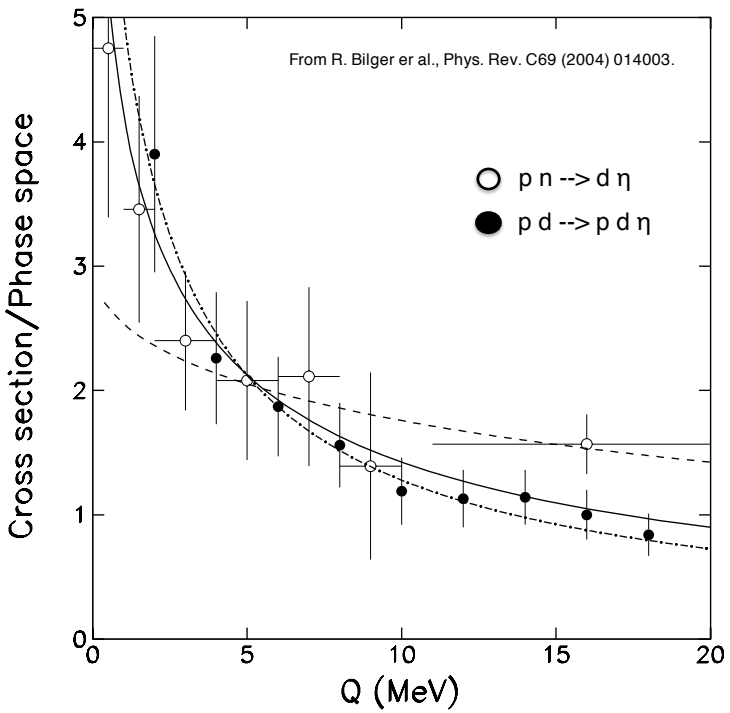
- Quasi-bound or virtual state?

→ Study of A-dependency of the FSI important, especially the light nuclei

→ $\mathrm{pn} \to \mathrm{d}\eta$; $\mathrm{pd} \to {}^3\mathrm{He}\eta$; $\mathrm{dd} \to {}^4\mathrm{He}\eta$;...

Available Data on pn→ dη





Current database on pn→ dη

- PINOT: η production much stronger in pn than in pp collisions
- Two measurements by PROMICE-WASA at CELSIUS pn→ dη via pd→ dηp$_{sp}$

  H.Calén et al., Phys.Rev.Lett. 79 (1997) 2642

  H.Calén et al., Phys.Rev.Lett. 80 (1998) 2069
- Near threshold data show clear FSI enhancement, steep rise up to 30μb
- WASA: η and deuteron measured

The η nucleon scattering length

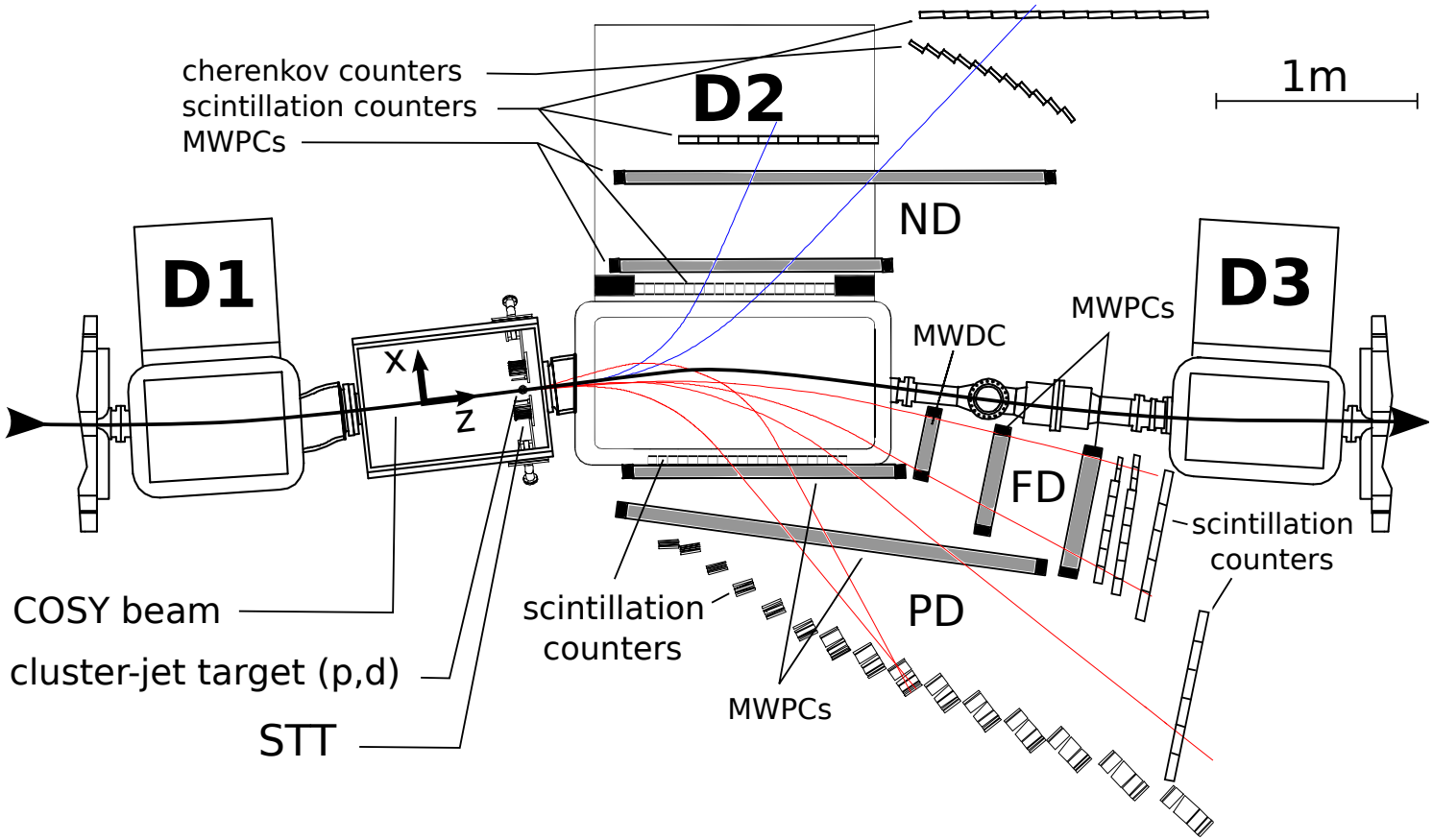
- Lots of possible η nucleon scattering lengths
- Huge range of dη scattering lengths still possible
- ANKE measurement will dwarf allowed region
  $\rightarrow$ More knowledge about elementary interaction between η and nucleon

ηN input $a_{\eta N}$ (fm)	Exact $A_{\eta d}$ (fm) AGS
$0.25+i0.16$	$0.73+i0.56$
$0.27+i0.22$	$0.71+i0.84$
$0.291+i0.360$	$0.38+i1.36$
$0.30+i0.30$	$0.61+i1.22$
$0.430+i0.394$	$0.50+i2.07$
$0.44+i0.30$	$1.15+i1.89$
$0.46+i0.29$	$1.31+i1.99$
$0.476+i0.279$	$1.49+i2.06$
$0.51+i0.21$	$2.37+i1.77$
$0.55+i0.30$	$1.64+i2.99$
$0.579+i0.399$	$0.34+i3.31$
$0.62+i0.30$	$1.80+i4.30$
$0.876+i0.274$	$-8.81+i4.30$
$0.888+i0.274$	$-8.63+i3.49$
$0.98+i0.37$	$-4.69+i1.59$

N.V. Shevchenko et al., Phys. Rev. C 58 (1998), R3055

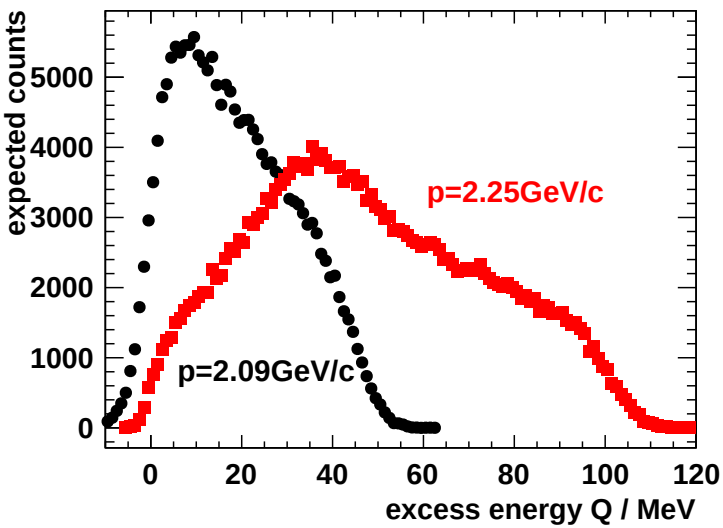
The reaction pn$\to$ dη at ANKE via pd$\to$ dηp$_{sp}$

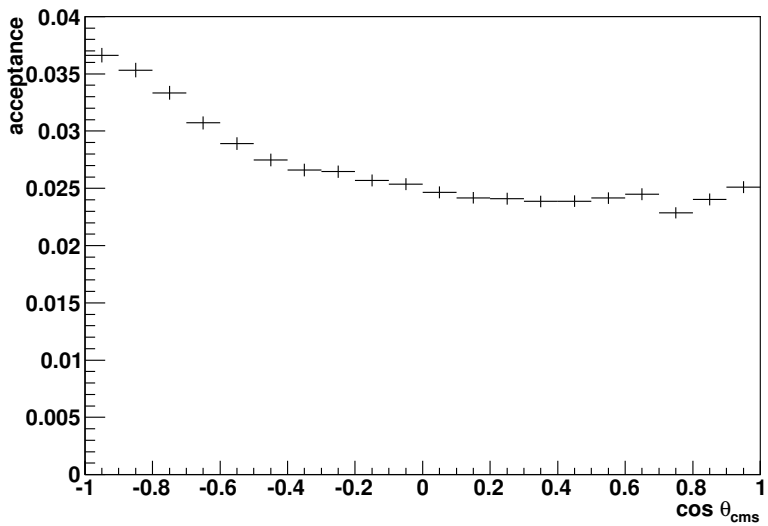
- pn$\to$ dη is studied by measuring pd$\to$ dηp$_{sp}$
- Identification by missing-mass method
- Determination of the excess energy on an event-by-event basis
- Measurement at two beam momenta ($p_1 = 2.09\,\mathrm{GeV/c}$ and $p_2 = 2.25\,\mathrm{GeV/c}$)



The reaction pn$\rightarrow$ dη at ANKE via pd$\rightarrow$ dηp_{sp}

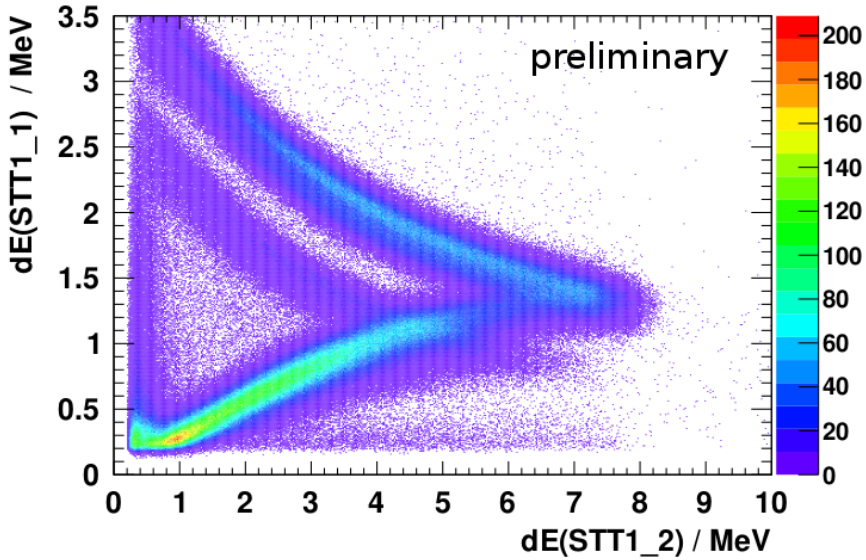
- Acceptance for an excess energy range from $Q = 0\,\mathrm{MeV}$ to $Q = 110\,\mathrm{MeV}$
- Acceptance for whole angular range
- Limit for S-wave FSI-ansatz

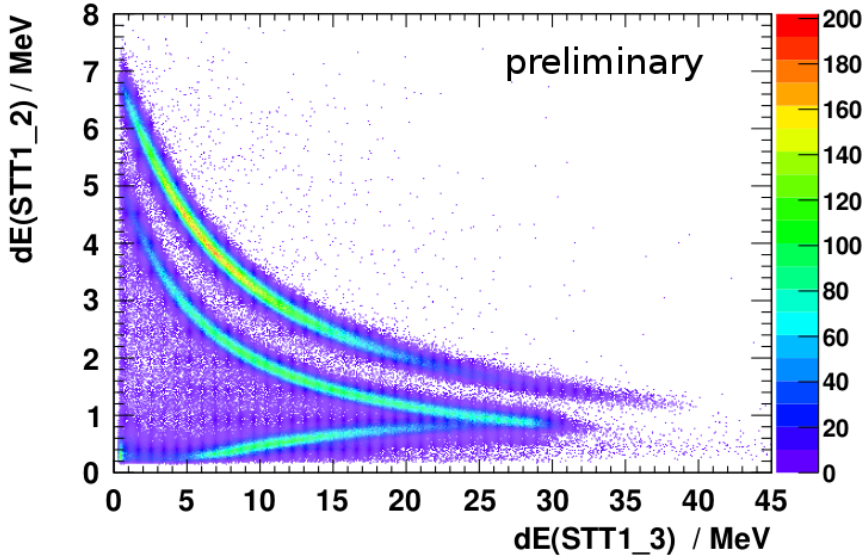




Identification of particles in the STTs

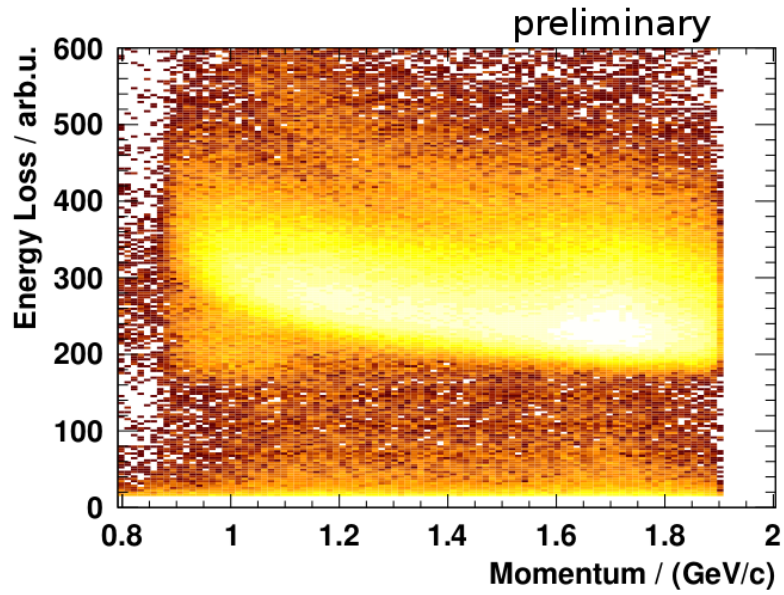
- Measurement with two Silicon Tracking Telescopes (STT)
- Placed 2.8 cm away from the target
- Cover polar angles from 75° to 140°
- $\Delta E \approx 160\,\mathrm{keV}(\sigma)$ and $\Delta\vartheta \approx 3.5°(\sigma)$

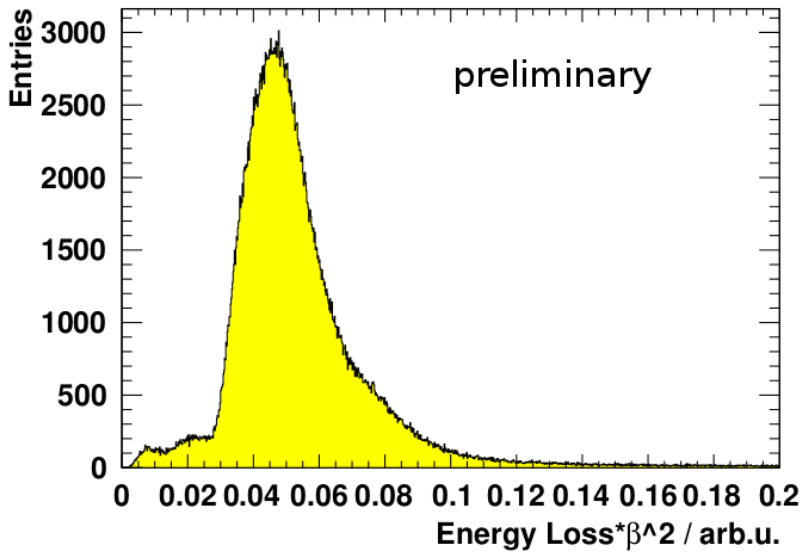




Identification of deuterons

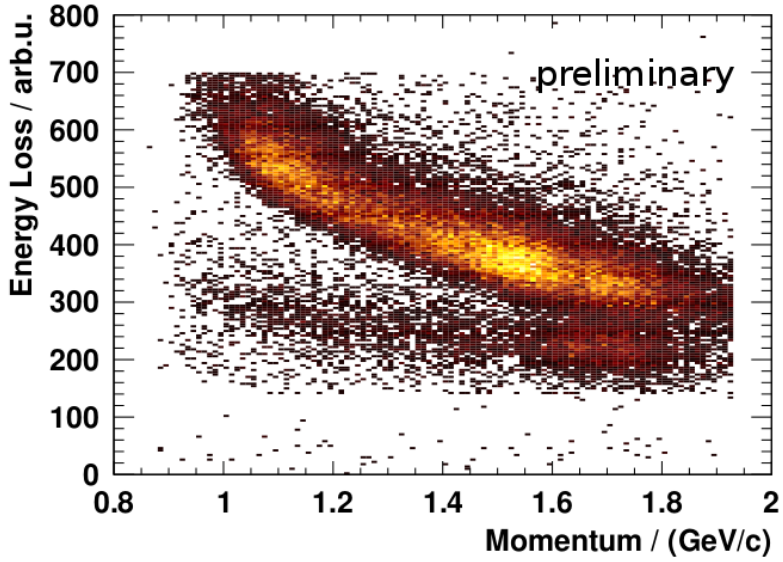
- Via energy loss in forward counter
- Challenging because of huge proton background
- Small deuteron band can be seen
- Good energy calibration needed

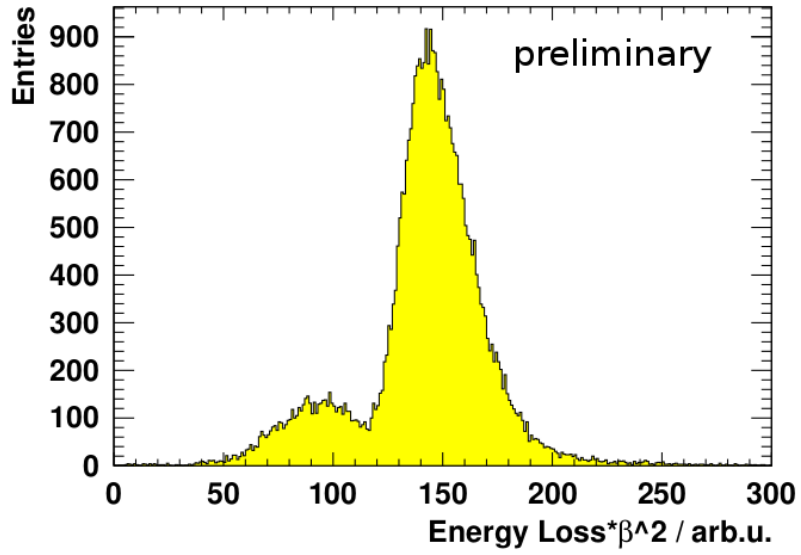




Extraction of cut parameters

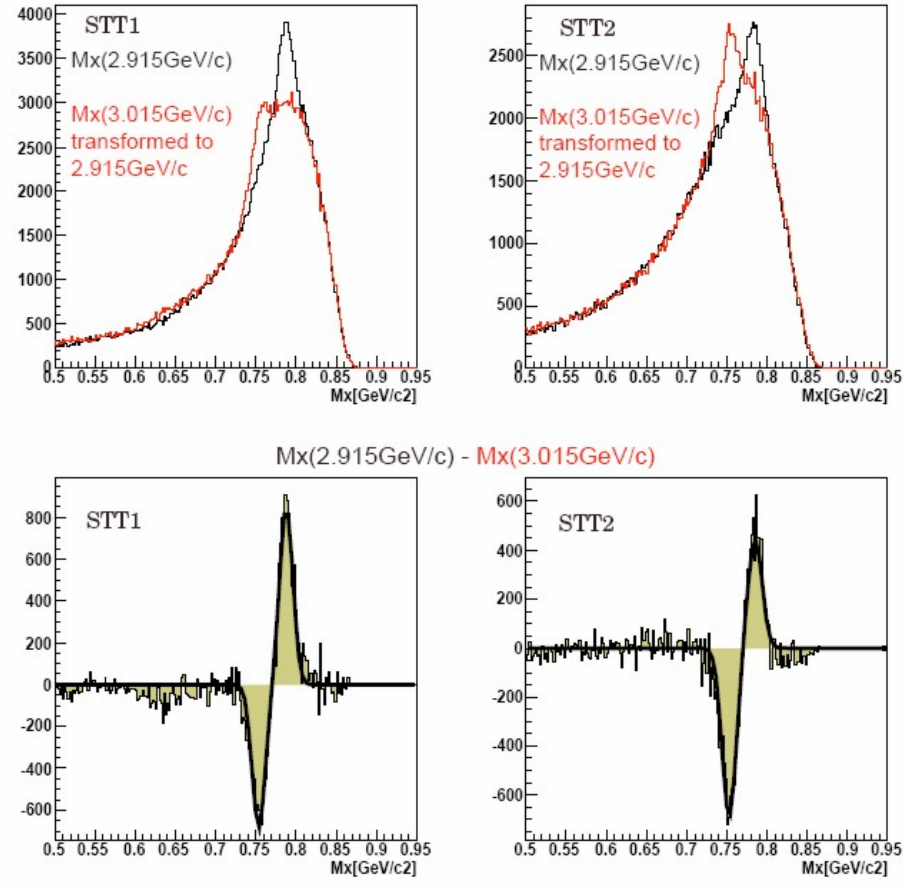
- Use of reaction $\mathrm{pd} \rightarrow \pi^{+}\mathrm{dX}$
- π^{+} in Positive Detector and particle in Forward Detector
- Identification of Pions via energy loss
- ToF allows separation of protons and deuterons
- Cut parameters are independent of reactions
- Huge reduction of proton background





Missing Mass for pn$\rightarrow$ dη

- $\mathrm{M_x} = |P_p^{beam} + P_d^{target} - P_{sp} - P_d^{final}|$
- Proton in one of the STTs
- Deuteron in Foward Detector
- Analyze data at higher beam momentum as if taken at lower ones
- Subtract resulting missing mass spectra
- Peak at η mass, negative peak at lower mass



S. Barsov et al., IKP Juelich Annual Report 2010

ANKE beam time

- 3 weeks of measurement at ANKE
- Approximately 100000 events between $Q = 0\,\mathrm{MeV}$ and $Q = 110\,\mathrm{MeV}$

Aims of beam time

- Calculate scattering length with a precision of 5%
- Measure differential cross section
- Influence of N^* will be investigated at higher excess energies

Summary

- Spectator protons can be identified and reconstructed
- Use of data with special trigger allows for extraction of cut parameters in Forward Detector $\rightarrow$ huge reduction of proton background
- More than 50000 (60000) events expected for lower (higher) energy $\rightarrow$ in agreement with preliminary results

$\rightarrow$ Total and differential cross sections in a excess energy range from $Q = 0\,\mathrm{MeV}$ to $Q = 110\,\mathrm{MeV}$

$\rightarrow$ Determination of limit for S-wave FSI-Ansatz

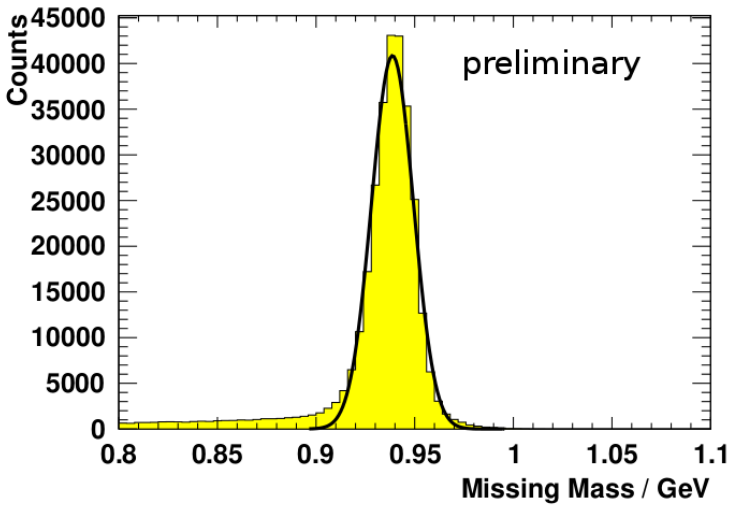
$\rightarrow$ Constrain allowed region of $\eta\mathrm{N}$ scattering length

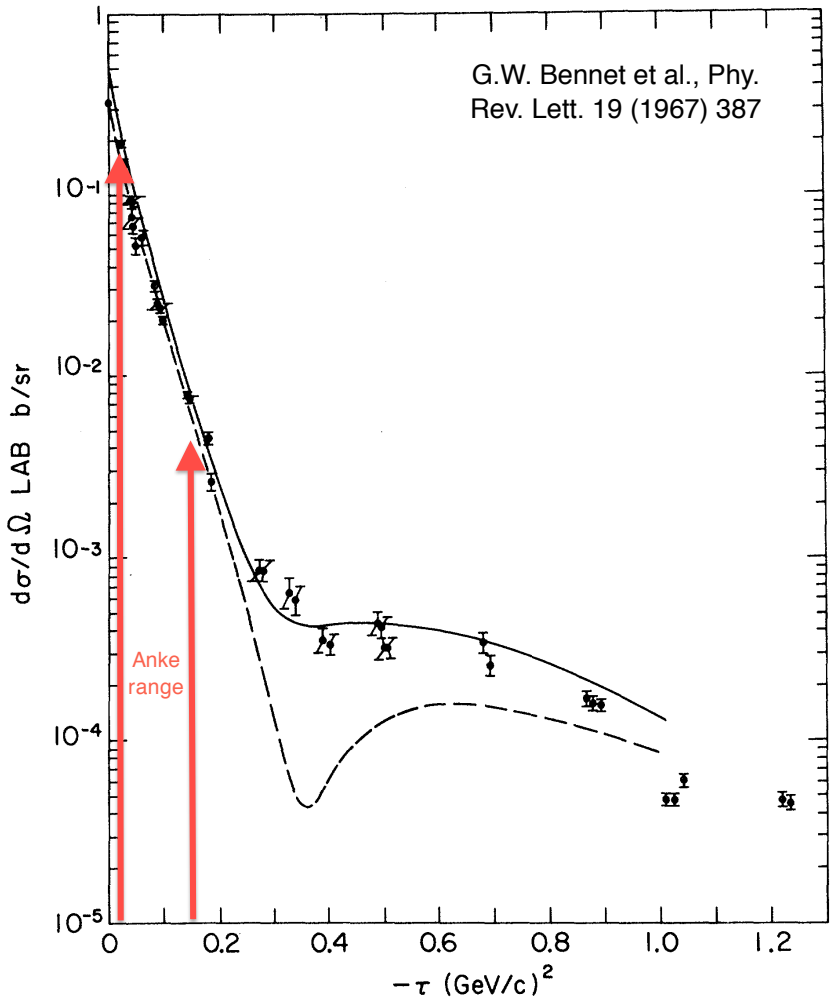
Thank you for your attention

Additional Slides

Elastic scattering

- Measured in parallel for an absolute normalization
- Deuteron measured in STT





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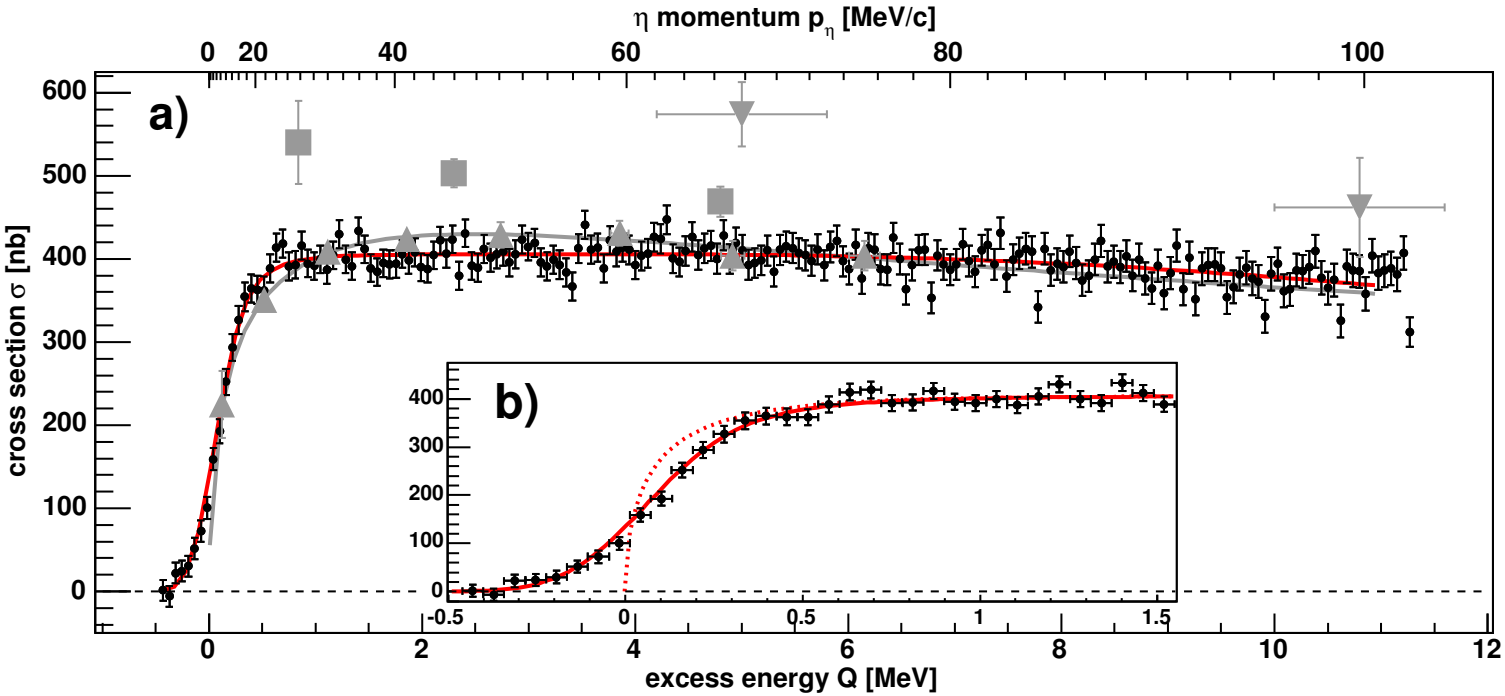
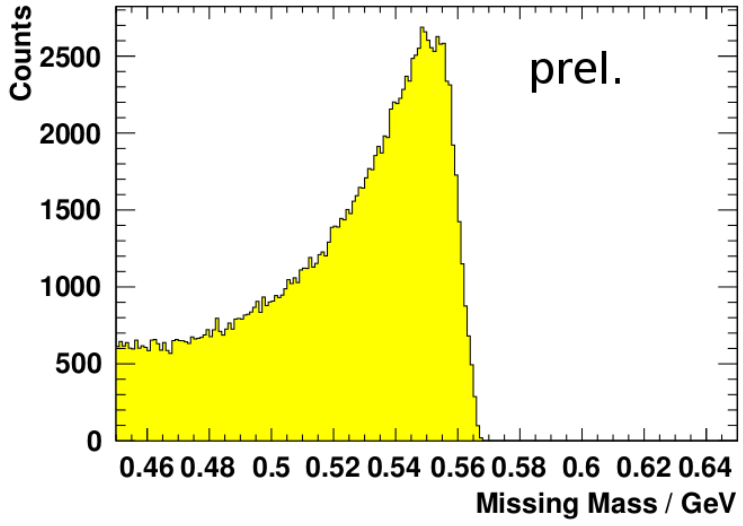
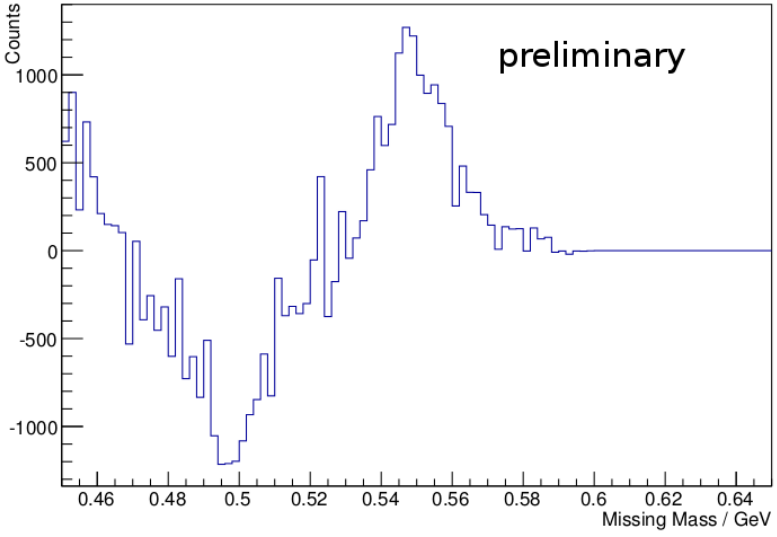


Uncorrected Missing Mass

- Huge Background
- Small enhancement at η mass can be suspected
- Background description challenging





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