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MÜNSTER

Meson production in pd fusion to ^{3}HeX with WASA-at-COSY

Nils Hüsken for the WASA-at-COSY Collaboration

Westfälische Wilhelms-Universität Münster, Institut für Kernphysik

25th International Nuclear Physics Conference, Adelaide Convention Centre, Australia

Hadron Structure & Spectroscopy (Session: R6)

September 2016

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GRK 2149

SEVENTH FRAMEWORK PROGRAMME

JÜLICH
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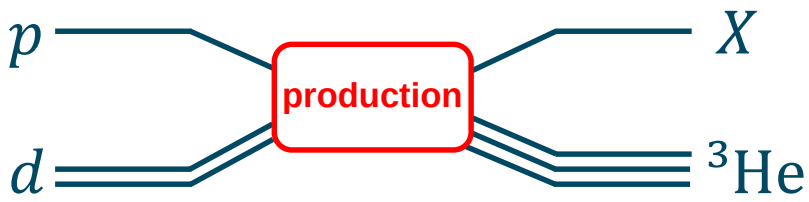
Meson production in pd fusion

Production of (pseudoscalar) mesons in pd collisions:

- many open questions:
  - production mechanism
  - role of nucleon resonances
  - in-medium modifications
  - final state interactions
  - multi-body interactions

- possible final states X:
  - single meson: $^3\mathrm{He}\pi^0$, $^3\mathrm{He}\eta$, ($^3\mathrm{He}\omega$, $^3\mathrm{He}\eta'$)
  - two mesons: $^3\mathrm{He}\pi^0\pi^0$, $^3\mathrm{He}\pi^+\pi^-$
  - three mesons: $^3\mathrm{He}\pi^0\pi^0\pi^0$, $^3\mathrm{He}\pi^+\pi^-\pi^0$

$$pd \rightarrow {}^3\mathrm{He}X$$



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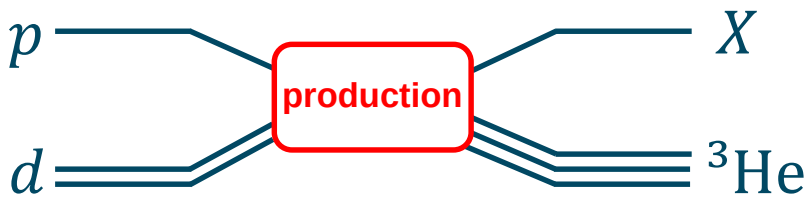

WASA-at-COSY

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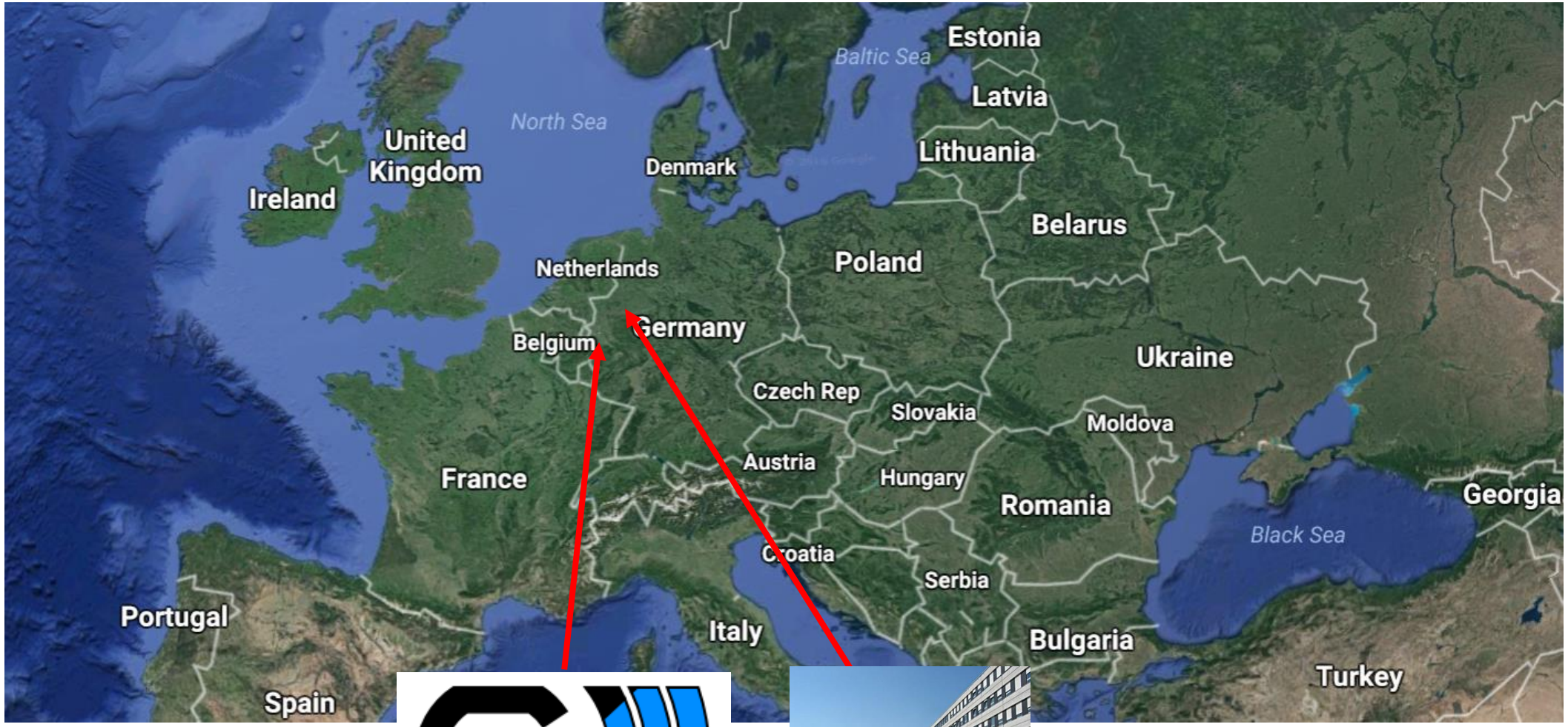

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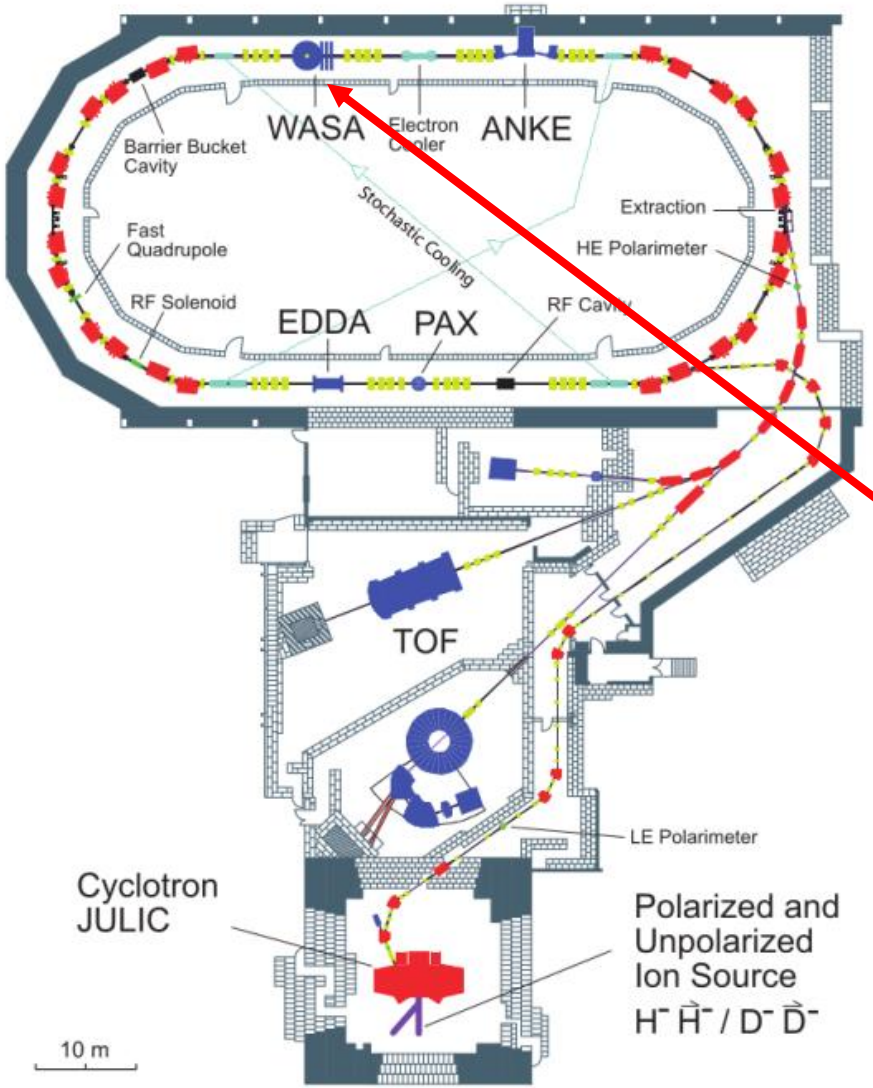
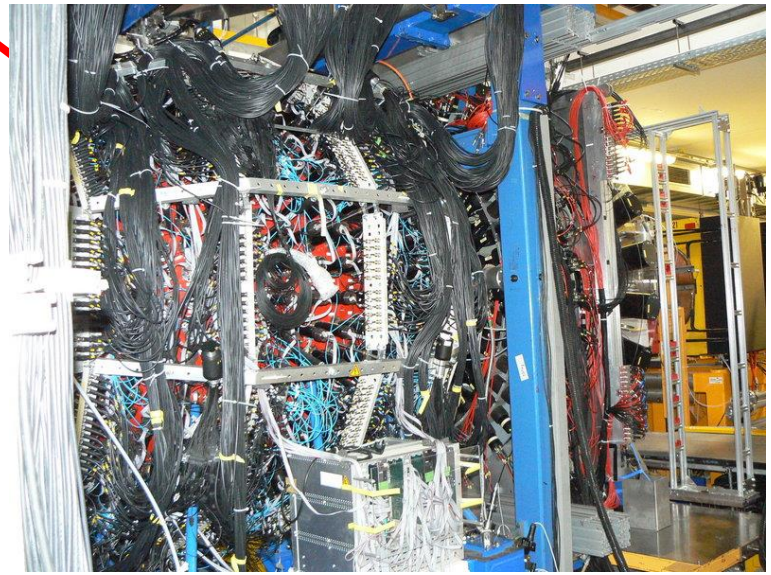
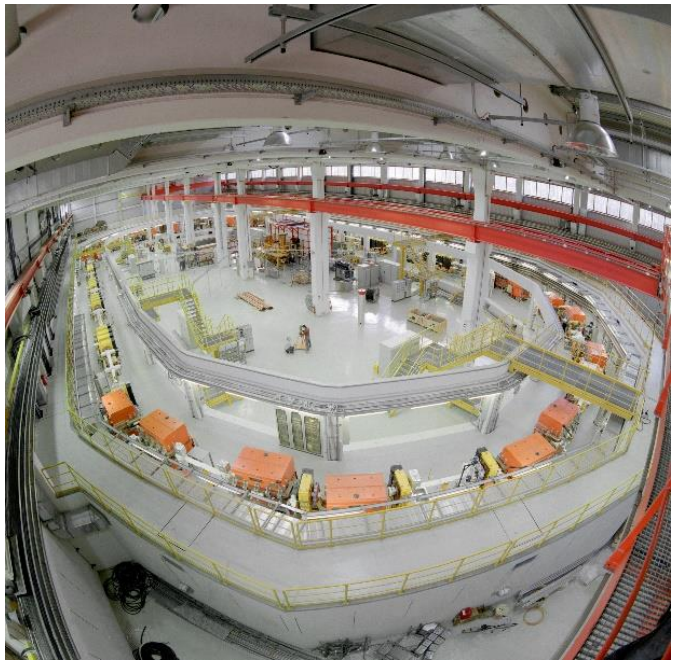


- polarized and unpolarized proton and deuteron beams
- momentum range from 0.3 GeV/c to 3.7 GeV/c
- **WASA**: internal experiment, proton or deuteron pellet target





WASA-at-COSY

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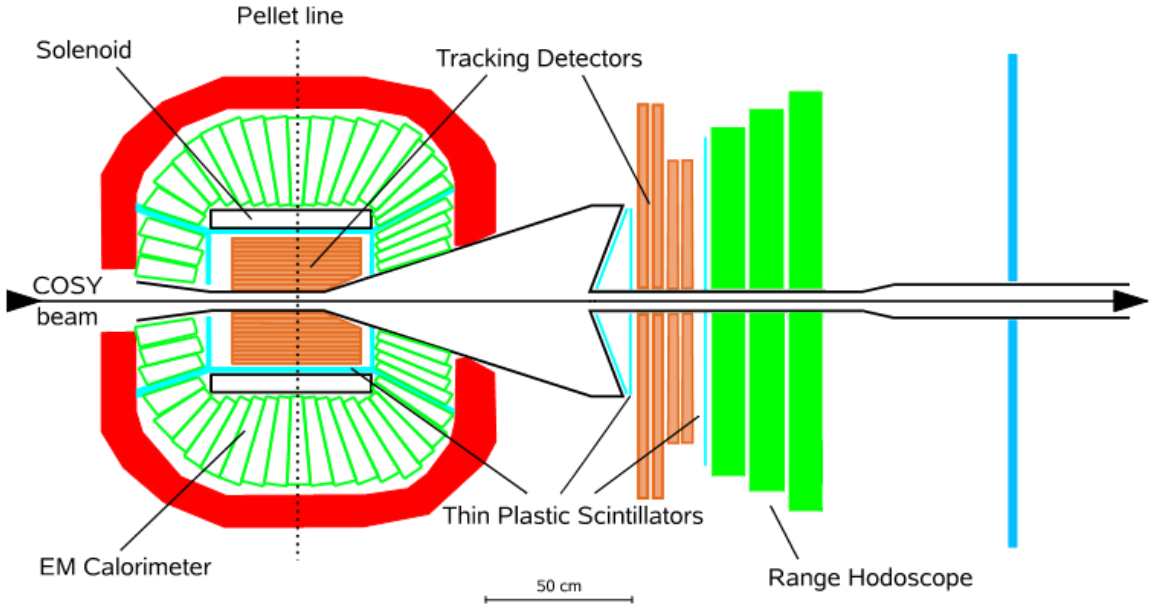
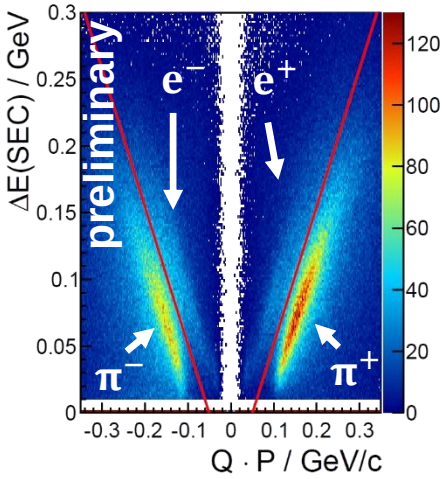
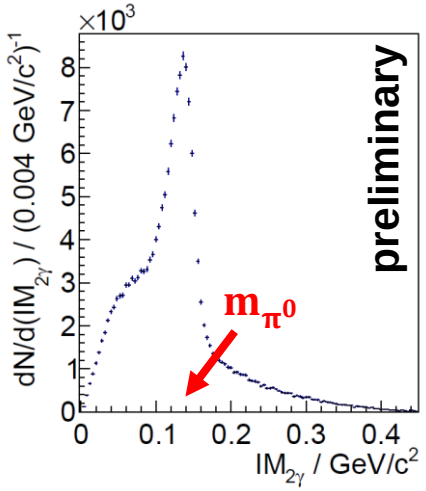
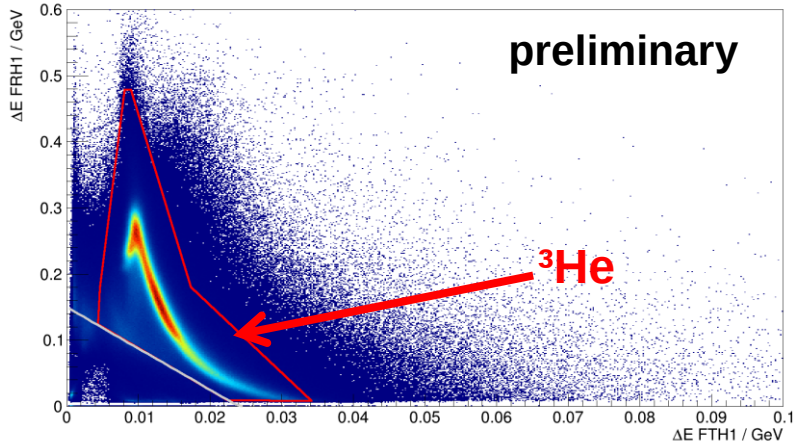
- Central detector:
  - solenoid & drift chamber
  - plastic scintillator
  - calorimeter
- Forward detector:
  - proportional chamber
  - scintillators
- near 4π-coverage
- detection & reconstruction of $\pi^{\pm}, e^{\pm}, \gamma, p, d$ and ^3He









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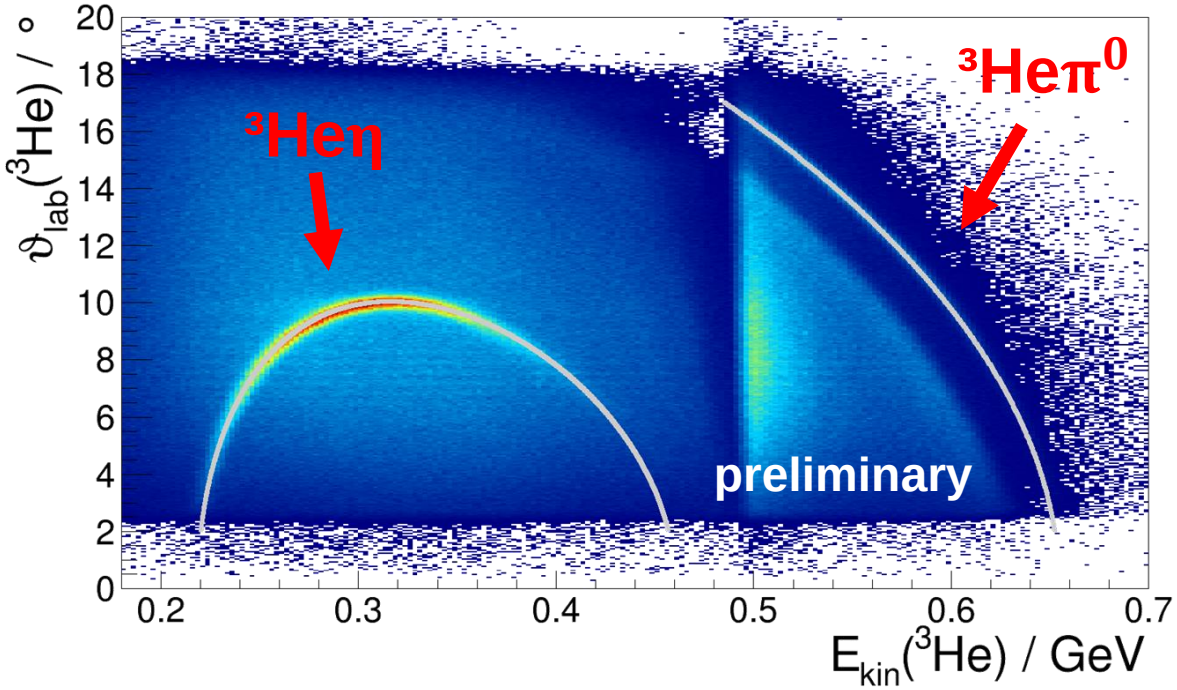
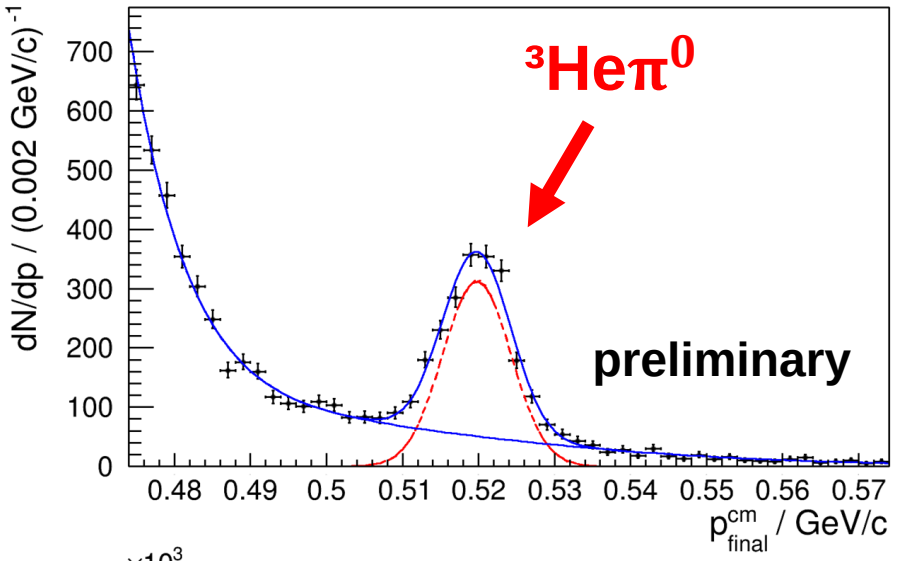
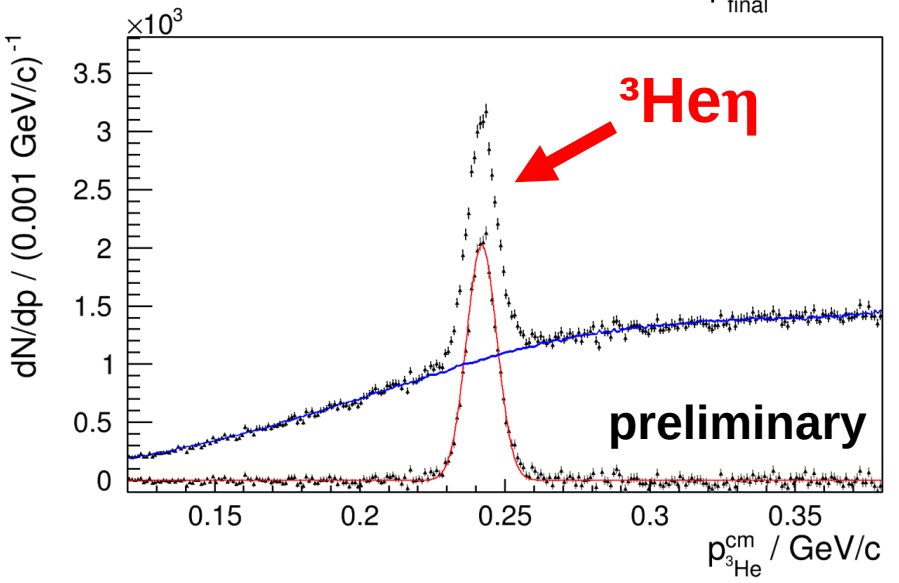
- calibration can be checked with two-particle kinematics
- identification of two-particle final states by final-state-momentum of ^{3}He





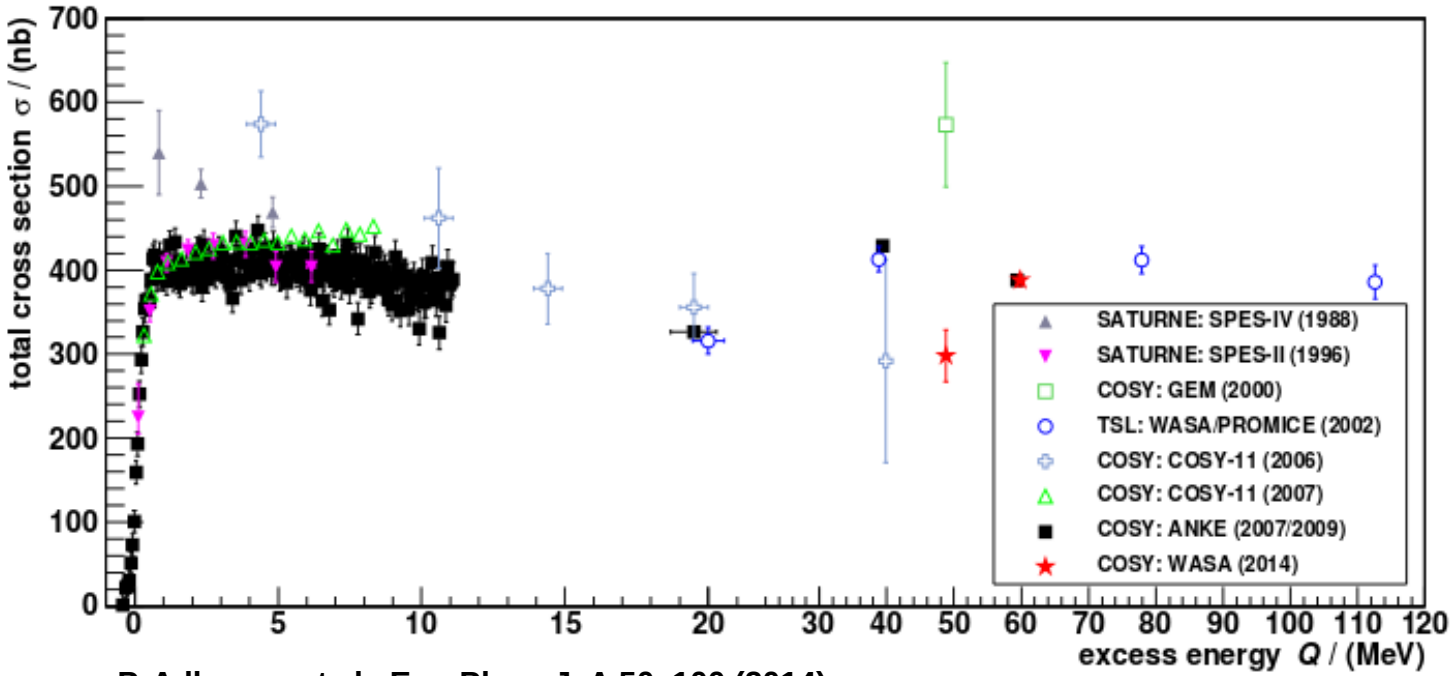


η production

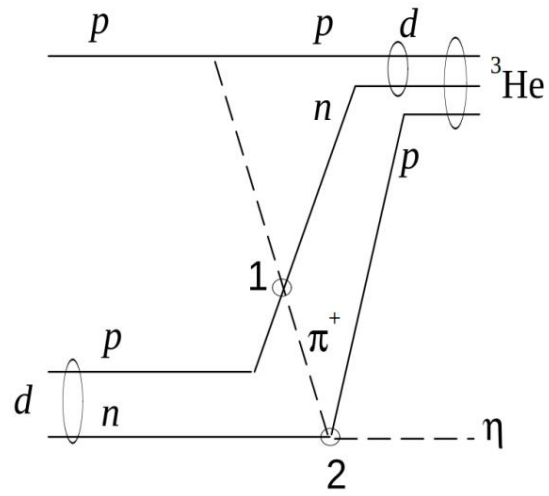
- Haider & Liu (1986): ηN interaction attractive in s-wave
  - inspired search for η-mesic nuclei

- large database near threshold
  - steep rise for $Q < 1.5$ MeV
  - attributed to quasi-bound ^{3}Heη

- large theory effort
  - two-step (three-body) process nicely describes data
  - FSI plays a strong role



P. Adlarson et al., Eur. Phys. J. A 50, 100 (2014)



K.P. Khemchandani et. al., Phys. Rev. C 76, 069801 (2007)

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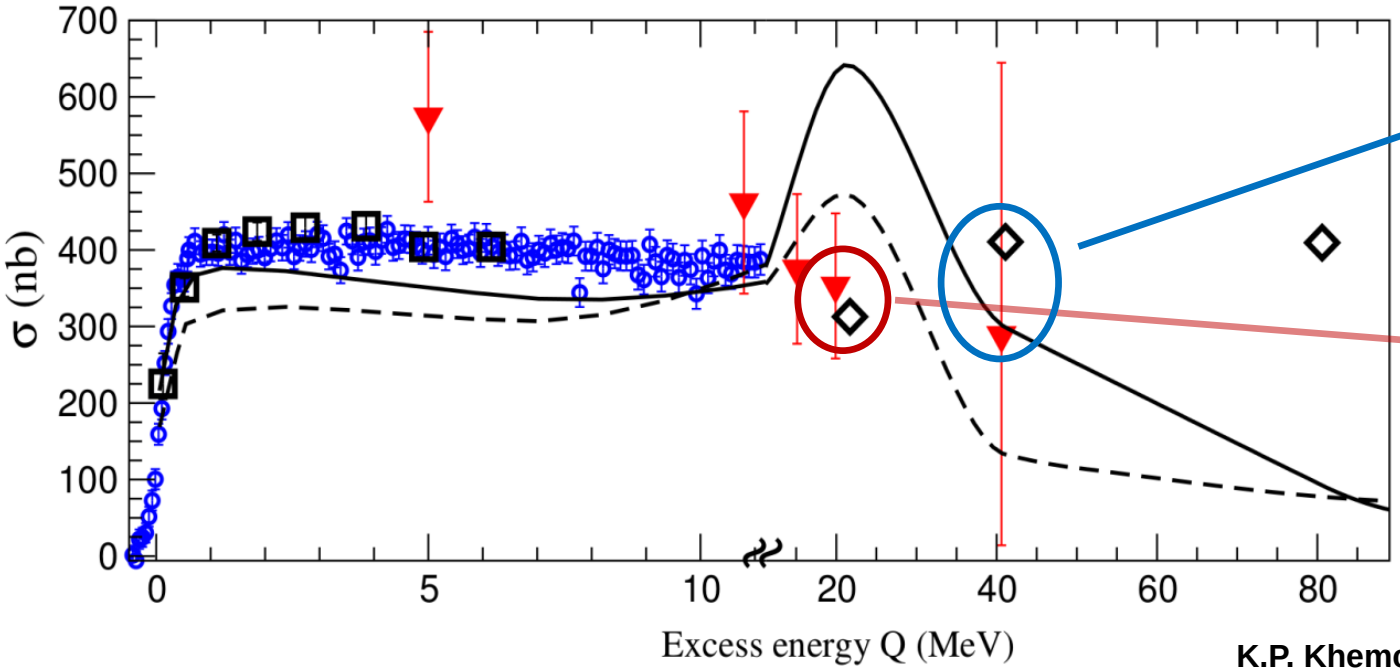
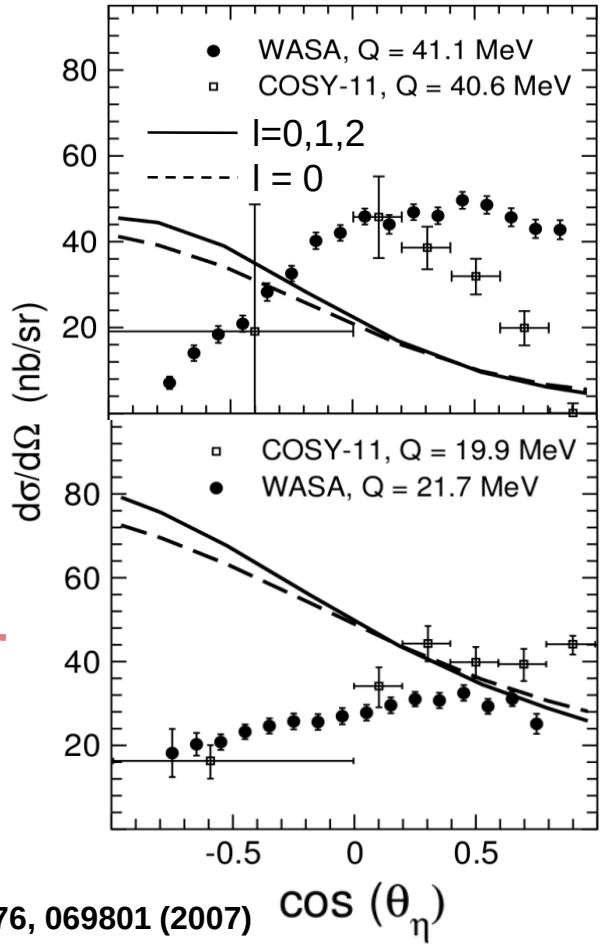


what happens at higher Q?



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- away from threshold:
  - higher partial waves important
  - no generally accepted model yet
- in pp collisions, $S_{11}(1535)$ dominates the production
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- open questions remain:
  - role of other nucleon resonances
  - $S_{11}(1535)$ in nuclear matter
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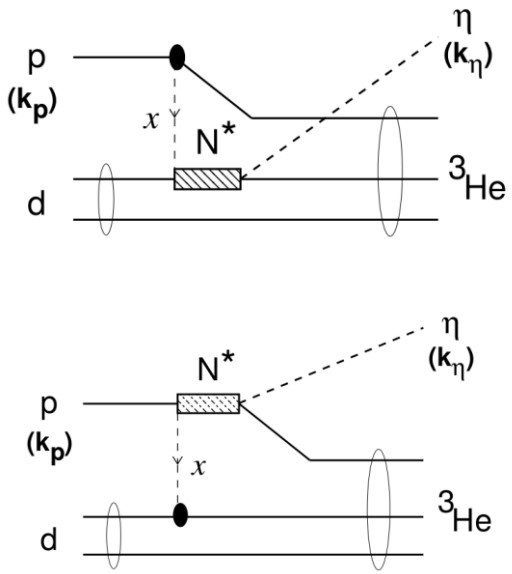
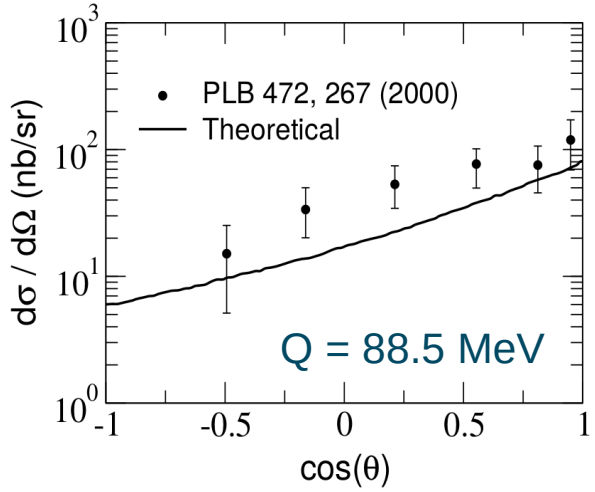
"useful to obtain more data on this reaction at high energies in the future"

N.G. Kelkar, Rep. Prog. Phys. 76 (2013) 066301





A.B. Santra et. al., Phys. Rev. C. 64, 025201 (2001)

S	L	π	J	S'	L'	wave
3/2	0	+1	3/2	1/2	1	p
3/2	1	-1	5/2	1/2	2	d
1/2	0	+1	1/2	1/2	1	p
1/2	1	-1	3/2	1/2	2	d
3/2	1	-1	1/2	1/2	0	s
1/2	1	-1	1/2	1/2	0	s
3/2	2	+1	3/2	1/2	1	p
1/2	2	+1	3/2	1/2	1	p
3/2	2	+1	1/2	1/2	1	p

H. Machner, J.Phys. G42 (2015) no.4, 043001

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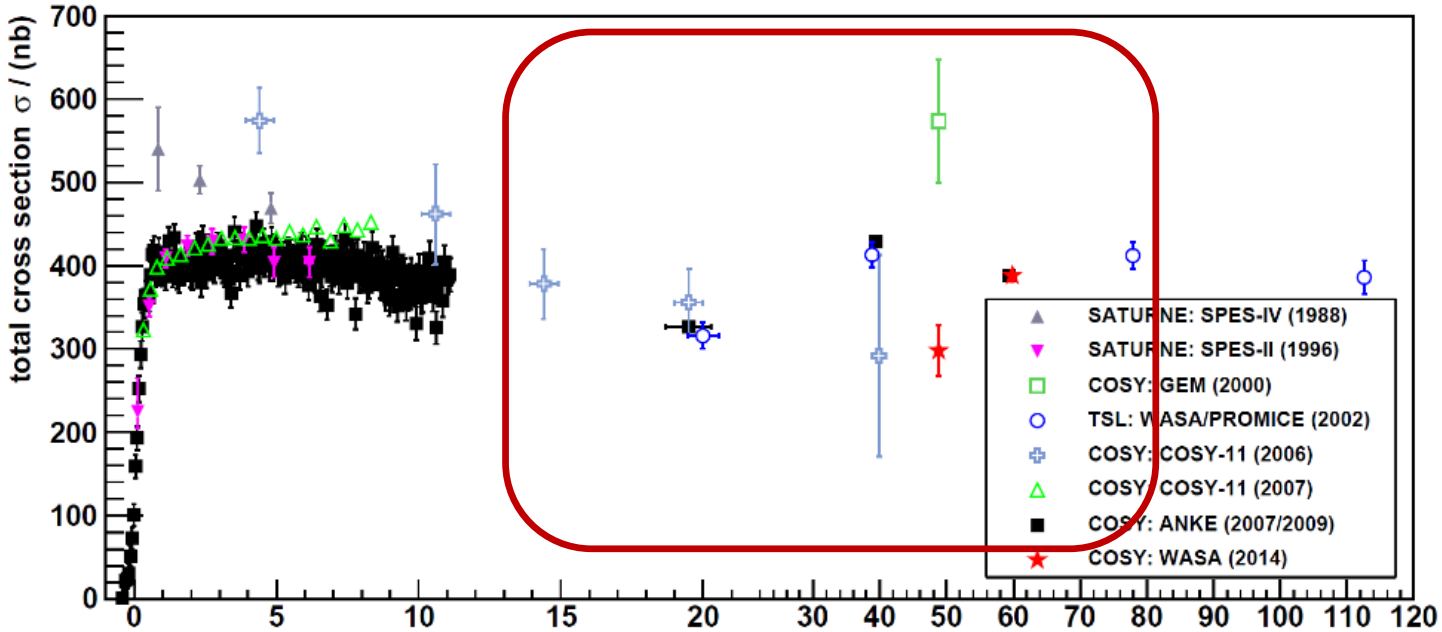

P. Adlarson et al., Eur. Phys. J. A 50, 100 (2014)

SC 0: p / GeV/c	1.60	1.62	1.64	1.66	1.68	1.70	1.72	1.74
SC 1: p / GeV/c	1.61	1.63	1.65	1.67	1.69	1.70	1.71	1.73

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  - nice agreement with previous WASA-at-COSY data
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  - distributions remarkably similar down to Q ≈ 40 MeV
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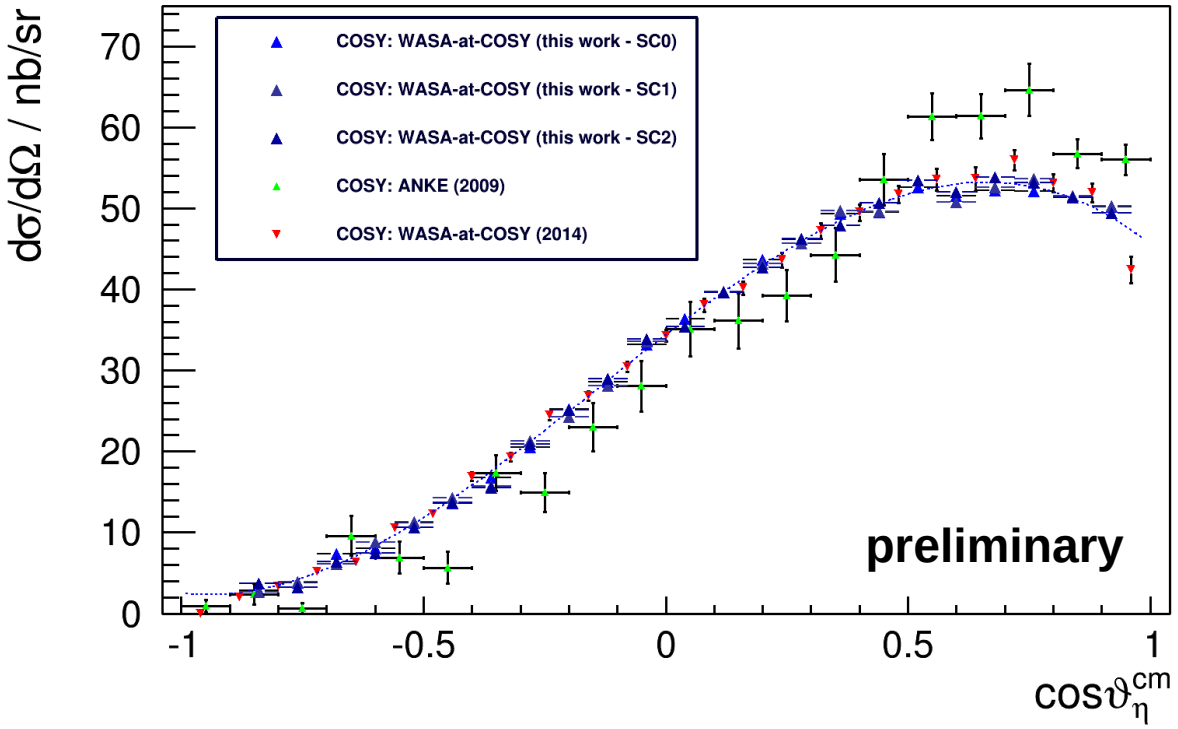

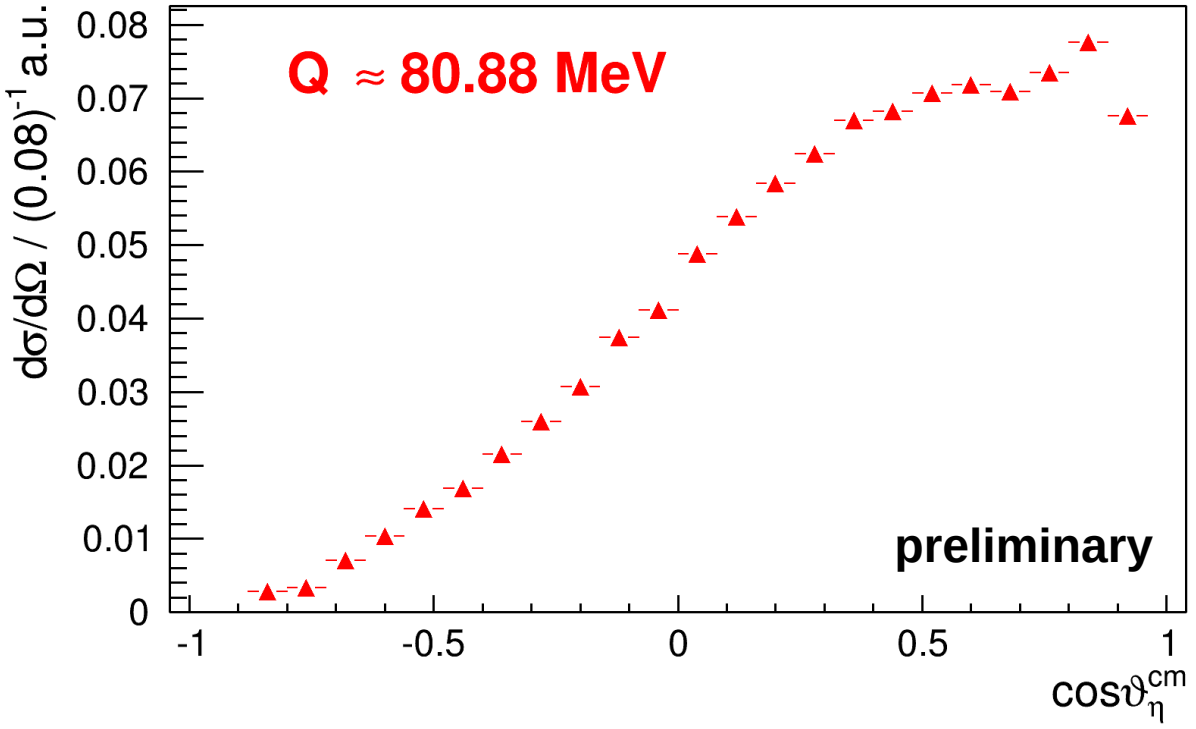

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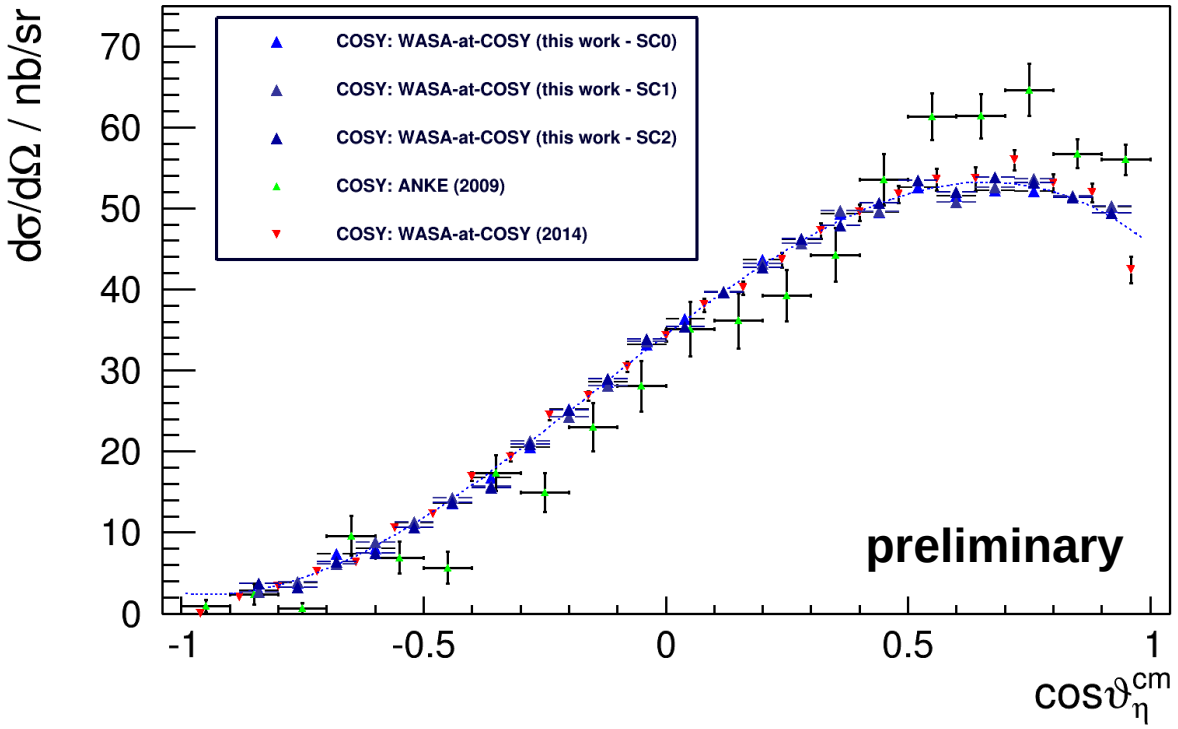

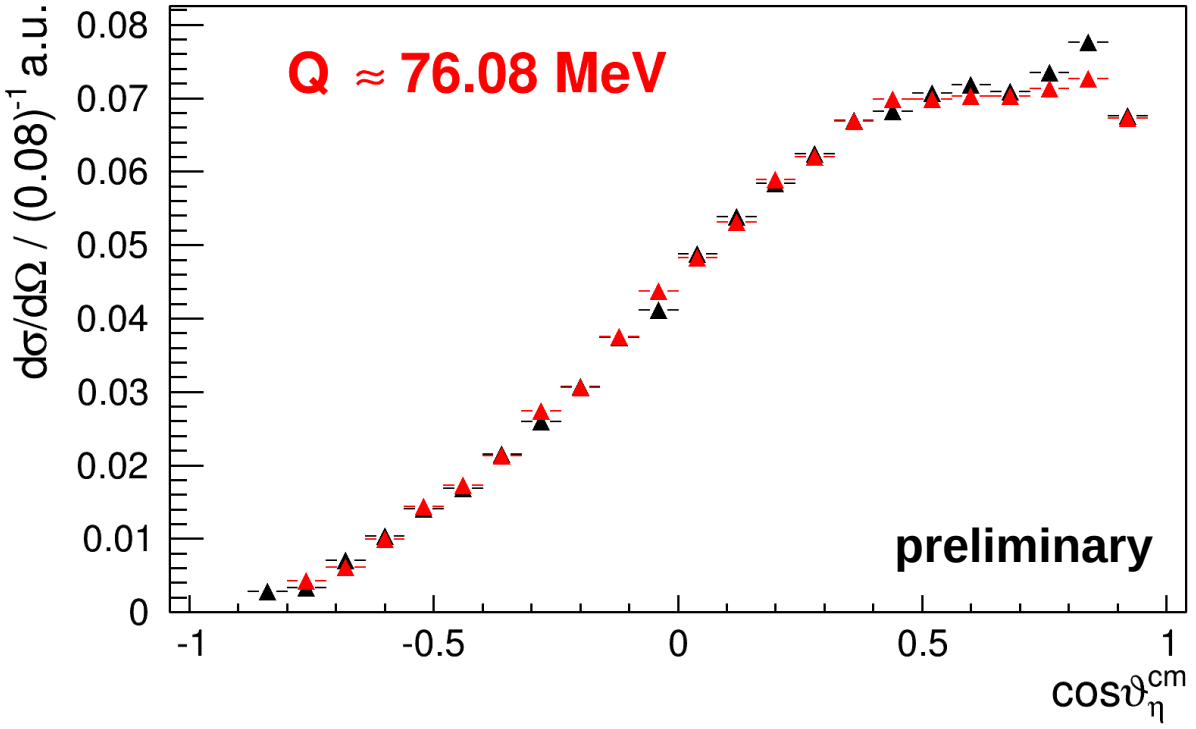

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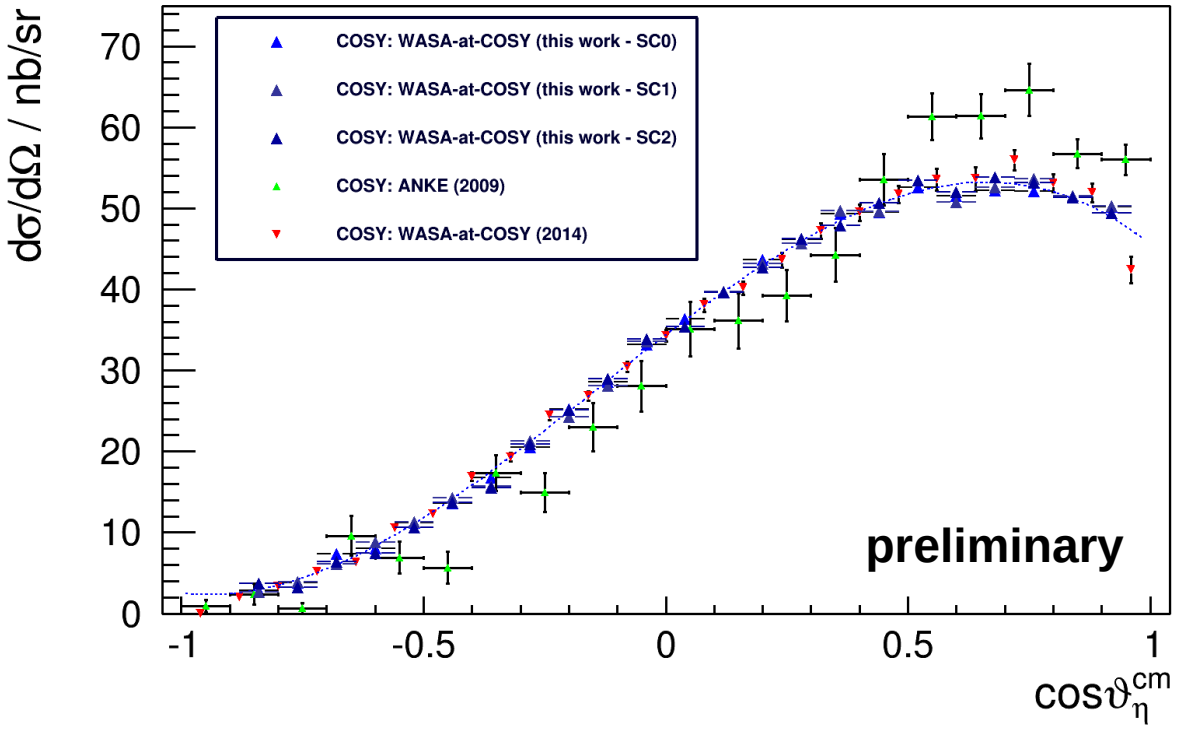

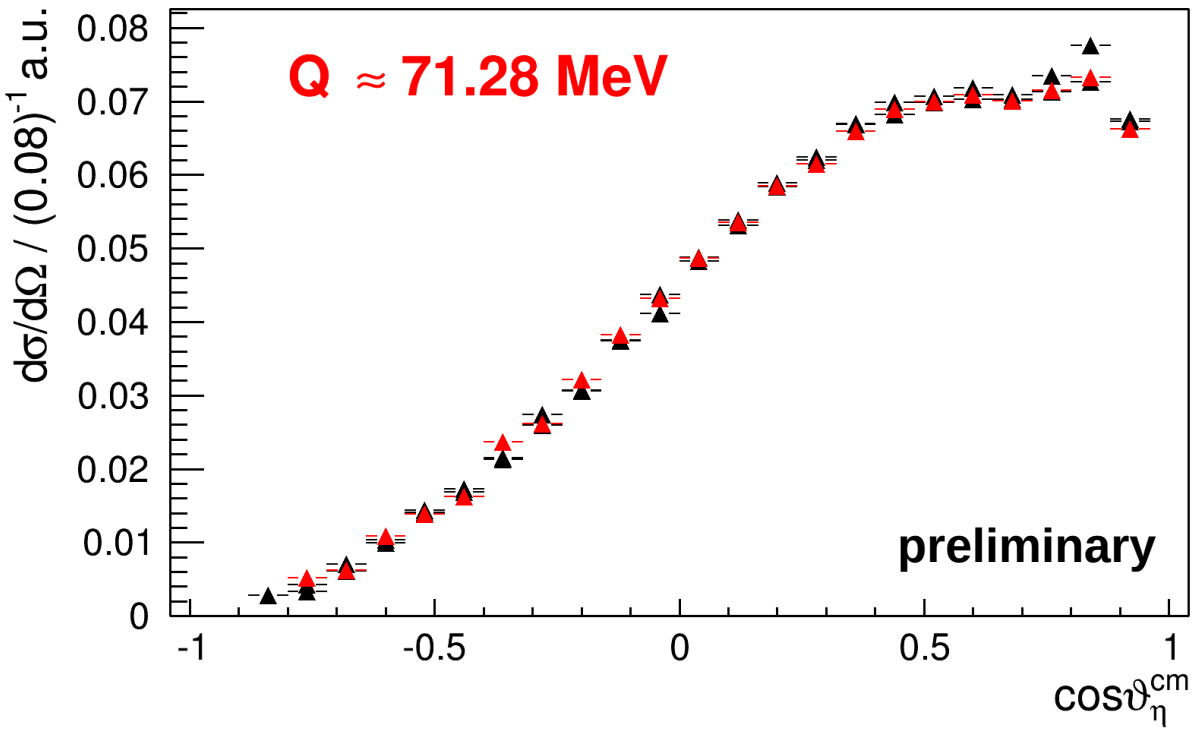

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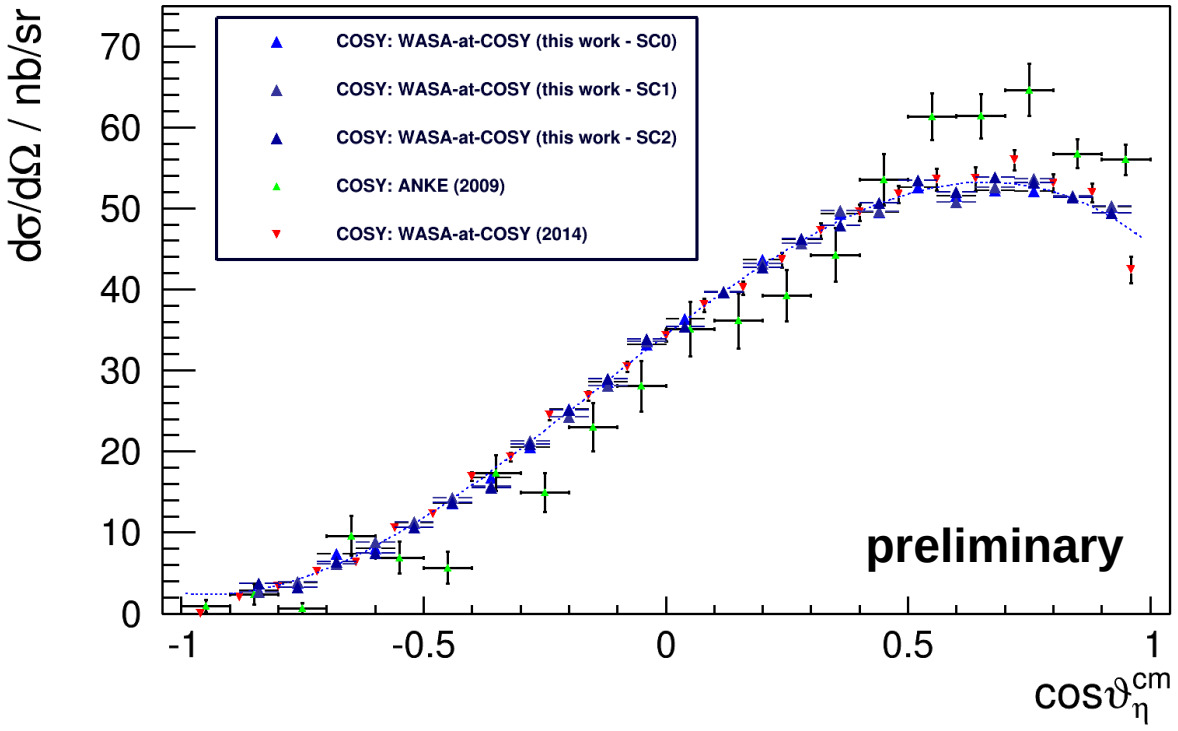

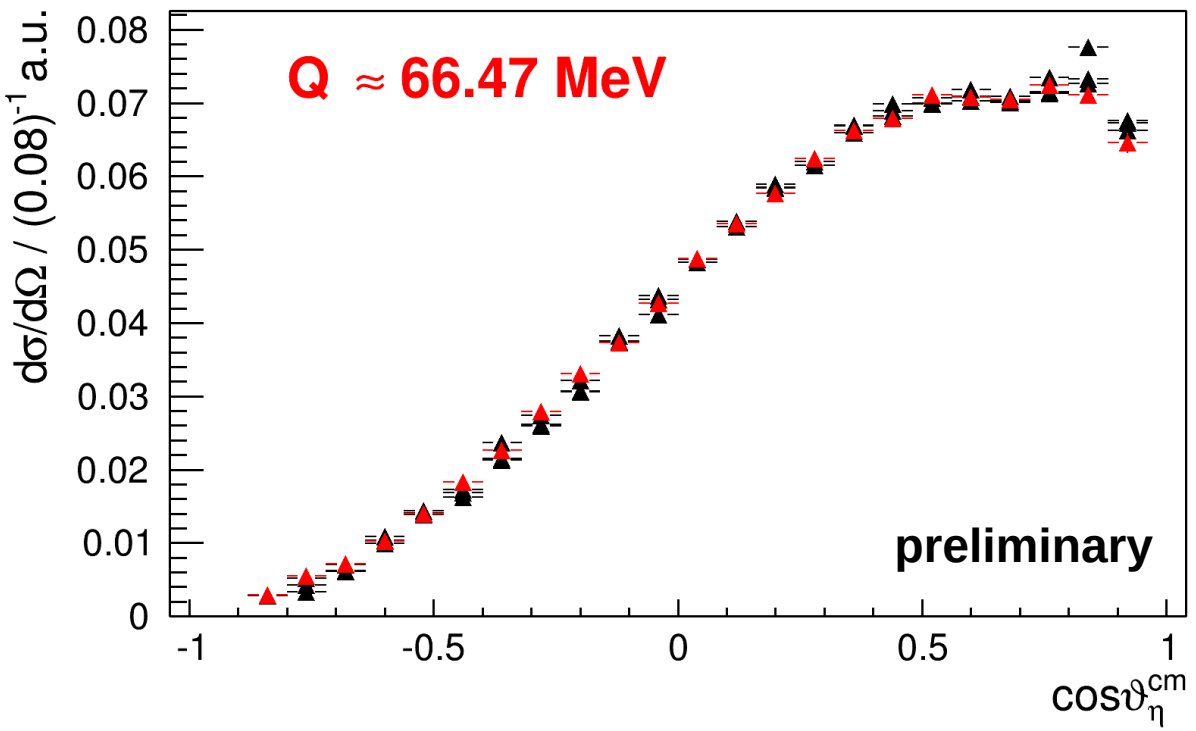

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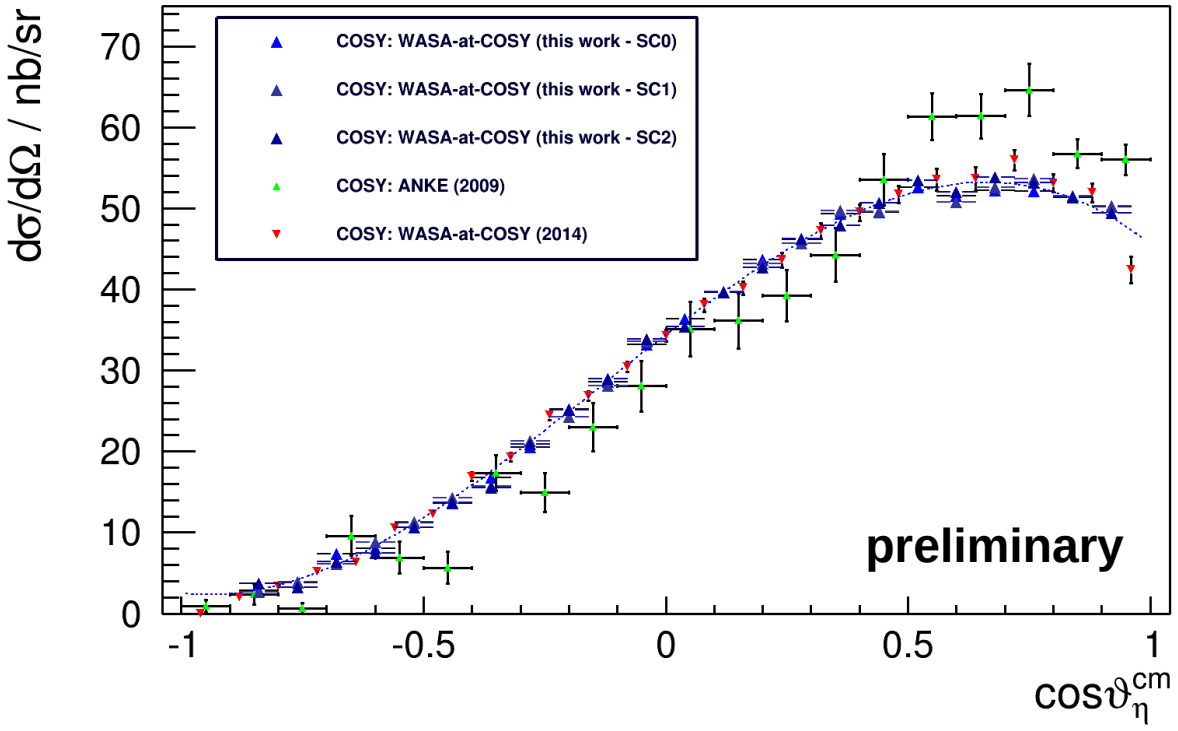

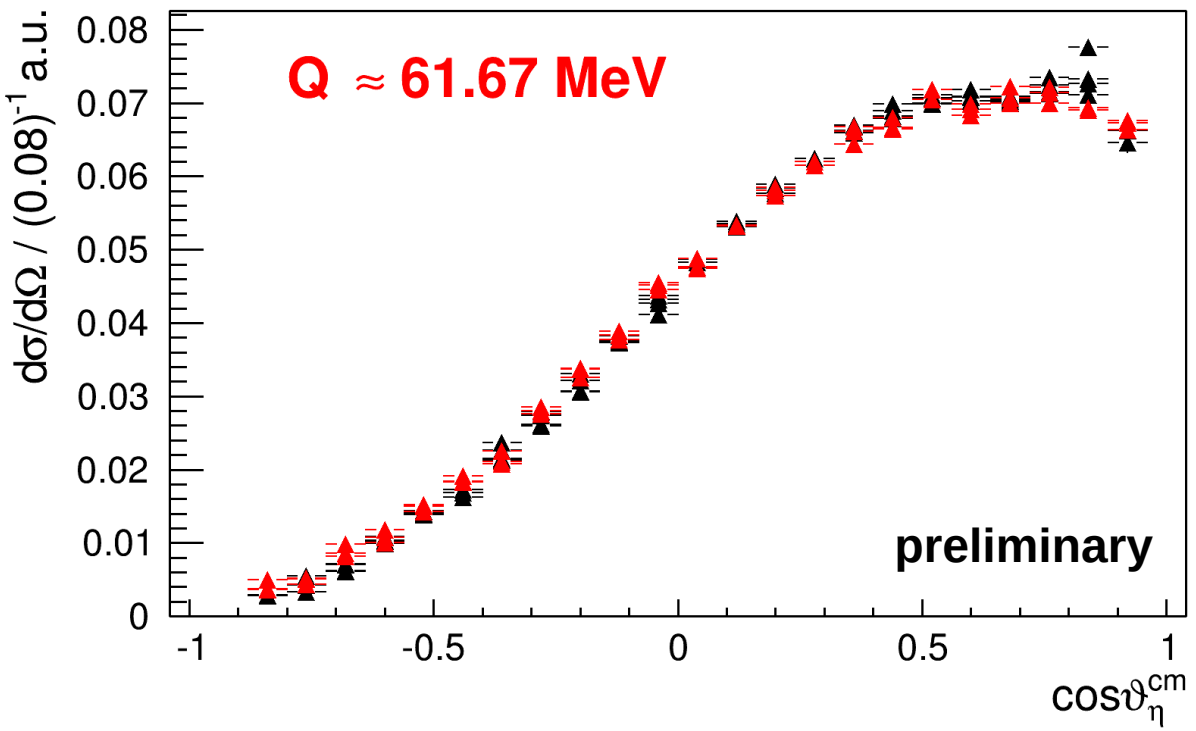

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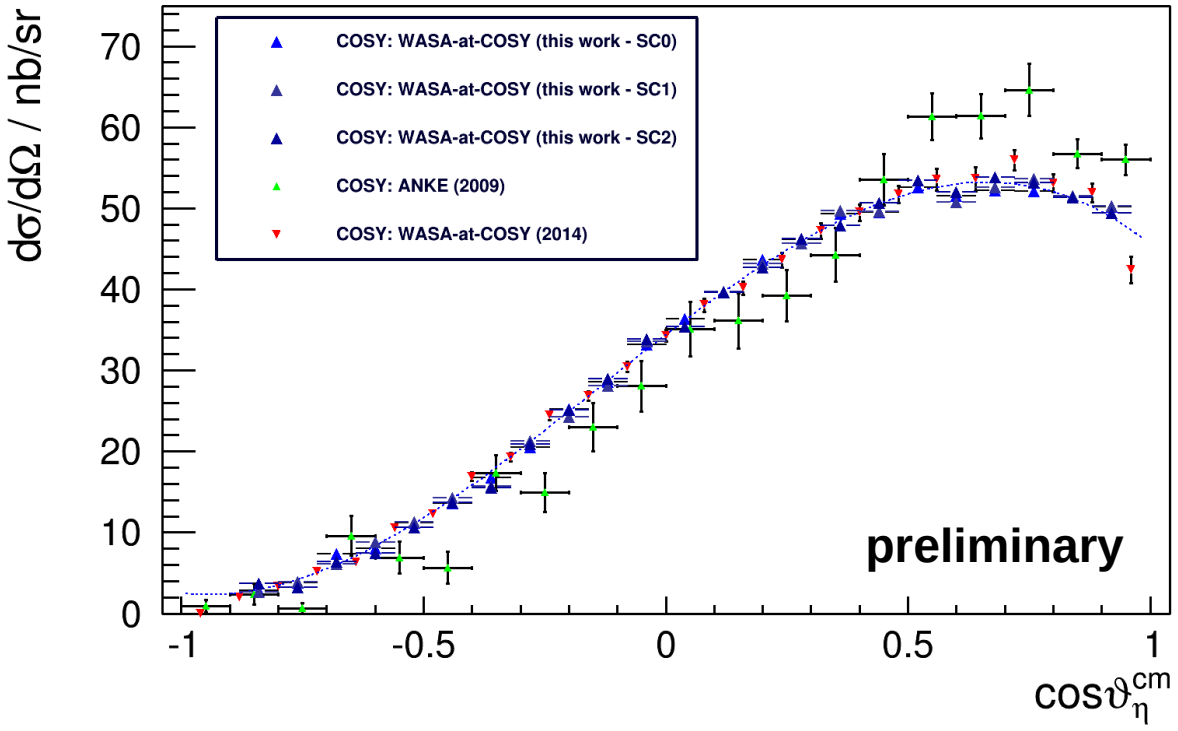

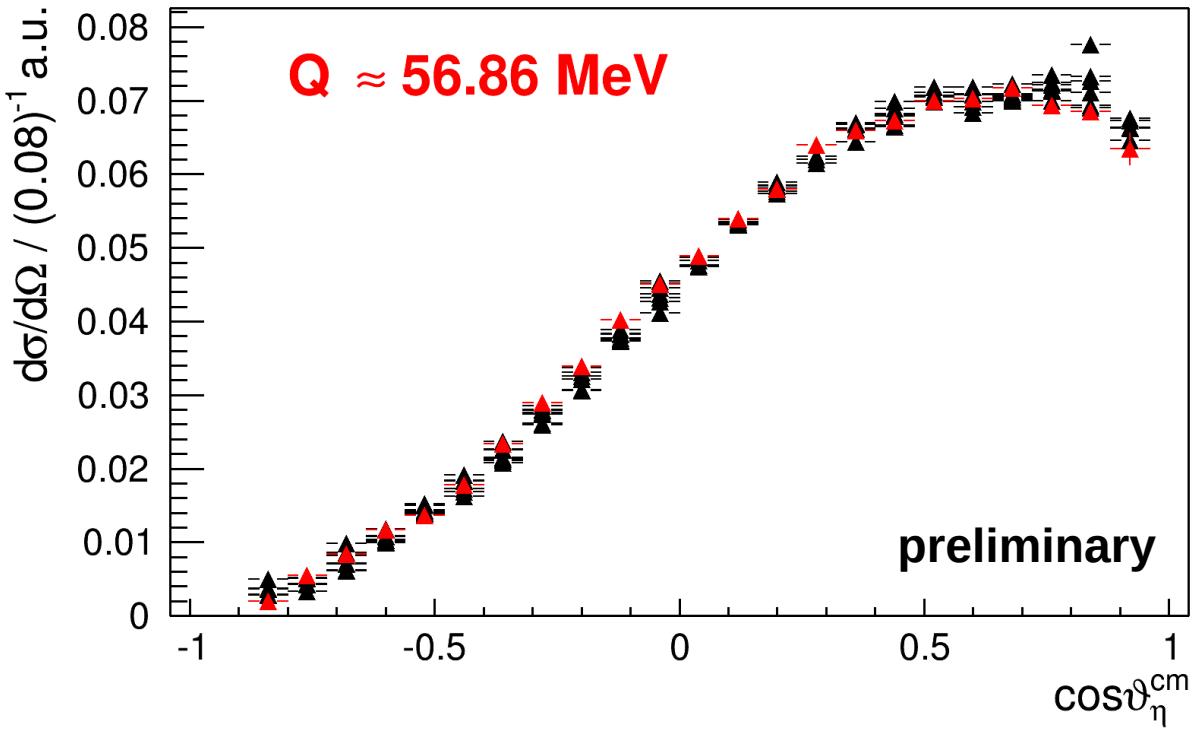

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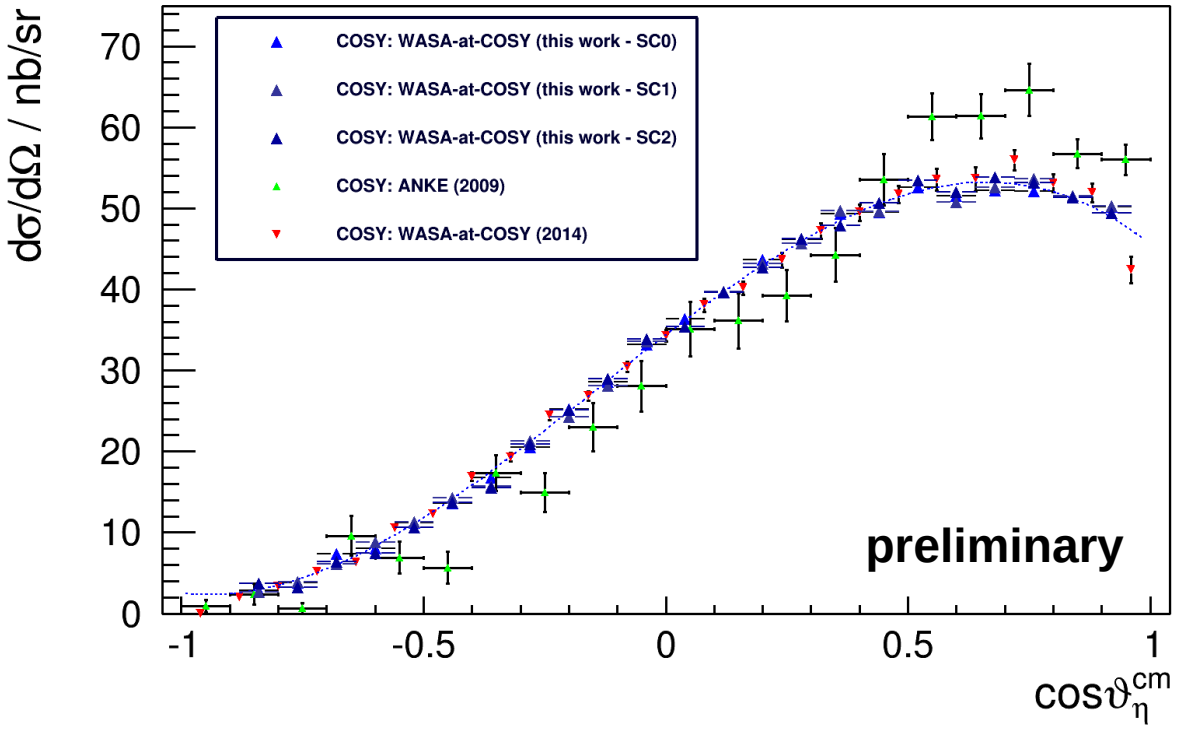

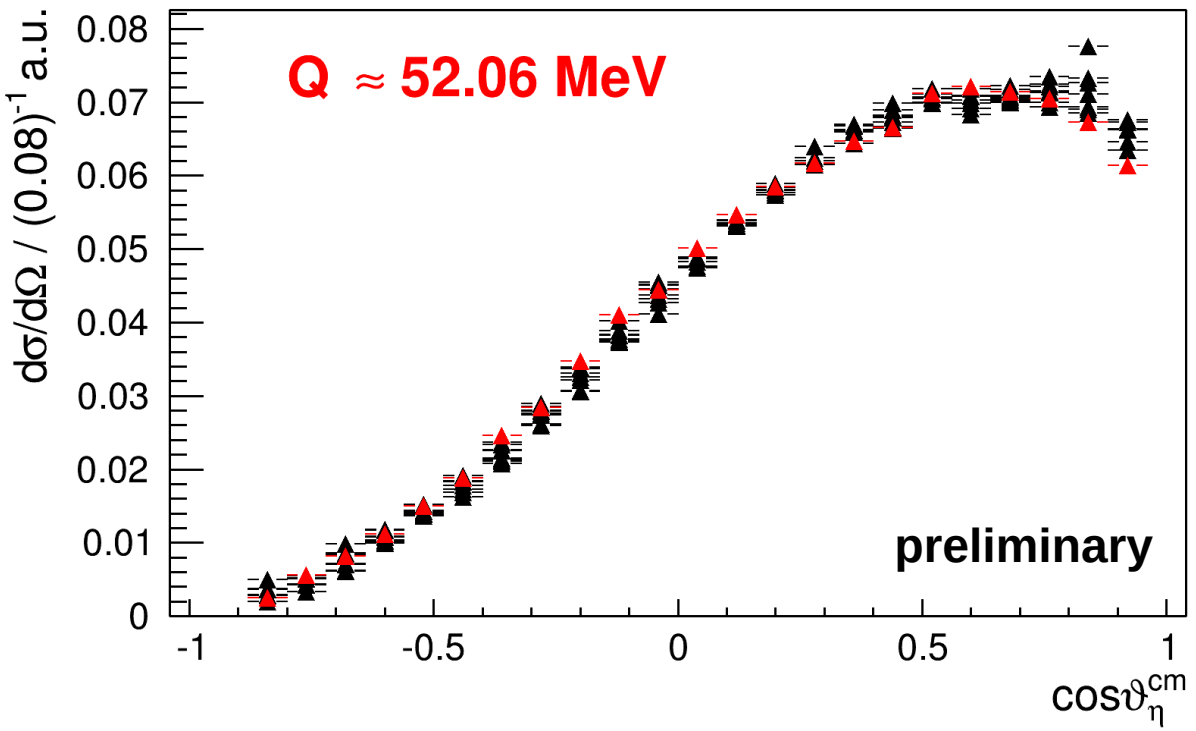

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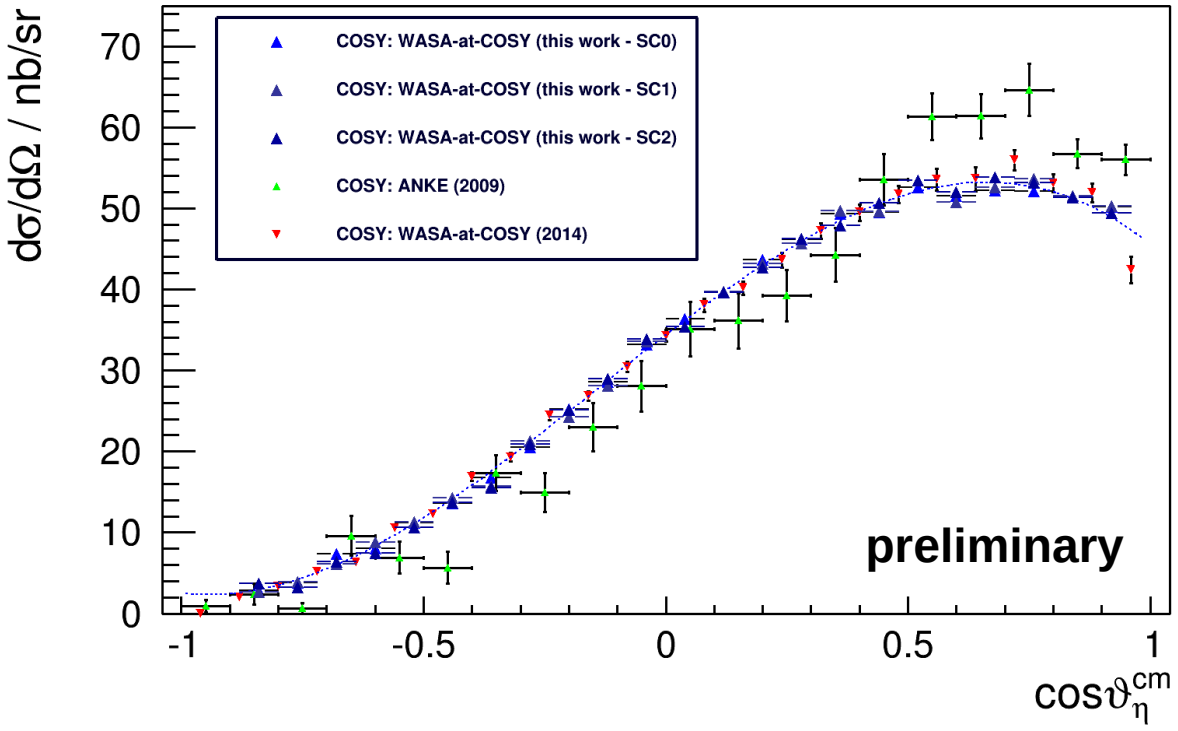

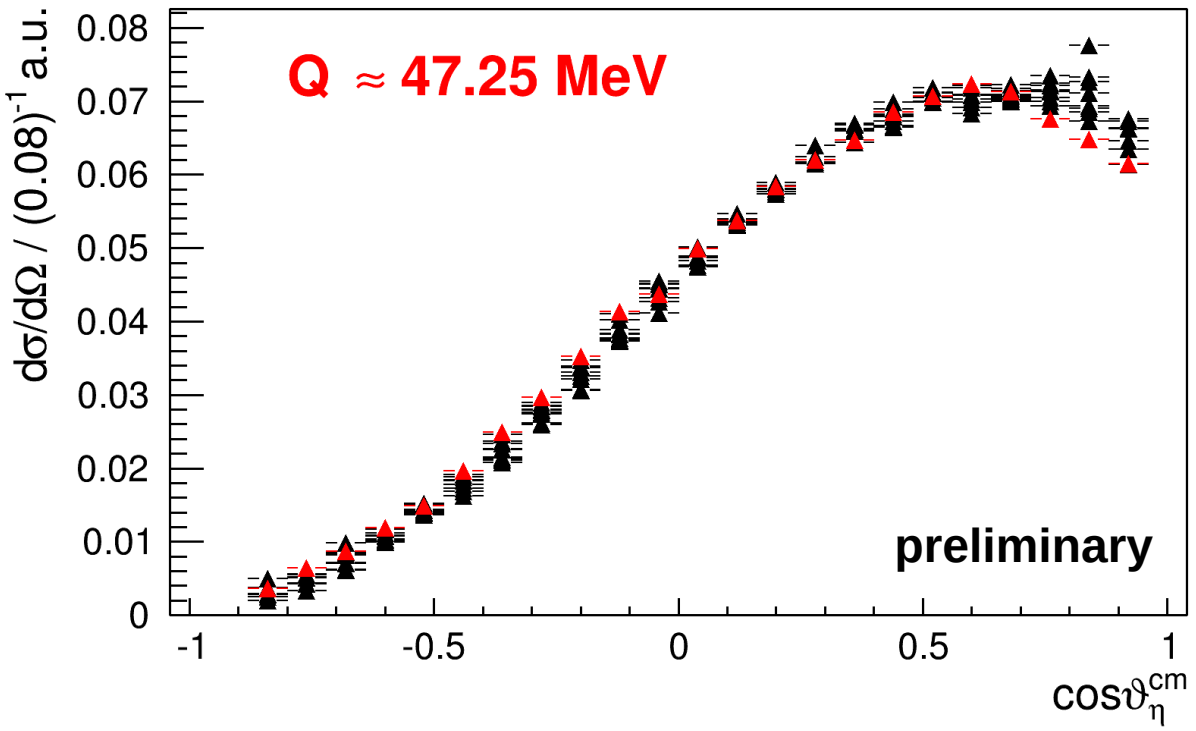

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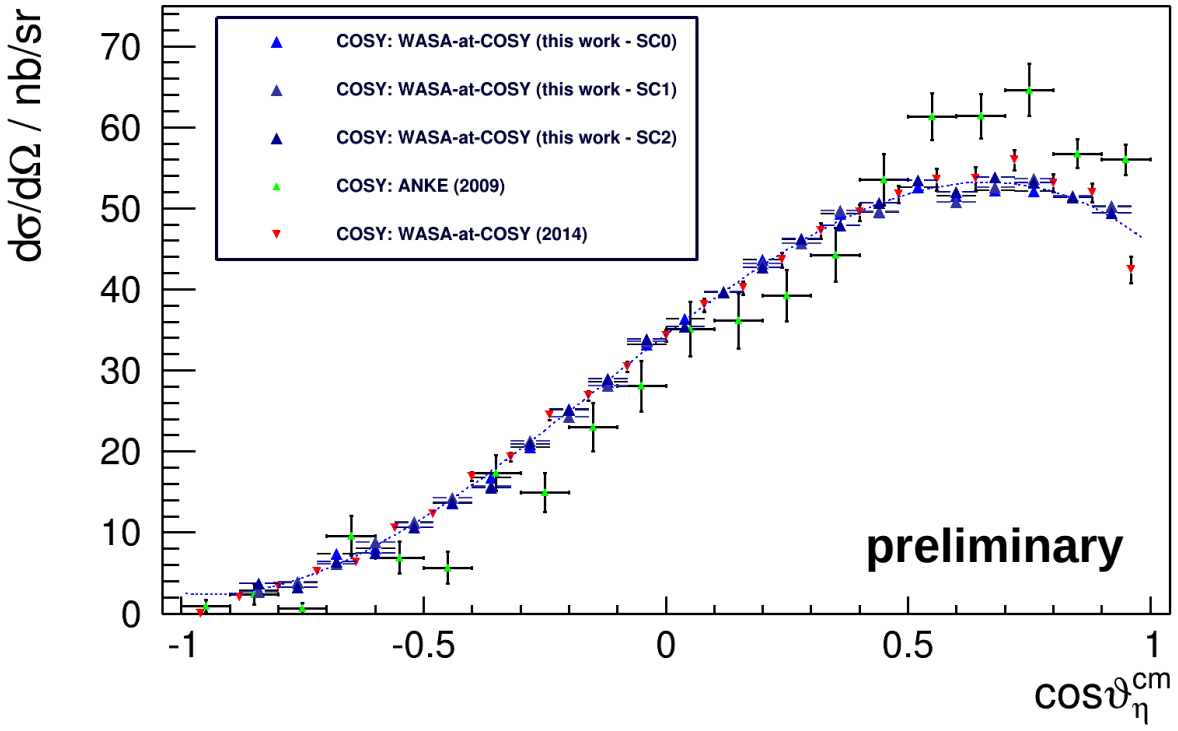

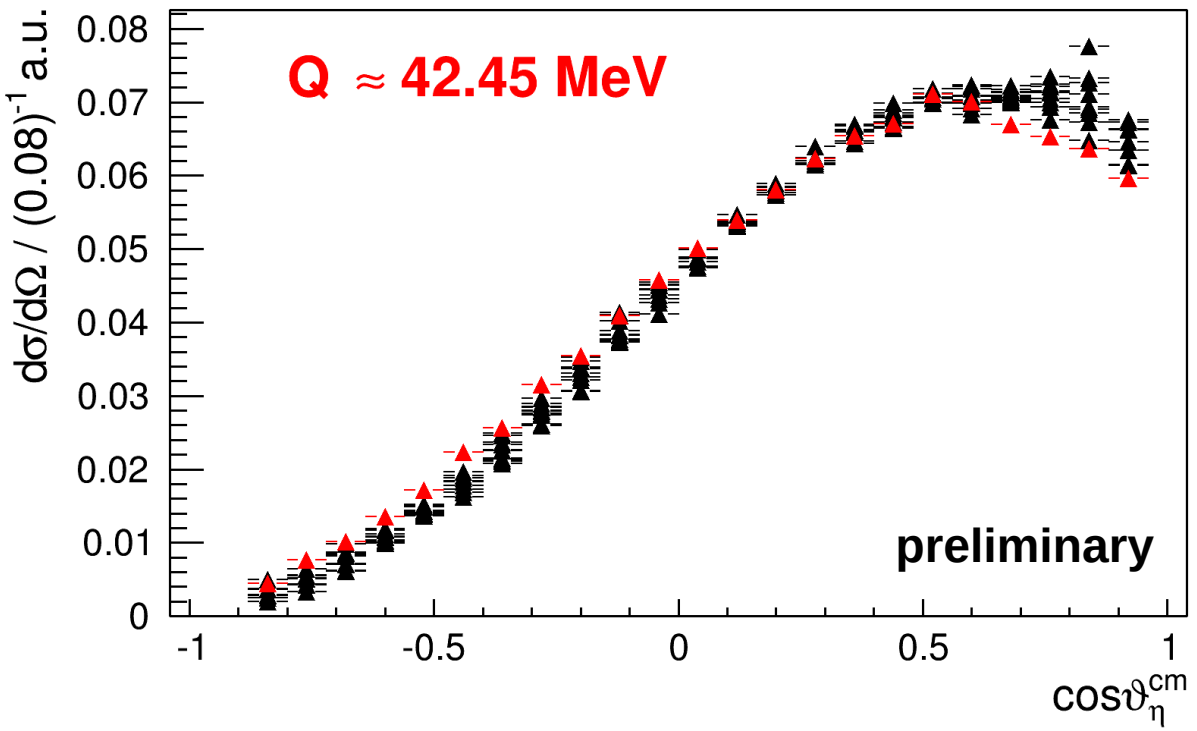

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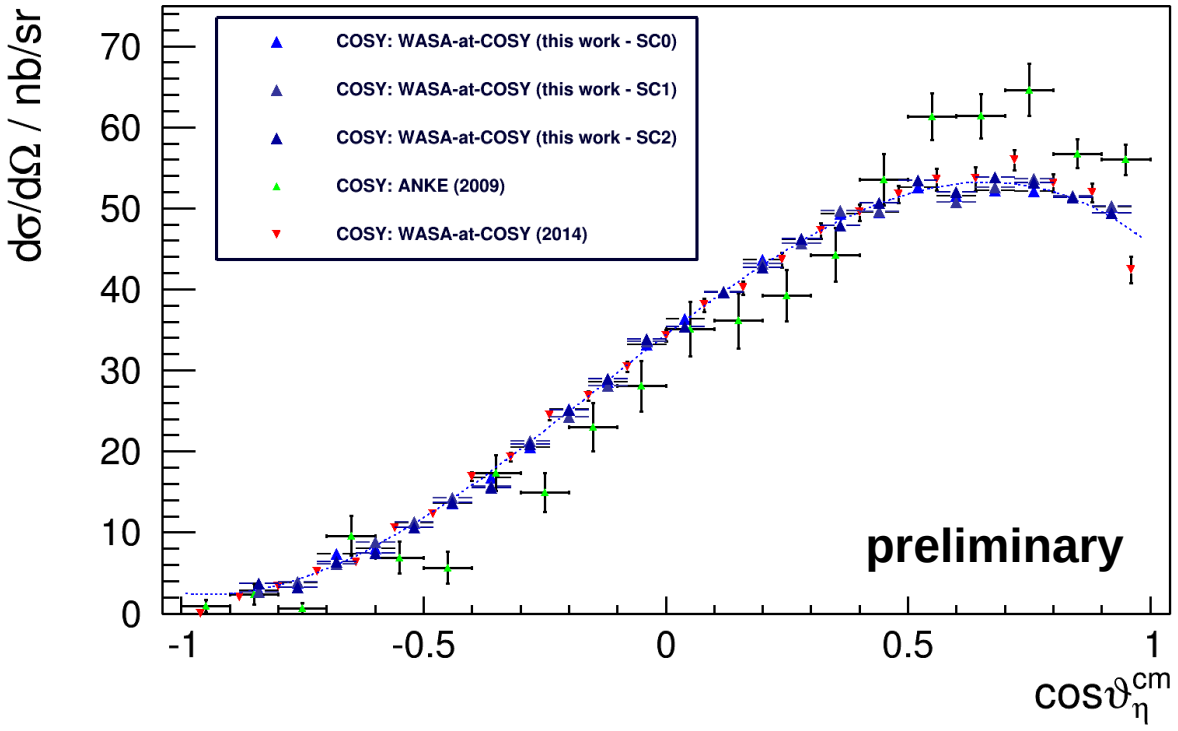

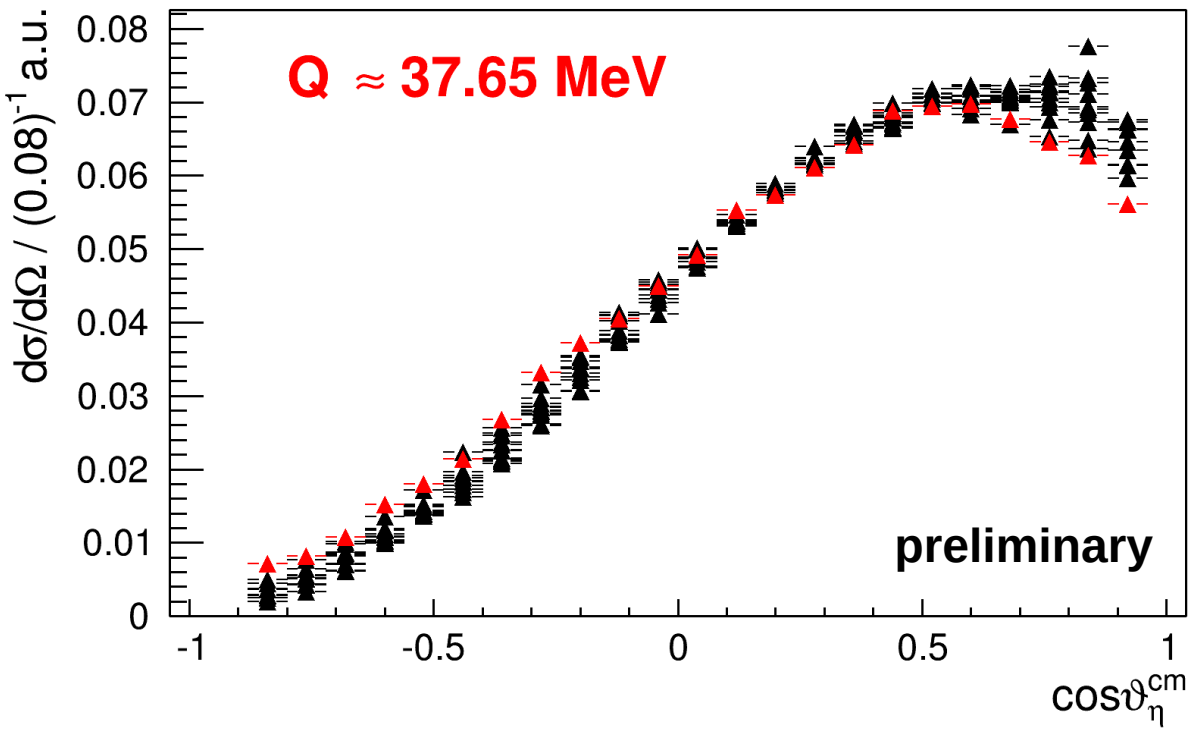

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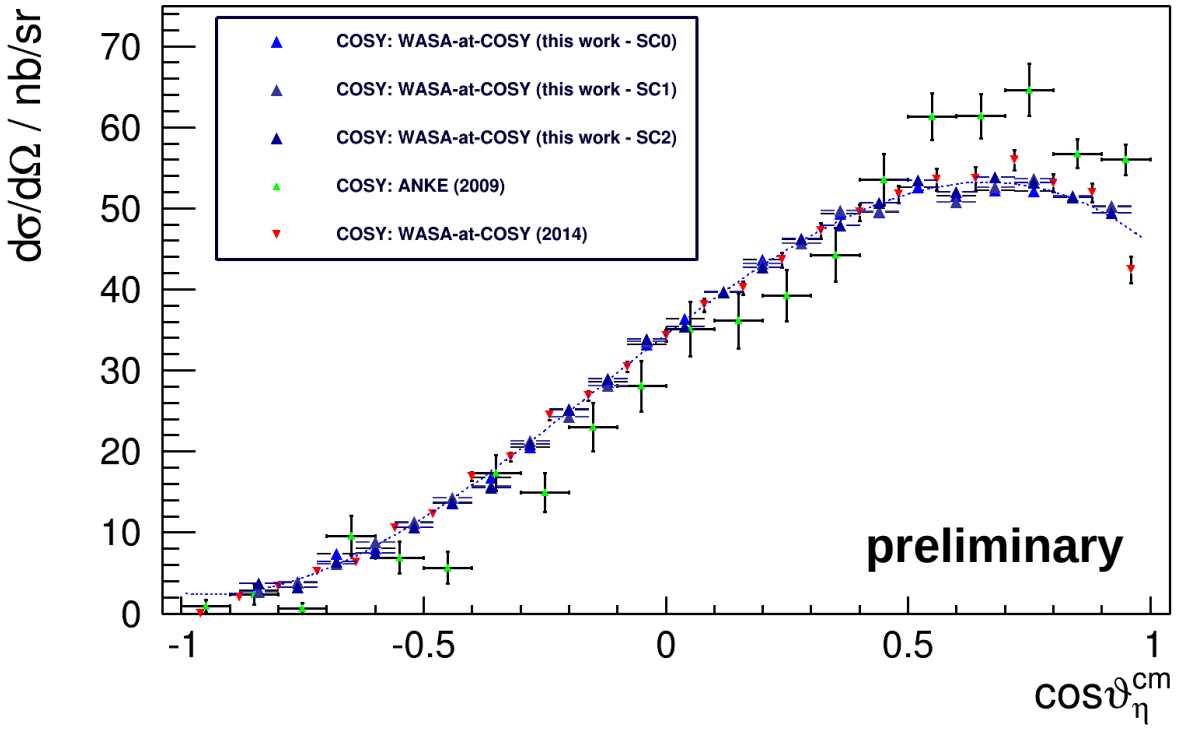

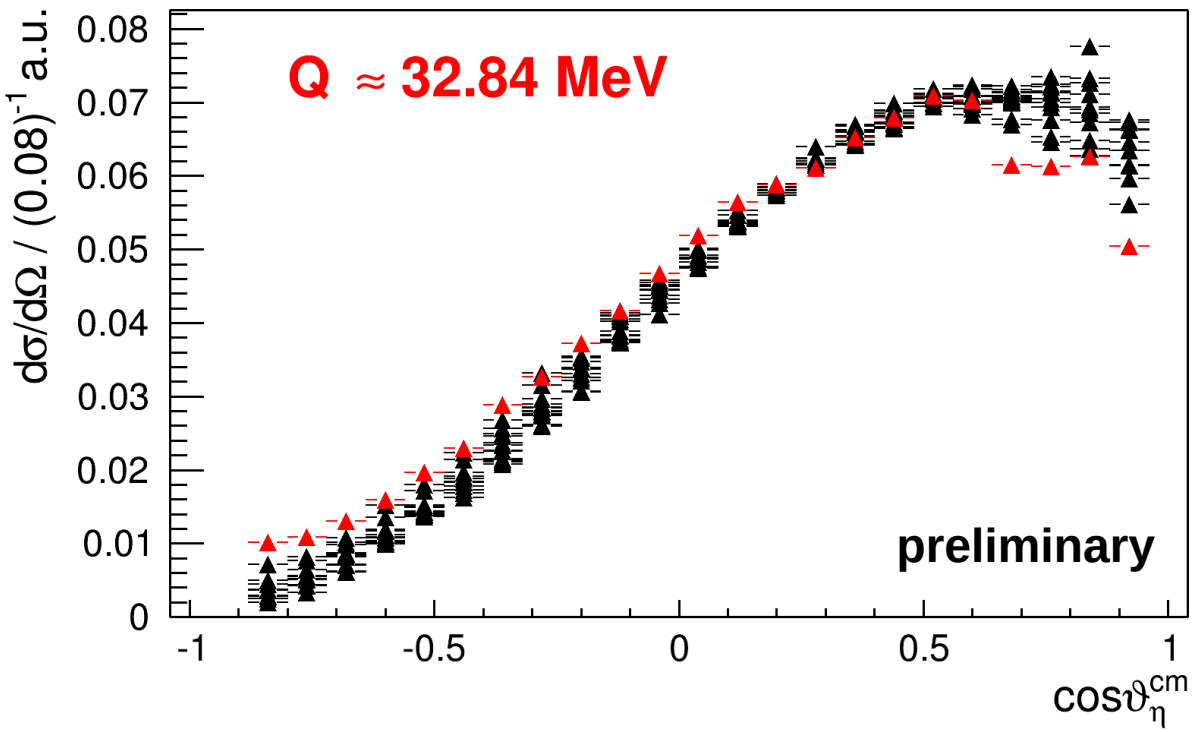

η production

- normalizing to ANKE (2009) and WASA-at-COSY (2014) measurements:
  - nice agreement with previous WASA-at-COSY data
  - systematics in check
- normalizing to unity, compare between energies:
  - distributions remarkably similar down to Q ≈ 40 MeV
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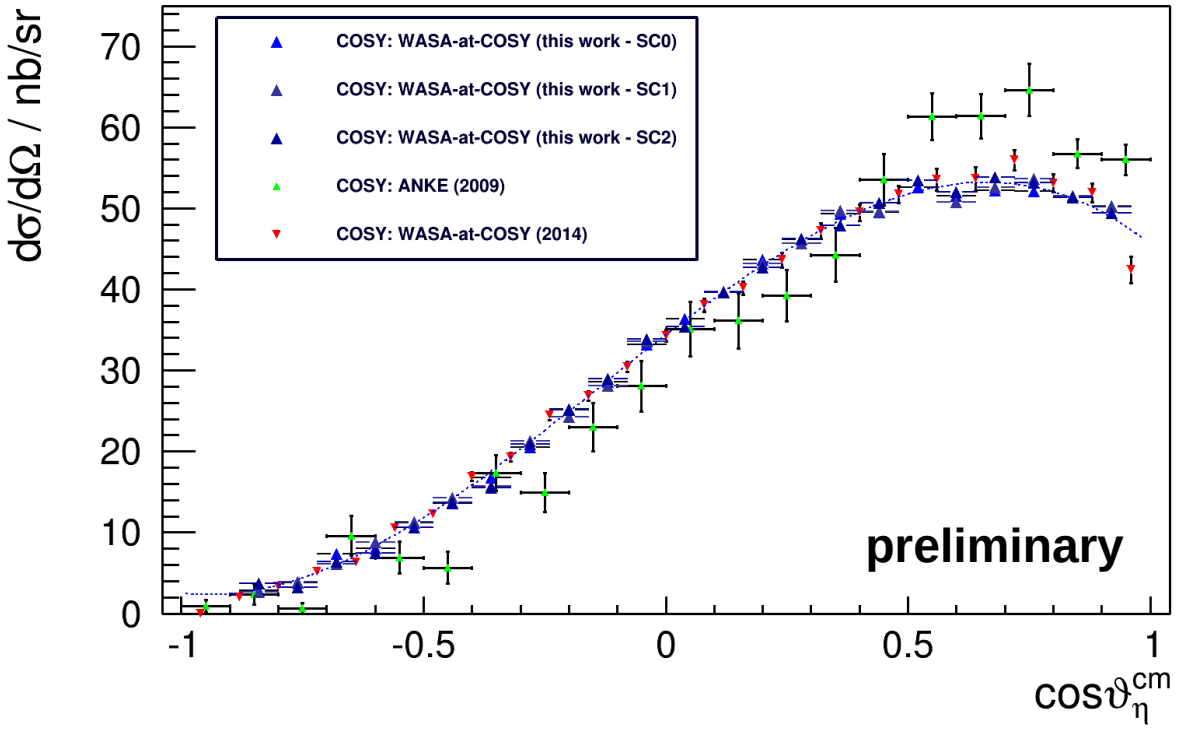

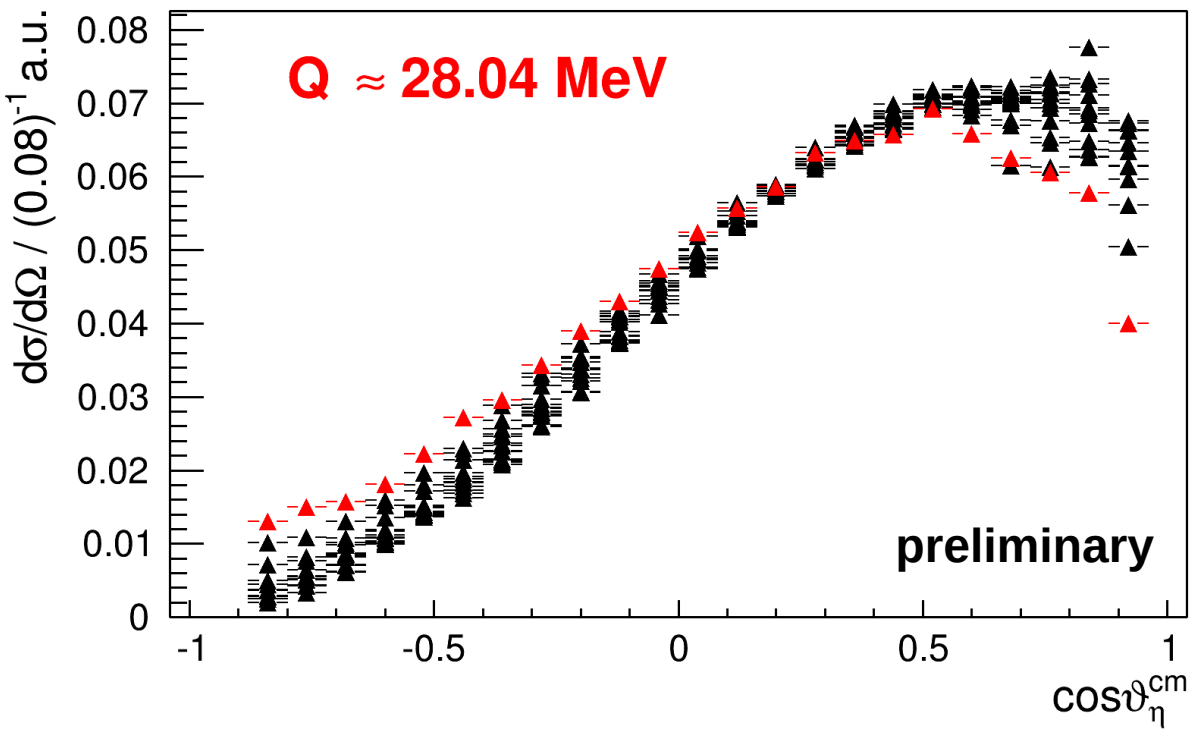

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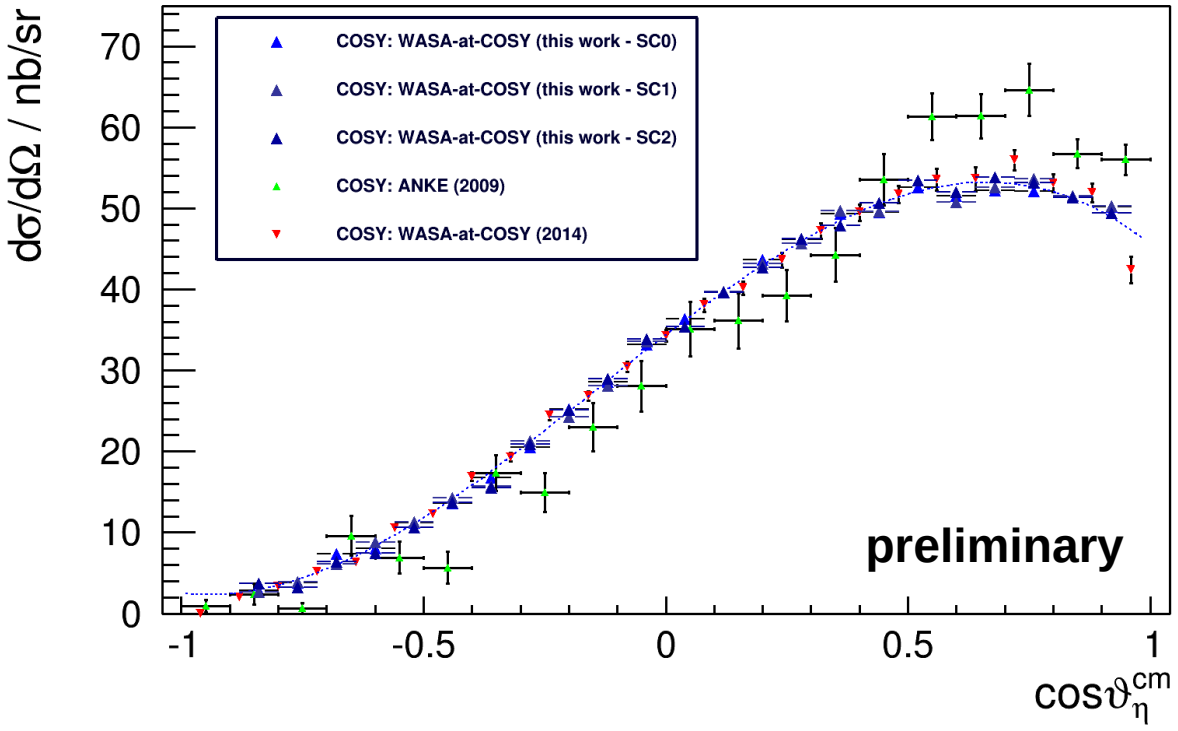

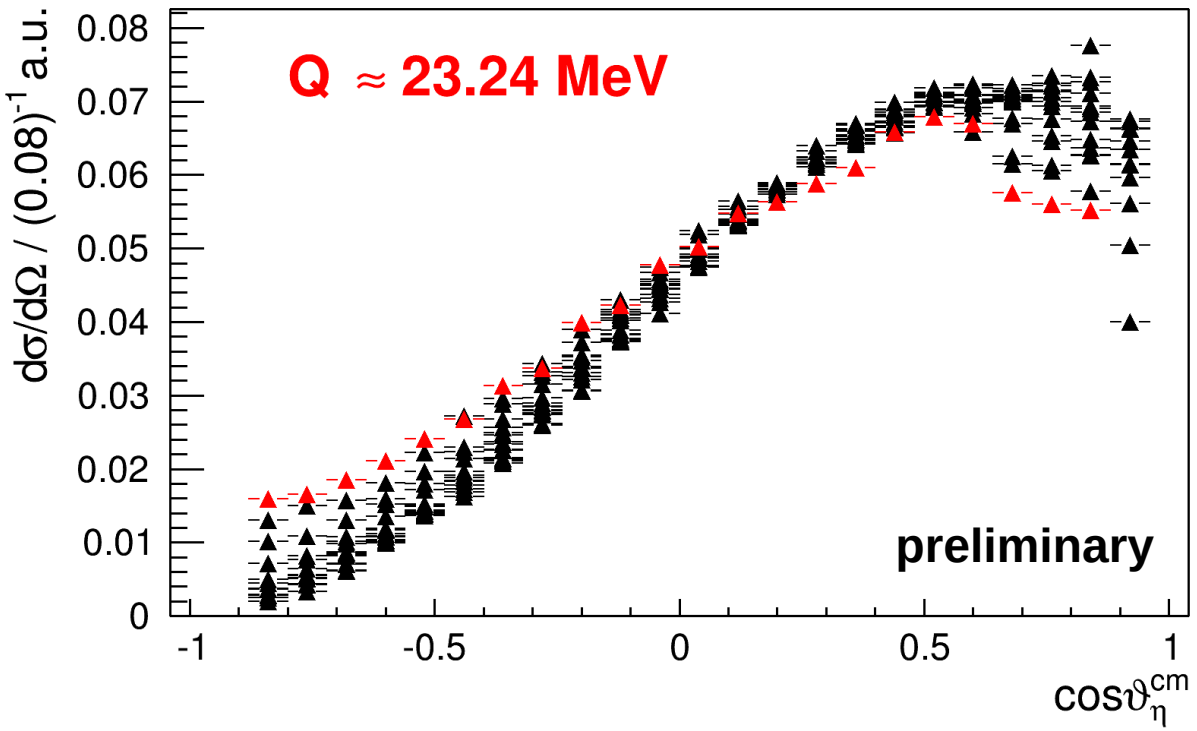

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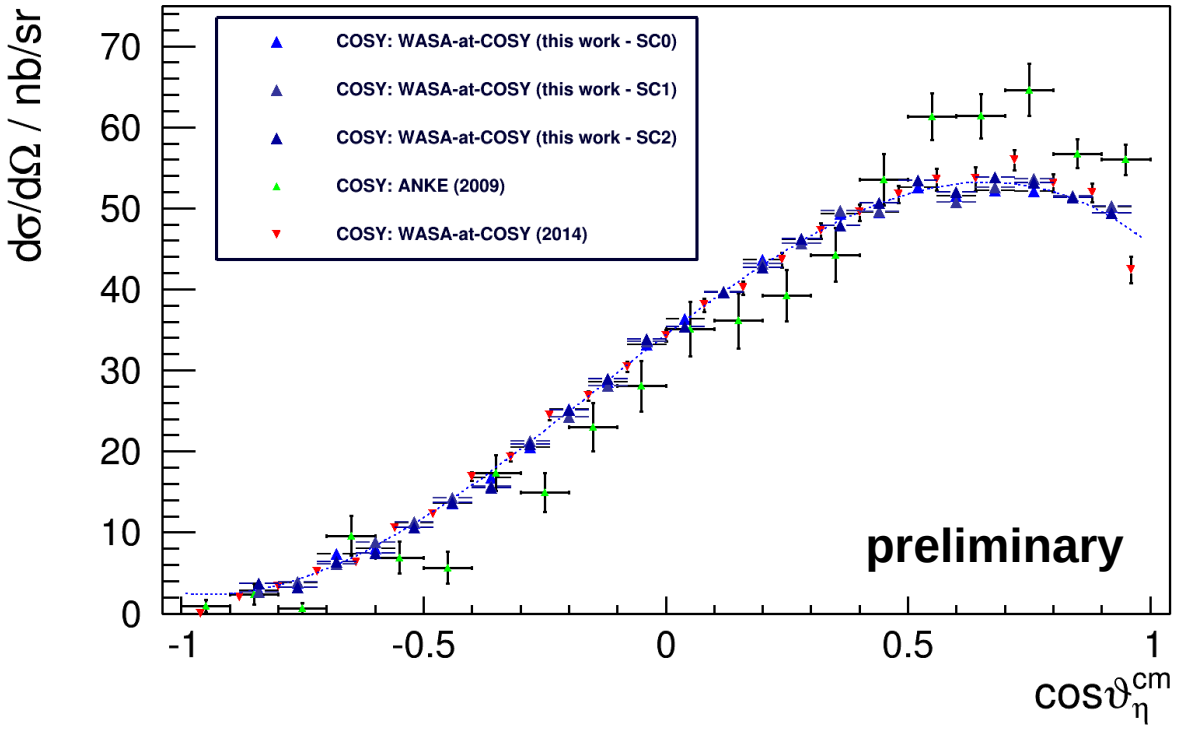

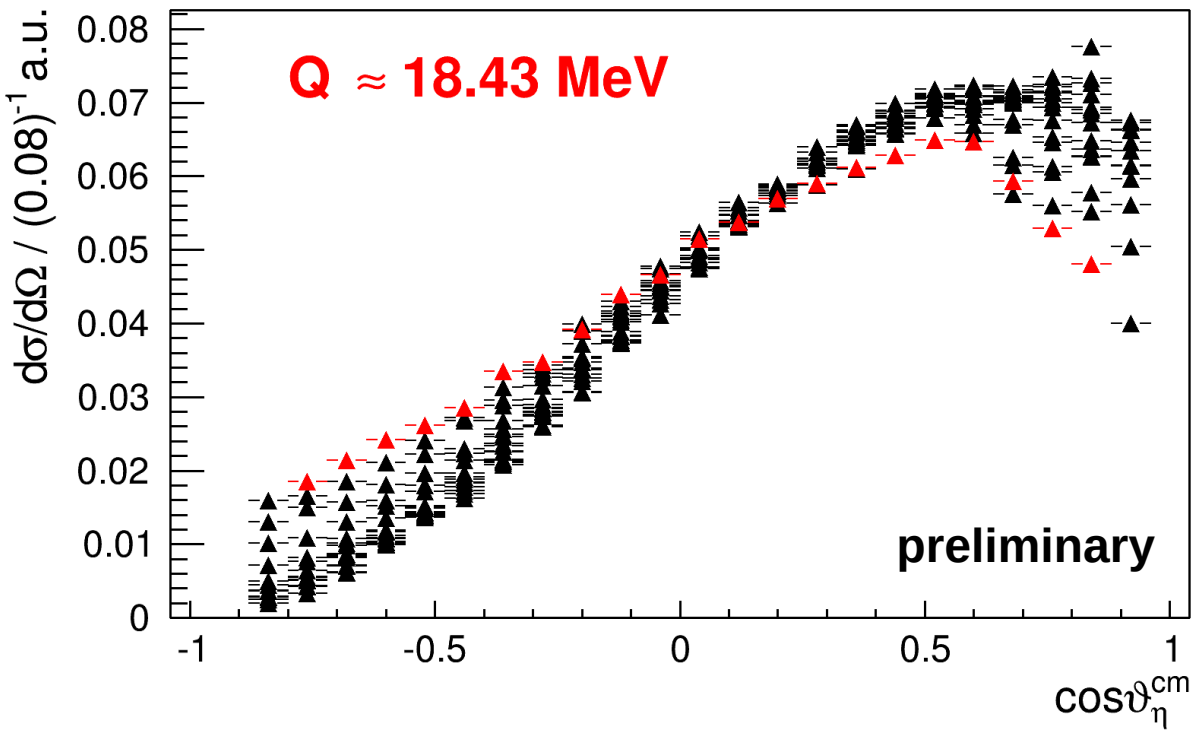

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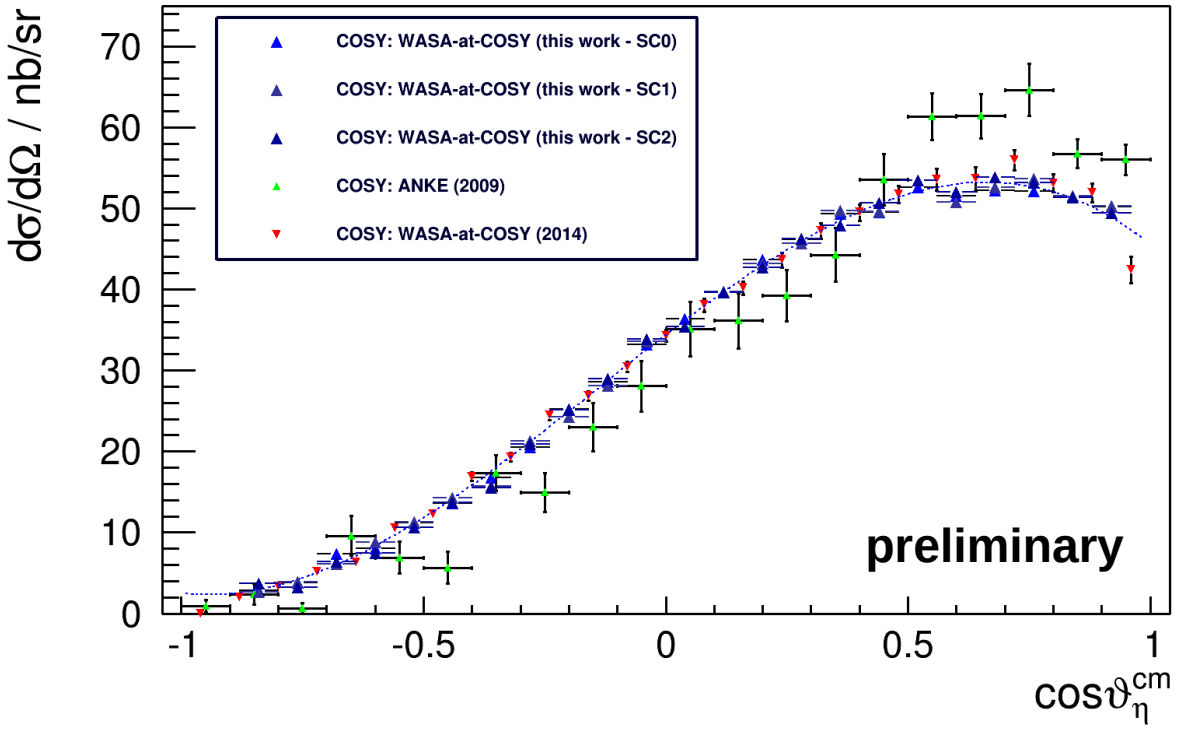
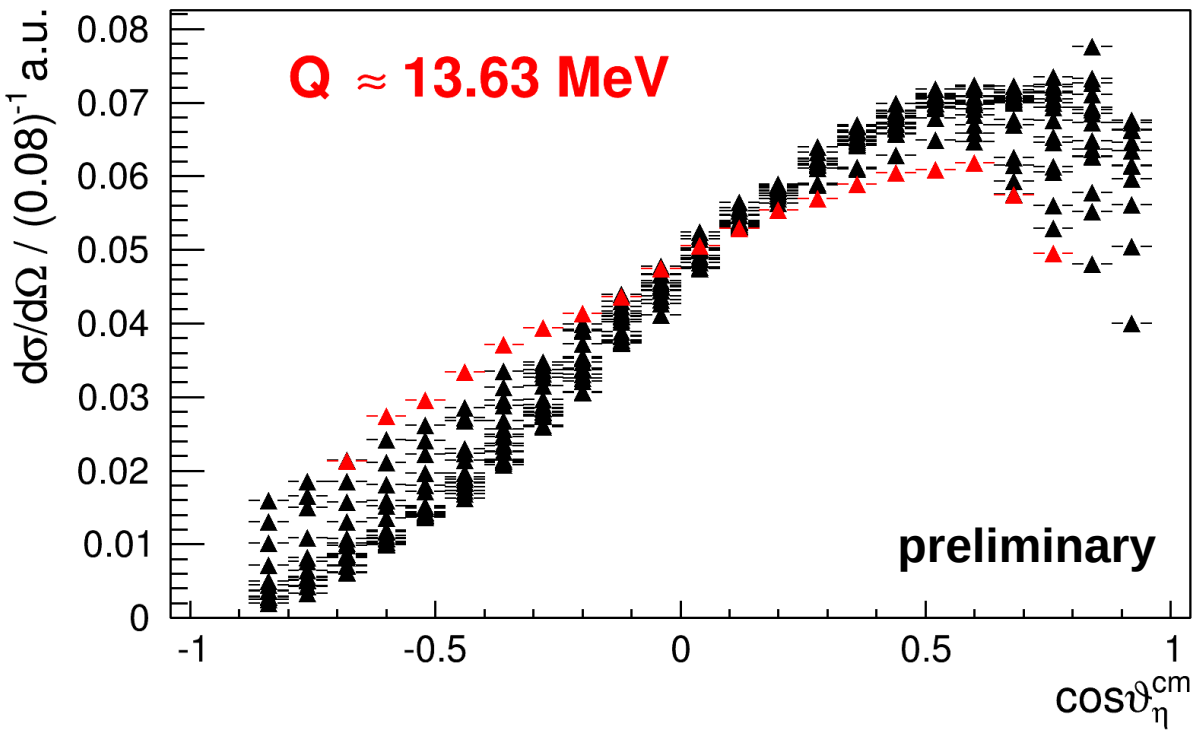
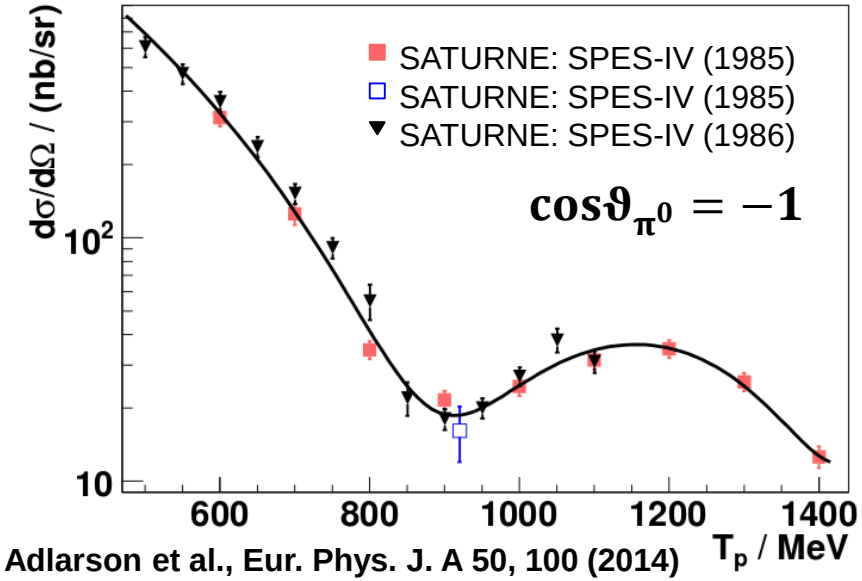




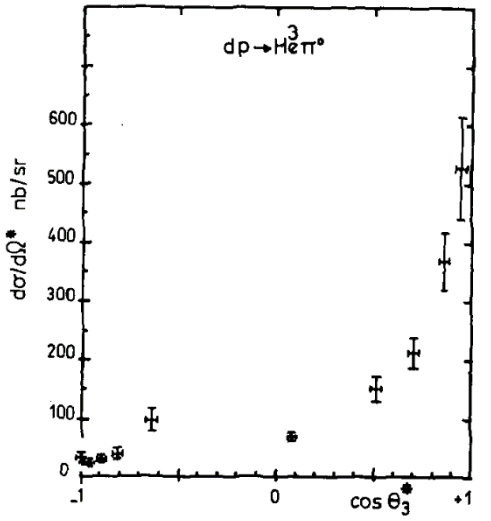
π^0 production

- broad database for $cos\vartheta_{\pi^0} = \pm 1$
- little information on angular distributions
- regularly used for luminosity determination in $pd \rightarrow {}^3HeX$ reactions

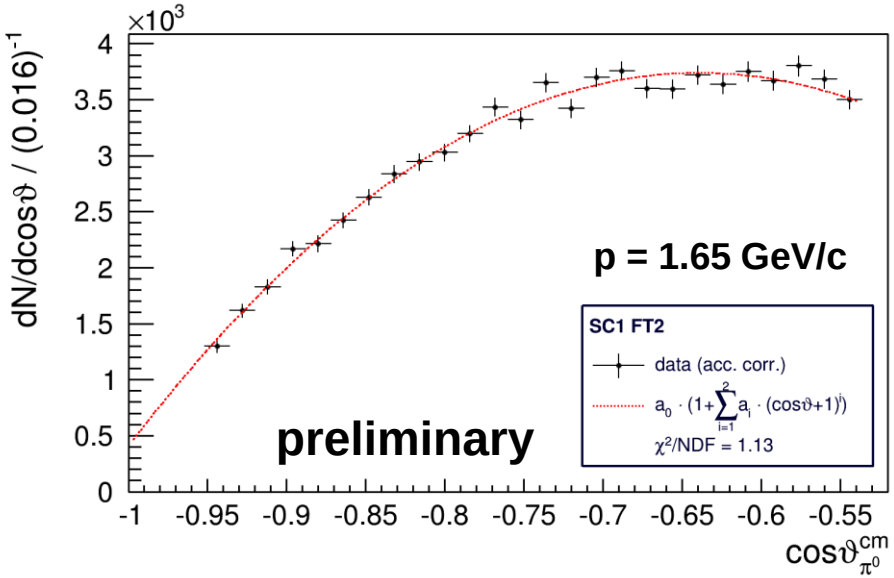
➢ extracting more information on angular distributions highly useful

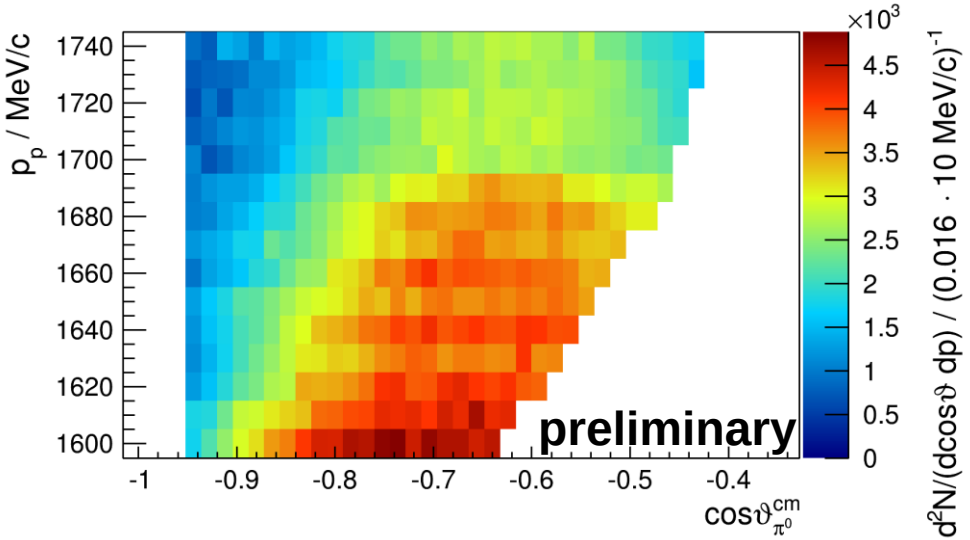


P. Adlarson et al., Eur. Phys. J. A 50, 100 (2014)



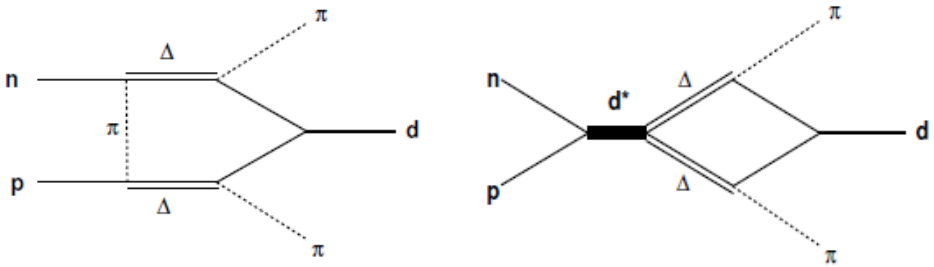
Banaigs, J. et al., Phys. Lett. 45B (1973), Nr. 4, 394



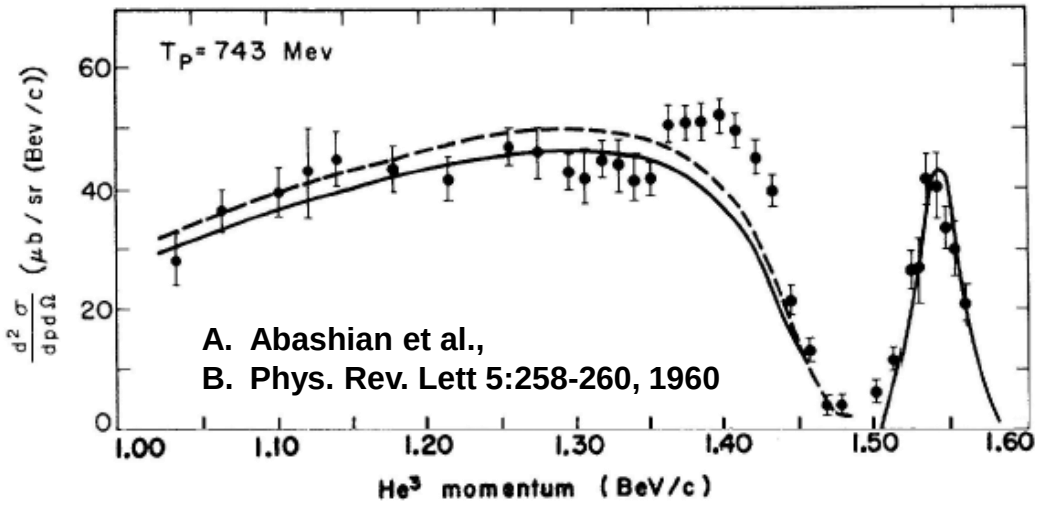


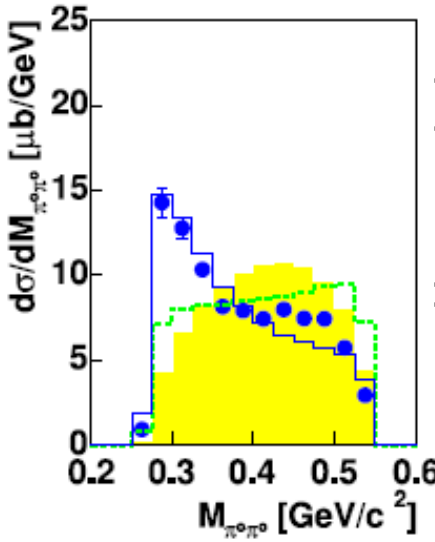
$\pi^0\pi^0$ production

- ABC effect discovered in 1960 by Abashian, Booth & Crowe
- first exclusive measurement only in 2005
- many explanations explored
  - ππ-FSI
  - ΔΔ production
  - recently: dibaryon d*(2380)

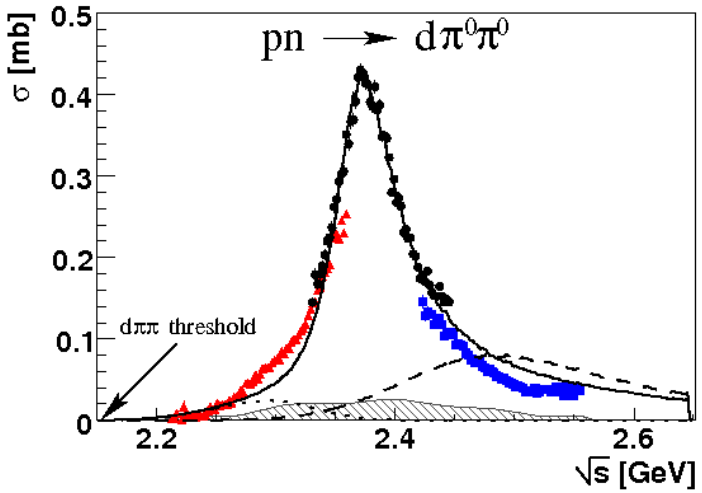


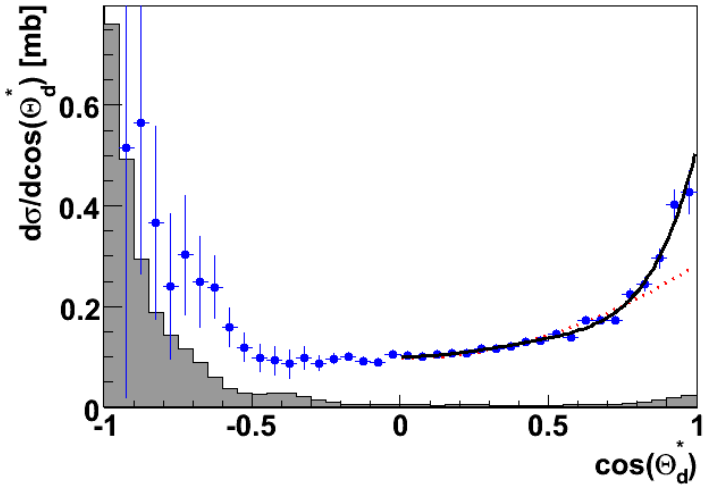
- connection to ^{3}He double pionic fusion?





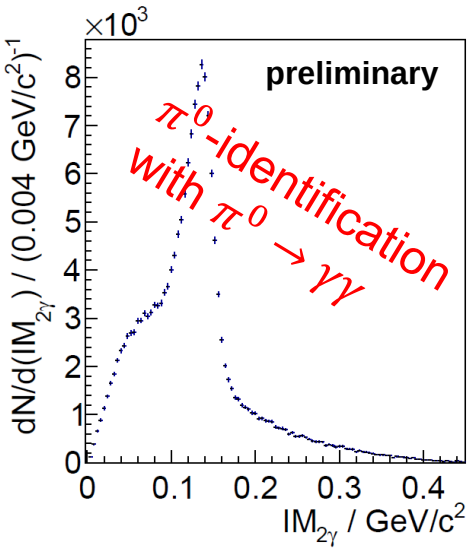
M. Bashkanov et al.,Phys. Lett. B 637:223-228, 2006.

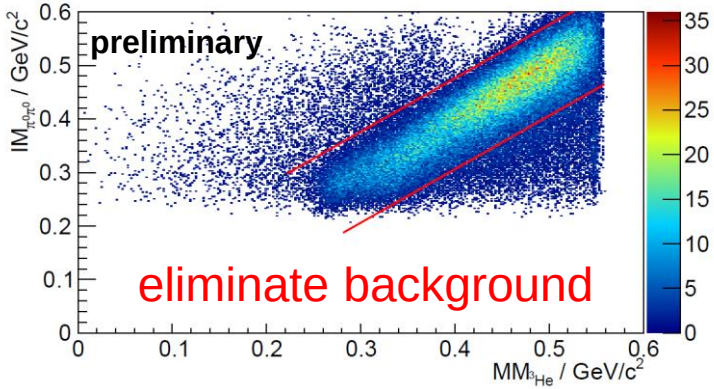


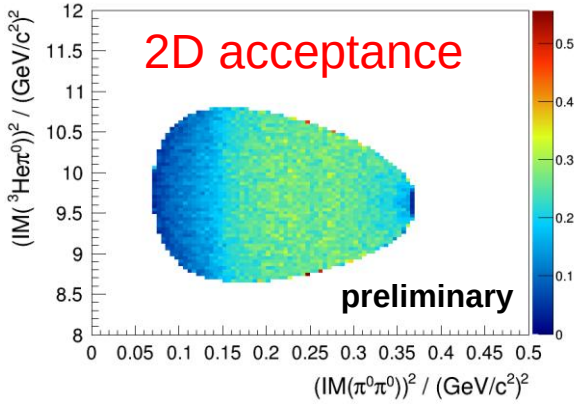


P. Adlarson et. al Phys. Rev. Lett. 106:242302, 2011

$\pi^0\pi^0$ production

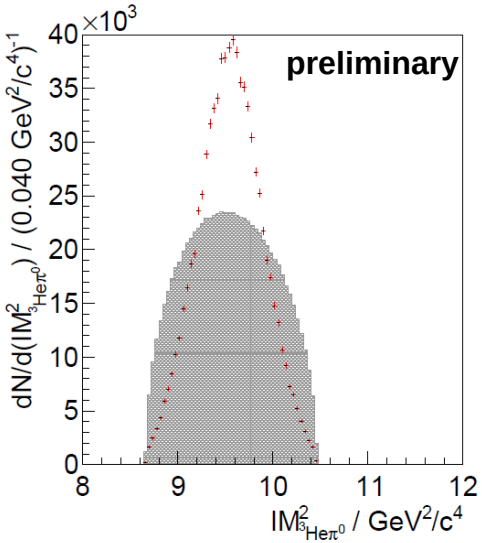


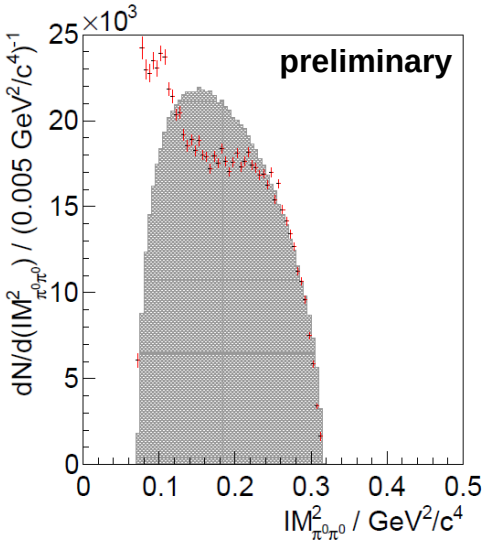


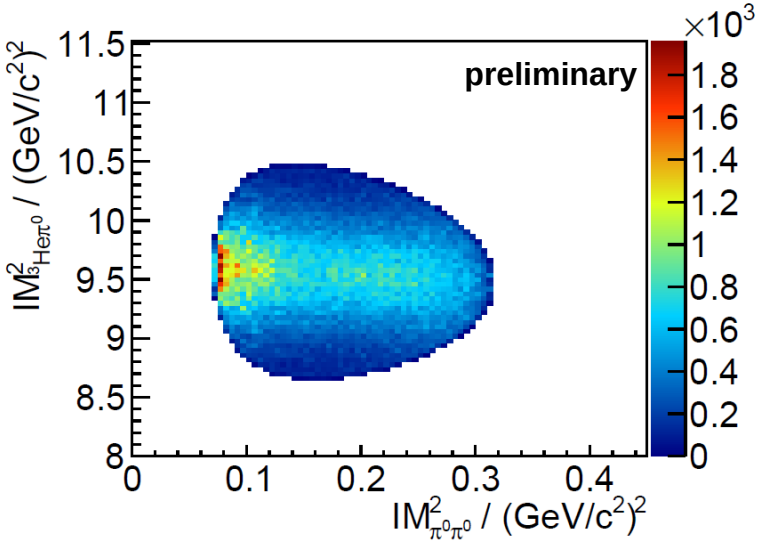


- π^0 reconstructed in $\gamma\gamma$ decay
- kinematically complete measurement of all final state particles
- kinematic fit can be used
- 2D acceptance correction performed

- $IM(\pi^0\pi^0)$ exhibits clearly visible ABC enhancement
- $IM(^3He\pi^0)$ hints at Δ-contributions
- high statistics allow detailed differential distributions



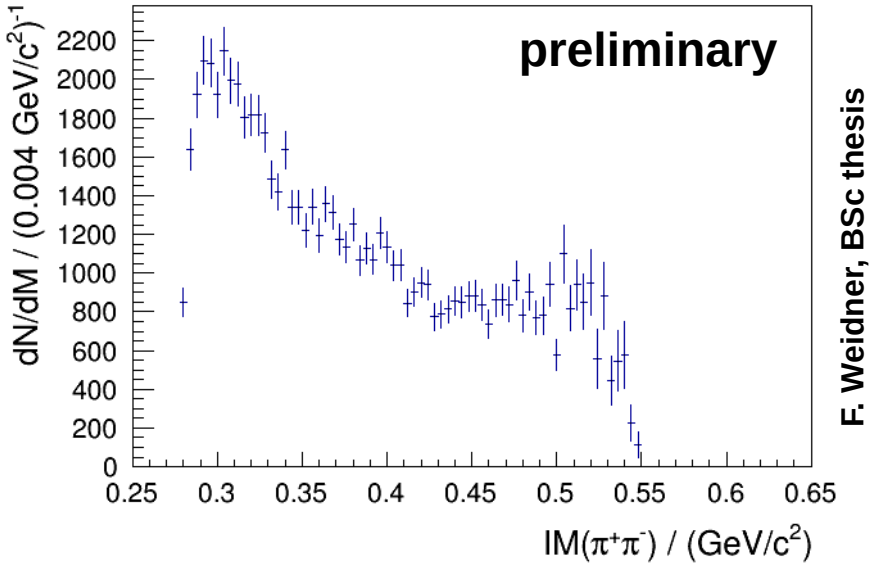


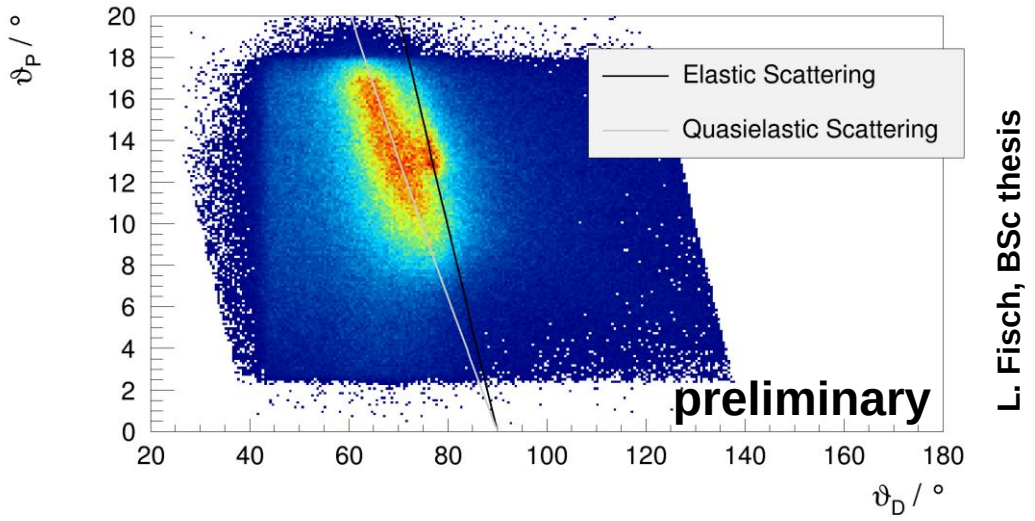


All figures from: L. Wölfer, BSc Thesis

Summary & Outlook

- new $\mathrm{pd} \rightarrow {}^{3}\mathrm{HeX}$ dataset at 15 different p_p between 1.60 GeV/c and 1.74 GeV/c
- no consensus on the η-production mechanism away from threshold
- detailed investigation of ϑ and Q dependency will provide new insight
- considerable extension of the current ${}^{3}\mathrm{He}\pi^{0}$ database
- ${}^{3}\mathrm{He}\pi^{0}\pi^{0}$ can be studied in unprecedented detail
- ${}^{3}\mathrm{He}\pi^{+}\pi^{-}$ currently under investigation
- (relative) normalization using pd elastic scattering





Thank you for your attention!

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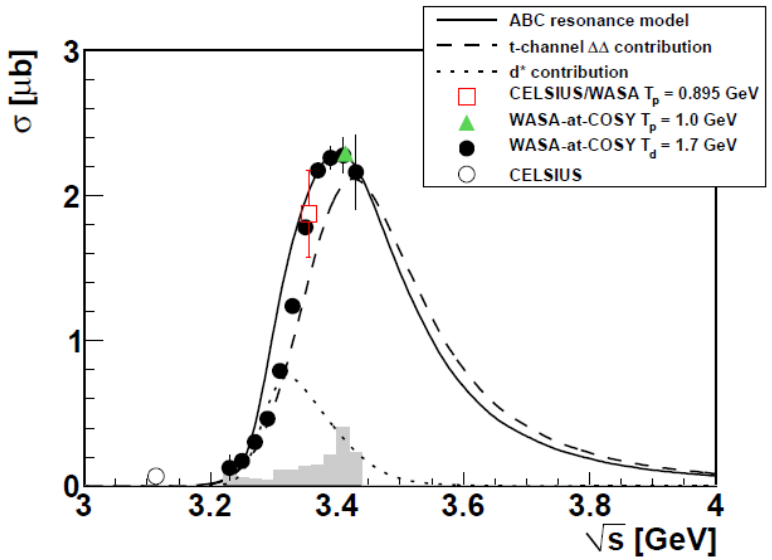
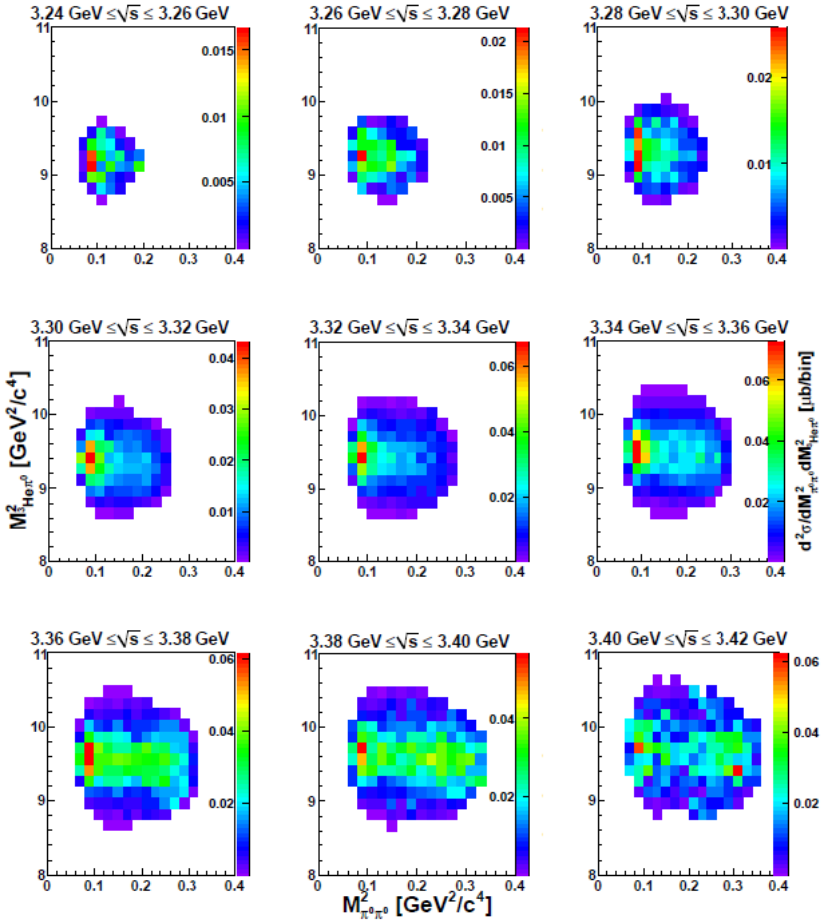
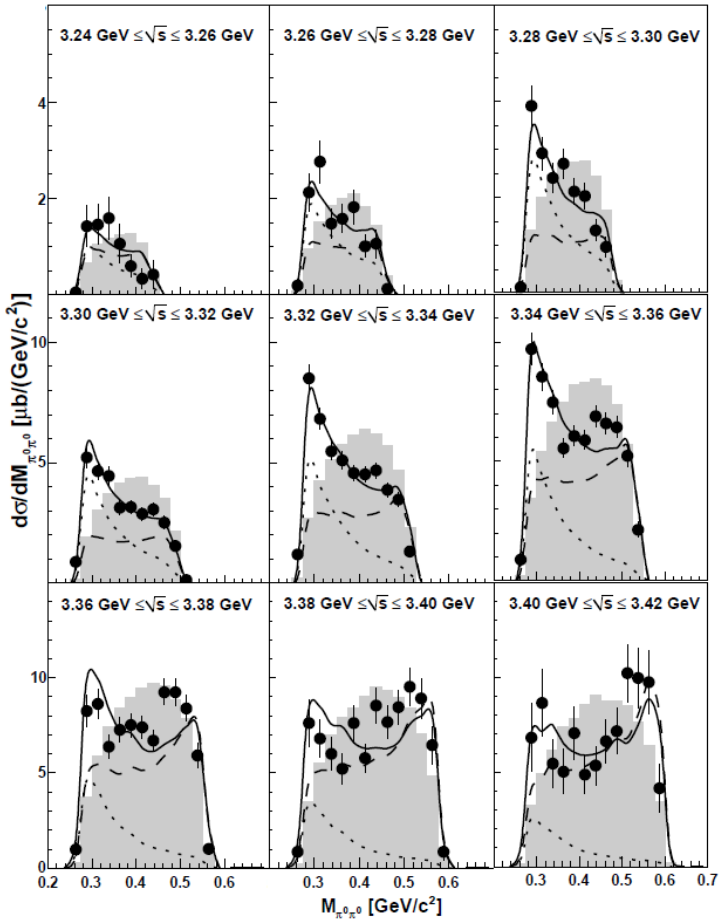
$^3He\pi^0\pi^0$ and the d*(2380) resonance

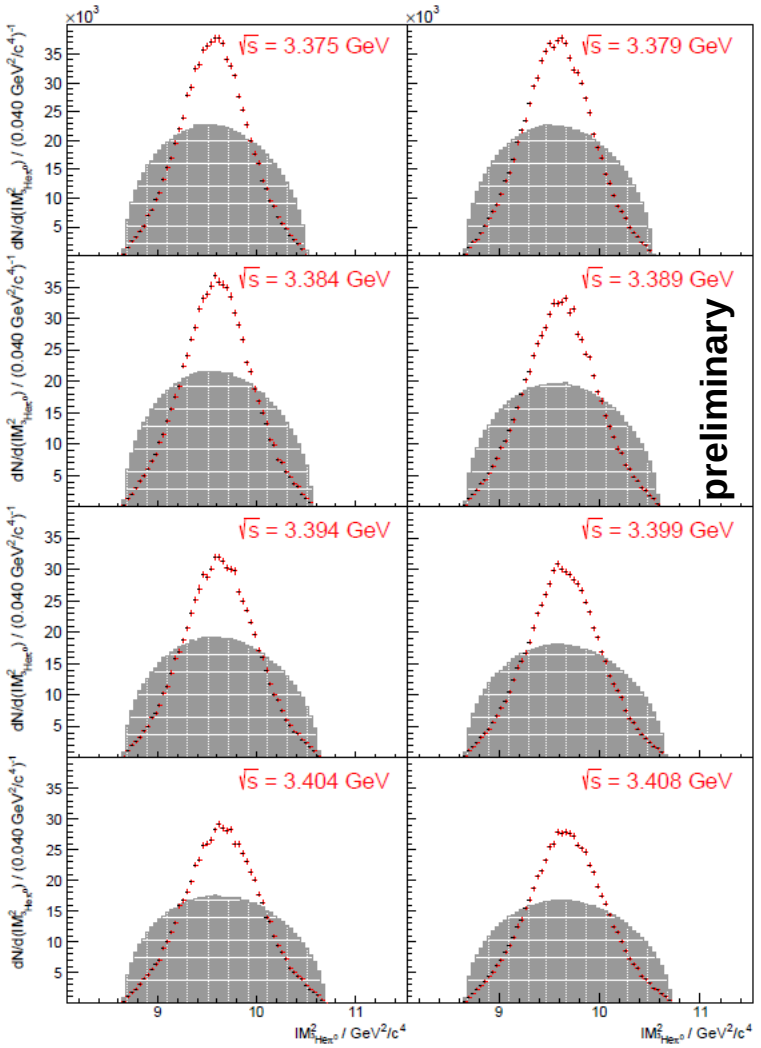


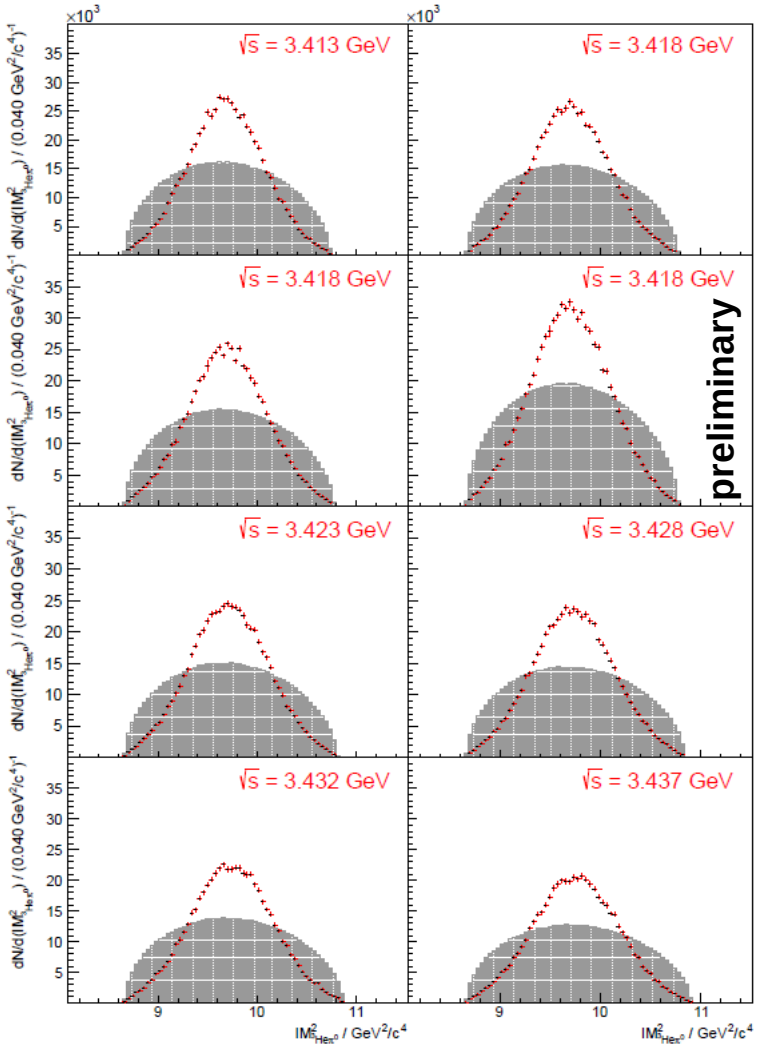




E. Pérez del Río: ABC Effect and d* Resonance in Double-Pionic Fusion to ^3He

Backup





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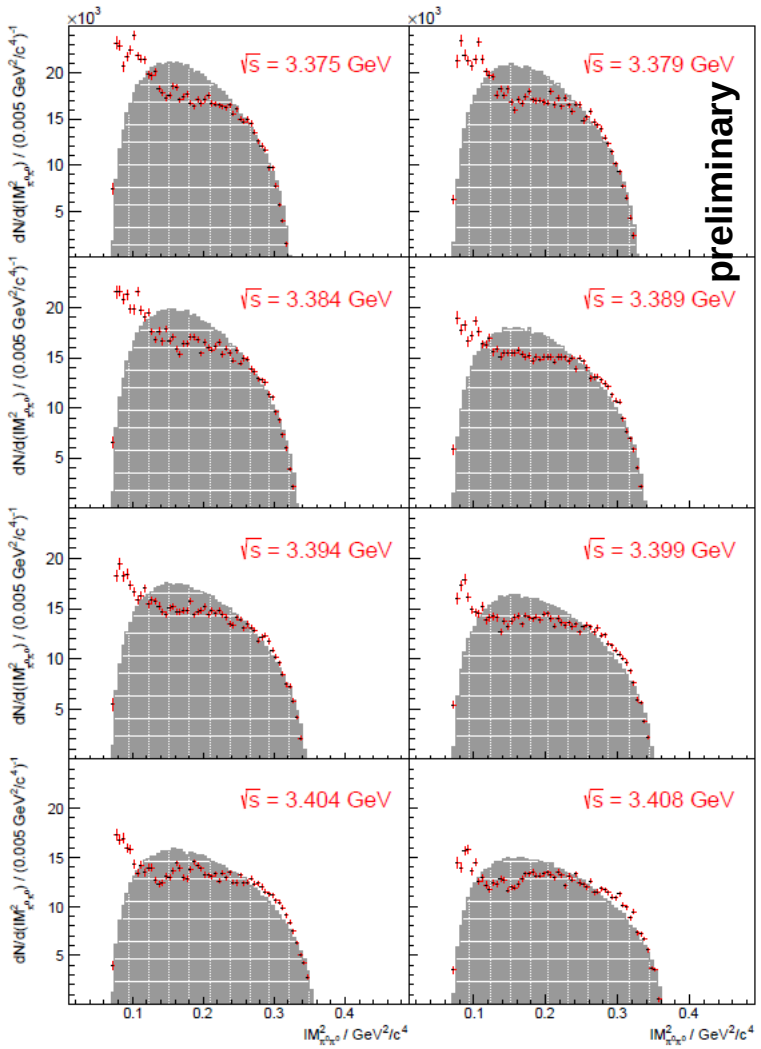

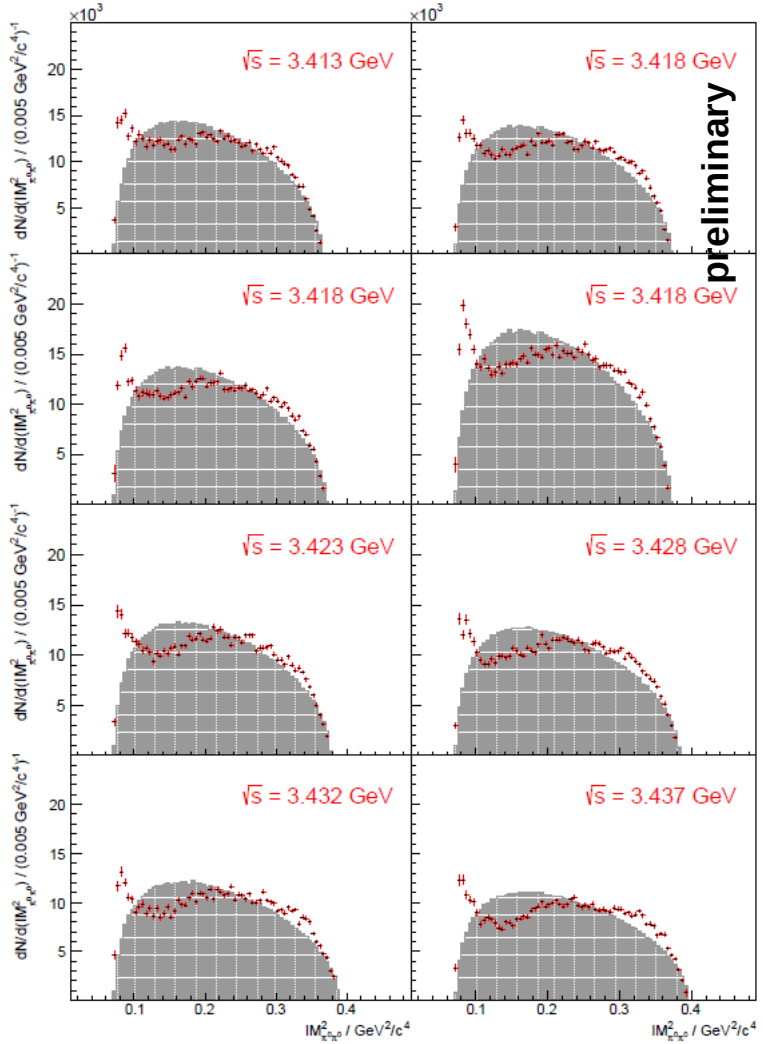

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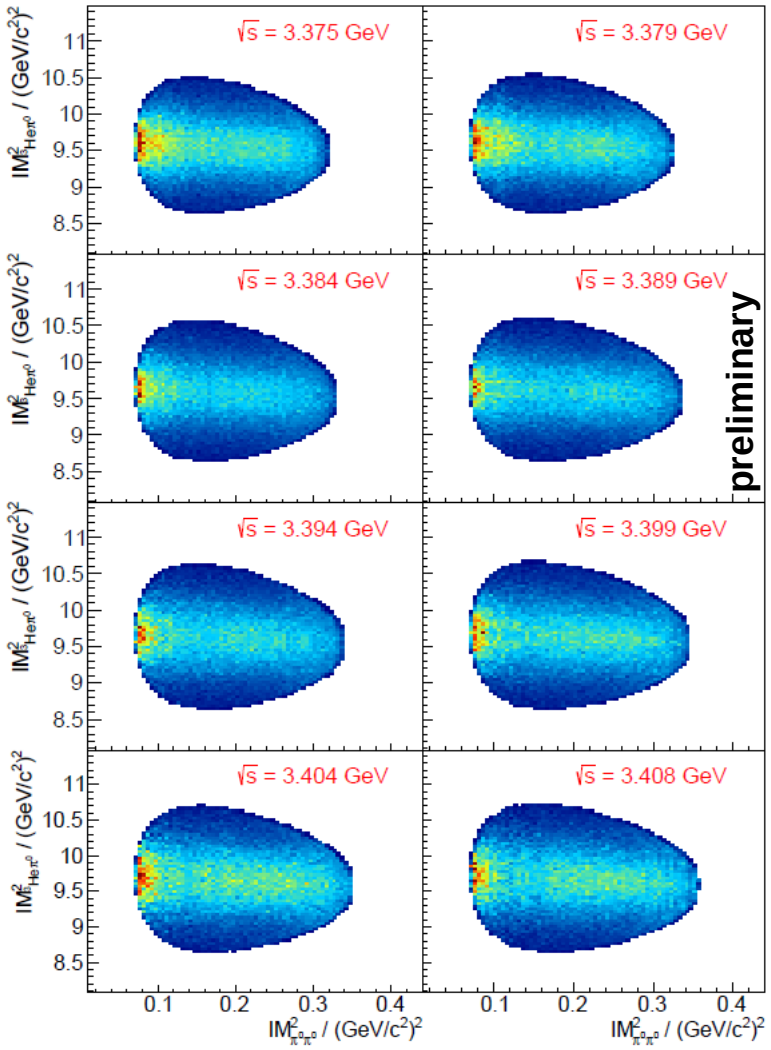

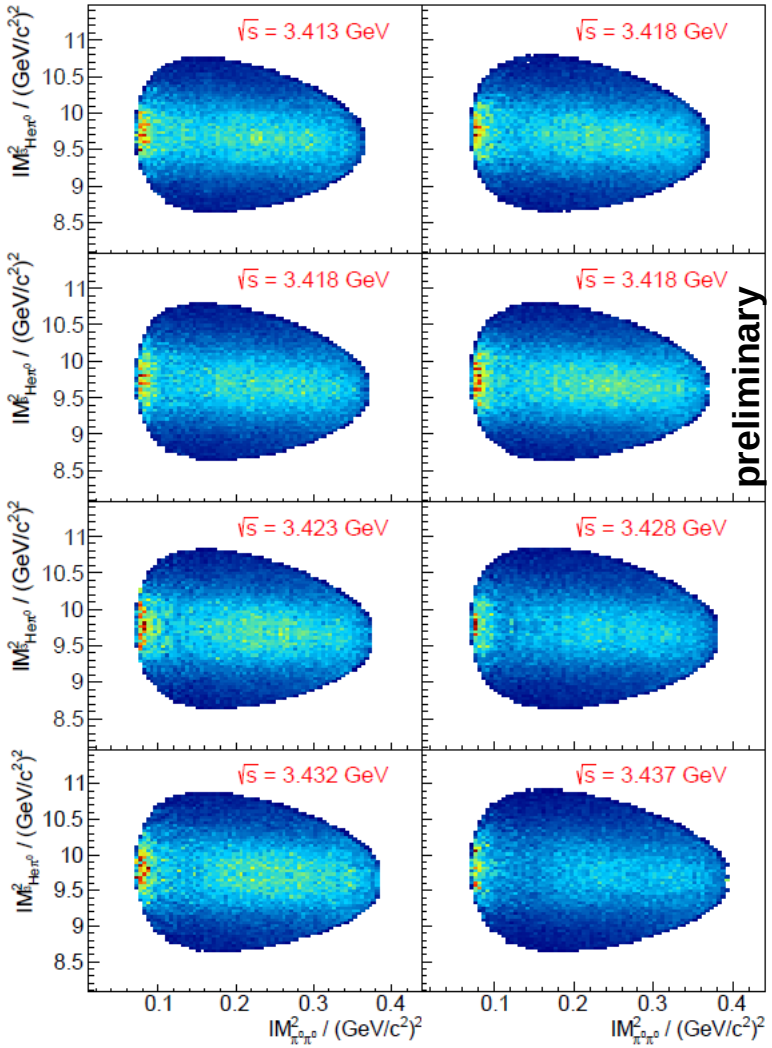

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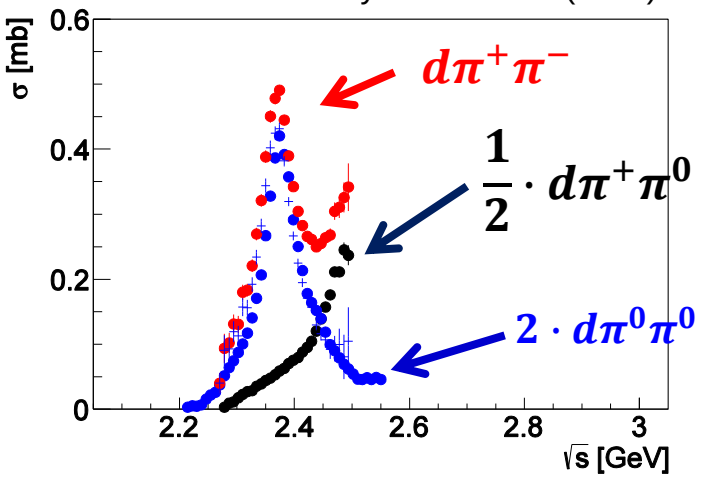
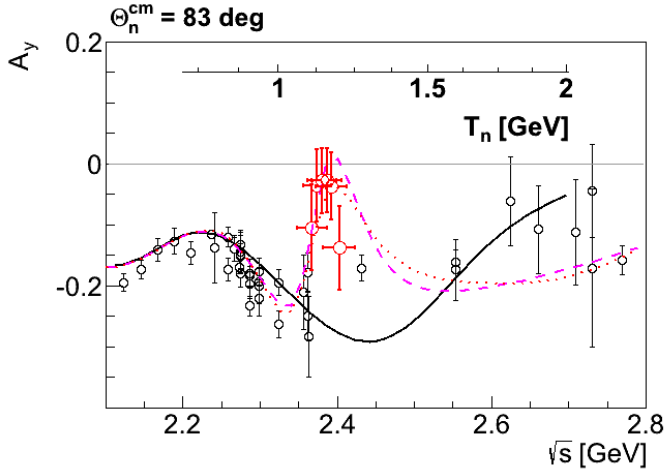
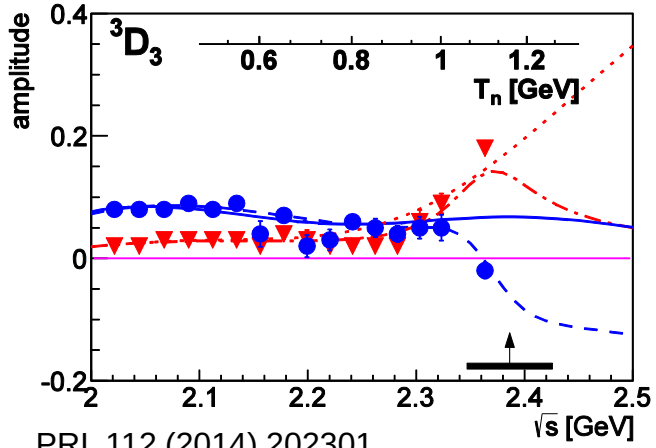
- subsequently, the dibaryon was confirmed in other channels

$$pn \to d^* \to pn$$

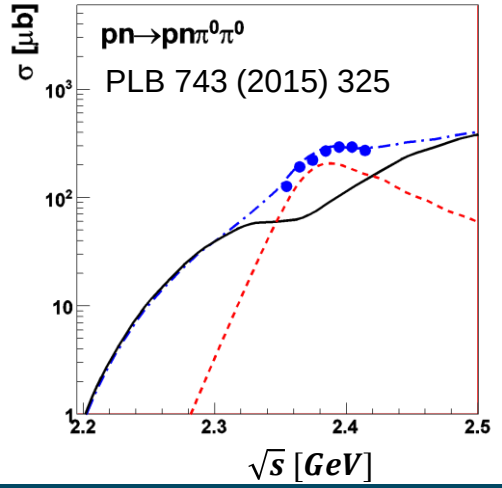
P. Adlarson et. al Phys. Lett. B721 (2013) 229

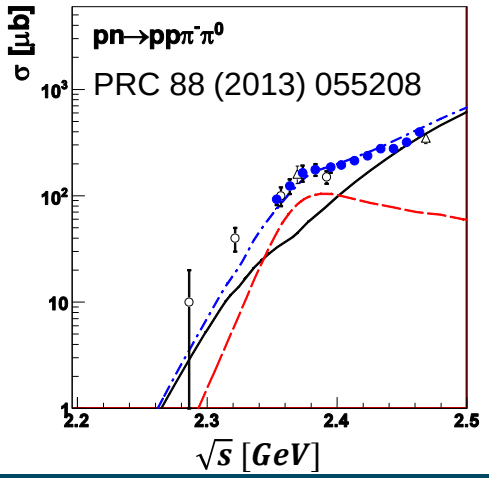


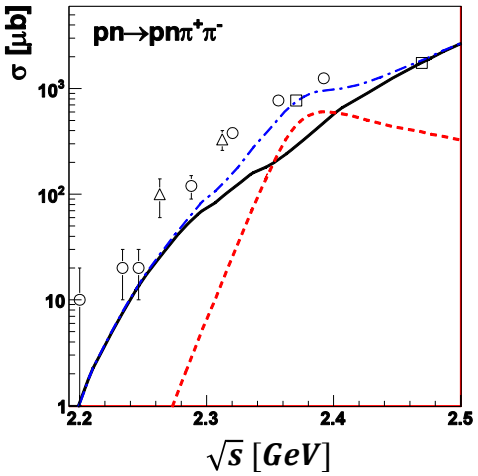




PRL 112 (2014) 202301
PRC **90**, (2014) 035204

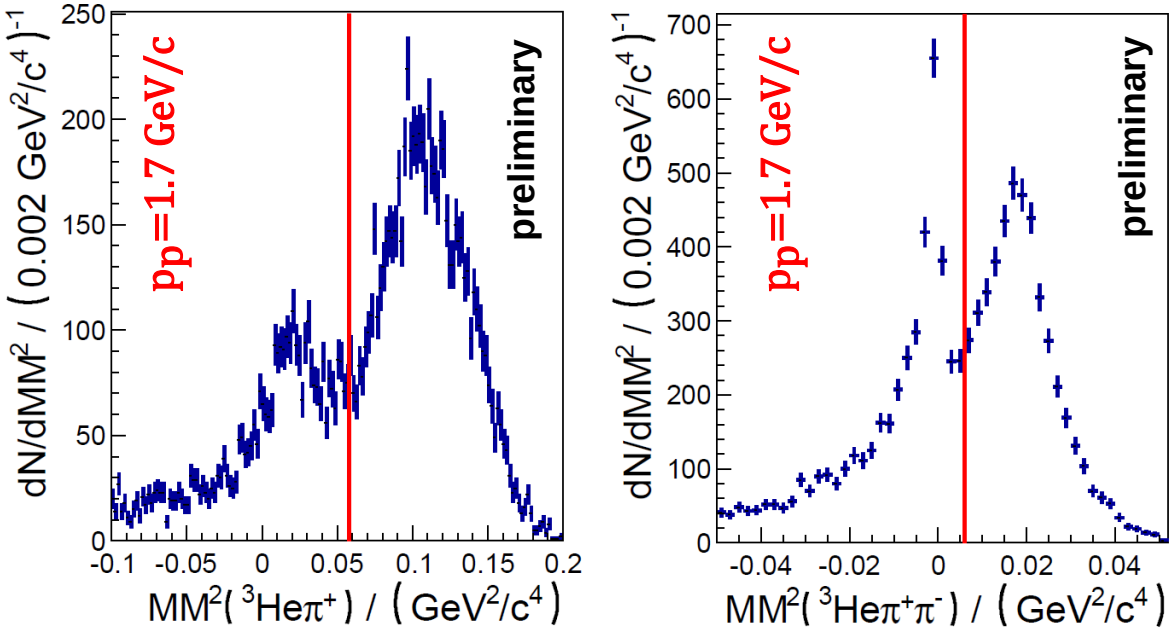


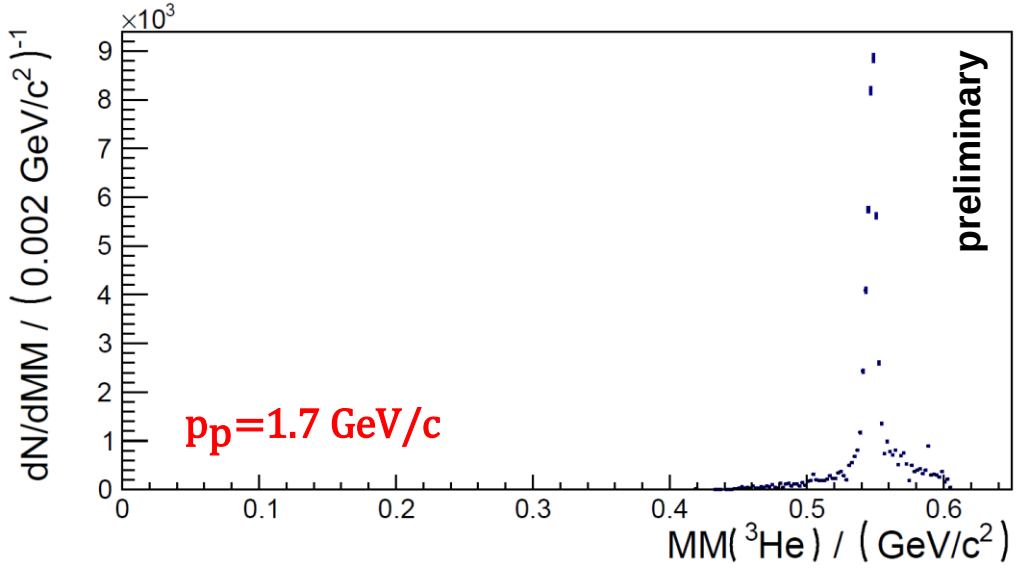


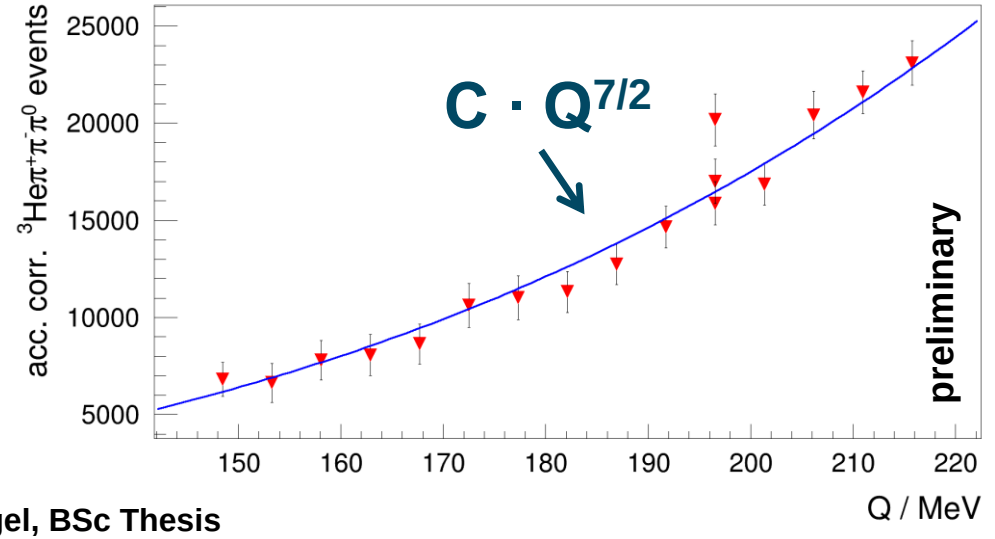


Backup

- $\pi^+\pi^-\pi^0$ production can also be studied
- nearly clean sample after cuts on MM(^{3}Heπ) and MM(^{3}He$\pi\pi$)
- clear η signal, on top of direct $\pi^+\pi^-\pi^0$ production





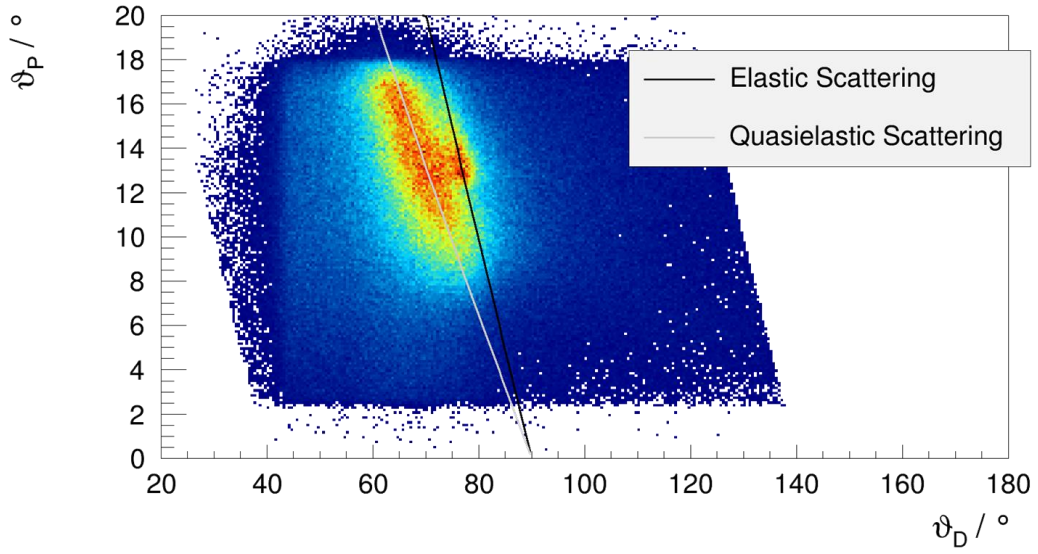


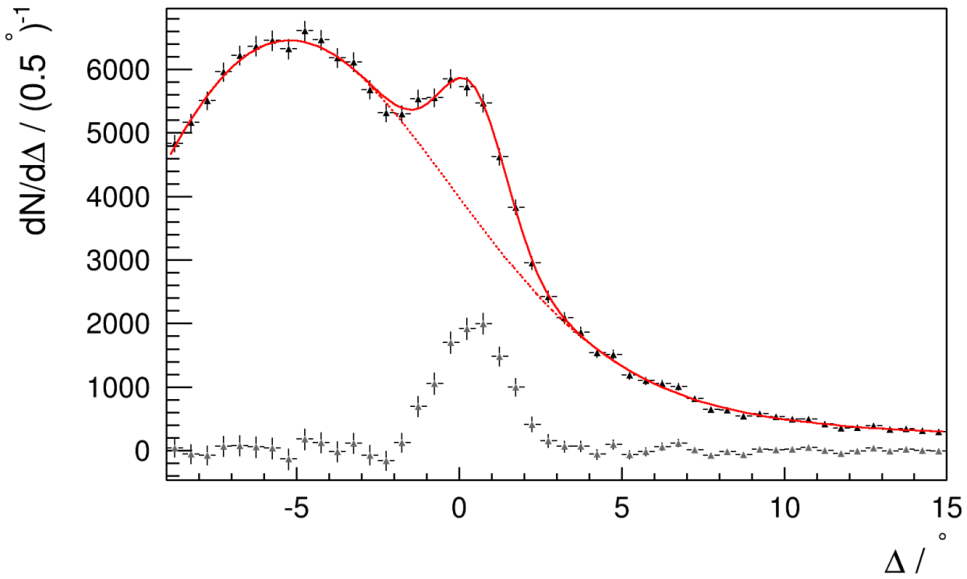
J. v. Wrangel, BSc Thesis

Backup

pd elastic scattering

- identified by scattering angle measurement
- signal/background separation using the difference to expected relation
- broad database of t-dependent cross sections available
- will allow for a normalization with a point-to-point uncertainty of ≈ 10%





L. Fisch, BSc thesis

Backup