Westfälische Wilhelms-Universität Münster

Investigation of the p+d→^{3}He+η' reaction at WASA-at-COSY

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on behalf of the WASA-at-COSY collaboration

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Why is $p+d \rightarrow {}^3He+\eta'$ of interest?

The higher mass of the $\eta'(958)$ compared to other pseudoscalar mesons is related to the $U_A(1)$ problem of QCD

Theoretical work by Nagahiro et. al. discusses the study of $\eta'(958)$ – mesic nuclei in order to investigate a mass reduction of the $\eta'(958)$ due to partial restoration of chiral symmetry

The U(1) problem*

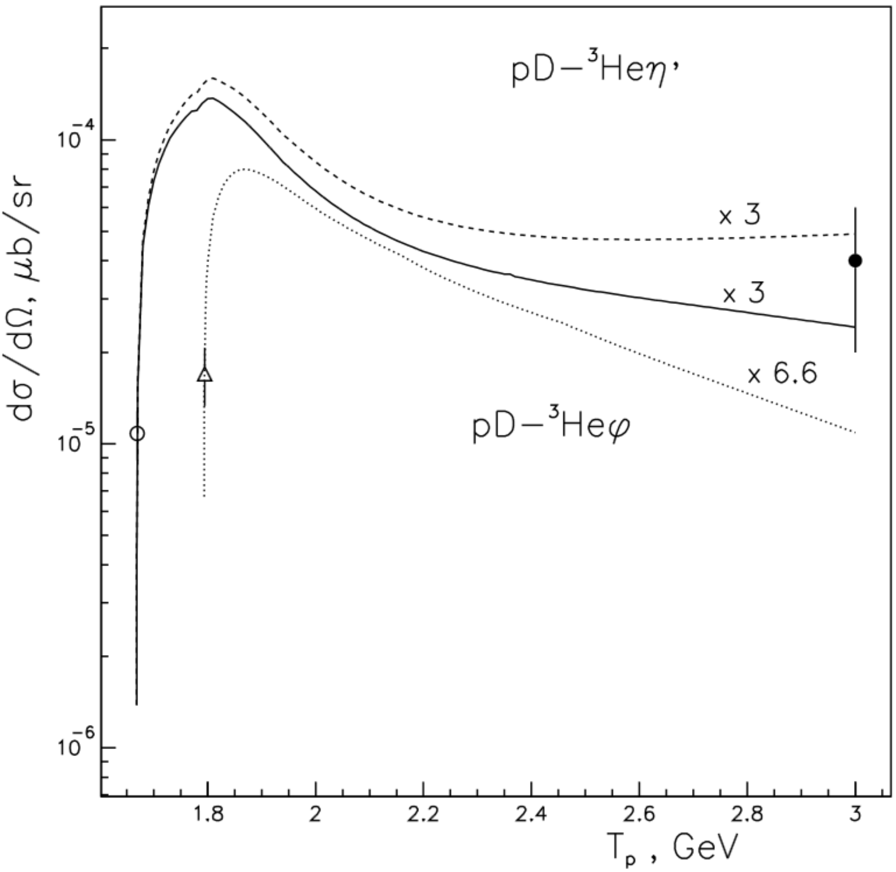
Steven Weinberg
Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts 02138
(Received 10 March 1975)

A detailed analysis of the problems associated with the conserved U(1) axial-vector current in quark-gluon models is presented. It is shown that such models involve a light isoscalar pseudoscalar boson, with a mass less than $\sqrt{3}\, m_\pi$. The existence of this boson would produce a strong off-shell variation in the $\eta \rightarrow 3\pi$ matrix element, thus invalidating the usual conclusions about the rate and energy dependence of this decay. Following Kogut and Susskind, it is proposed that the light Goldstone boson is actually a dipole, with positive- and negative-metric parts, which cancel in matrix elements of gluon-gauge-invariant operators but not in operators such as the U(1) current. It is shown that the masses of the observable pseudoscalar bosons and the η decay rate are then just as they would be in a theory without the U(1) symmetry, and in fair agreement with experiment. The application of current algebra to theories with charmed quarks is briefly discussed.

$$m^2 = \begin{cases} \dfrac{3m_\pi^2}{1+2z^2} + O\left(\dfrac{m_\pi^4}{m_K^2}\right) & , \\[2ex] \tfrac{4}{3} m_K^2 \left(1 + \tfrac{1}{2z^2}\right) + O\left(m_\pi^2\right) & . \end{cases}$$

S. Weinberg, Phys. Rev D 11, 3583 (1975)
H. Nagahiro et al., Phys. Rev. C 85, 032201(R) (2012)

Motivation for our measurements

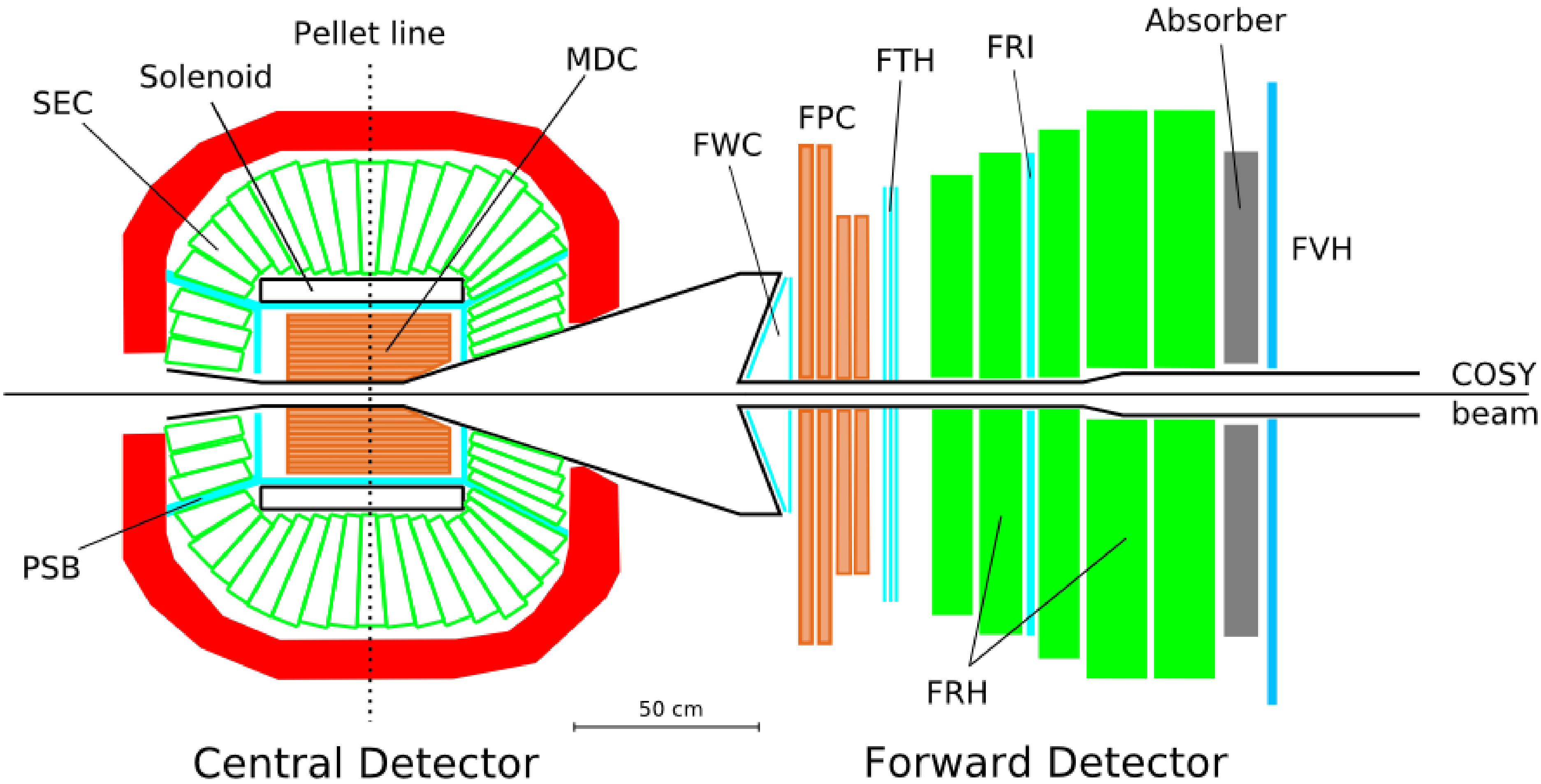


Previous measurements and theoretical predictions (two-step mechanism) :

$d\sigma/d\Omega < 1$ nb/sr

Two test beamtimes at **T_P = 1800 MeV** & **T_P = 1850 MeV** with the WASA-at-COSY setup to determine cross sections and check for the feasibility of using this channel for studies on the $U_A(1)$ problem

Kondratyuk et al., Phys. At. Nucl. N3, 60:468-477 (1997)
R. Bertini et al., Preprint LNS/Ph/94-16
H. Brody et al., Phys. Rev. D9 (1974)

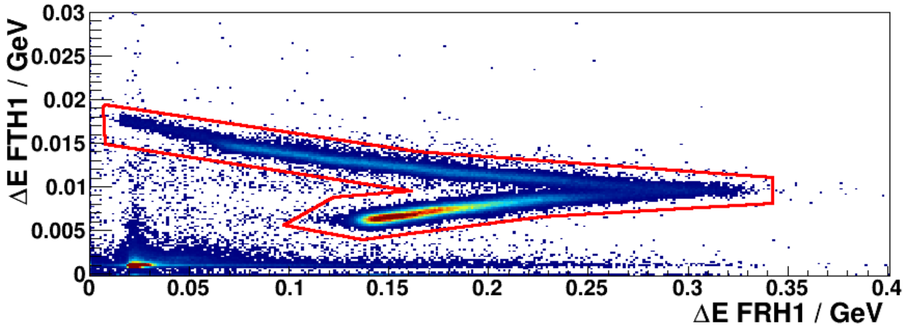


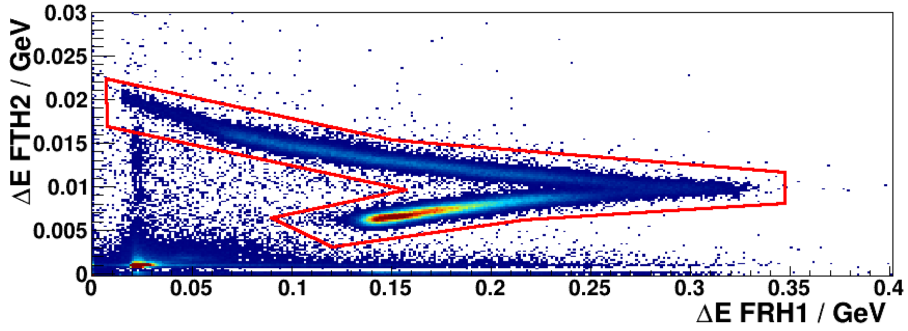
^{3}He detected in Forward Detector measuring (E,υ,φ) → Four-momentum

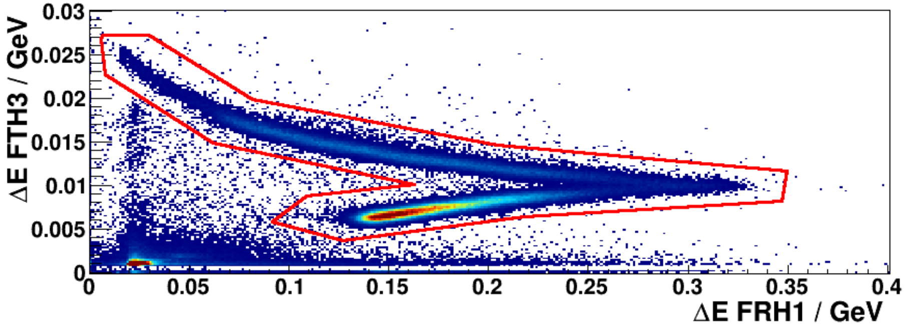
➢ missing mass technique

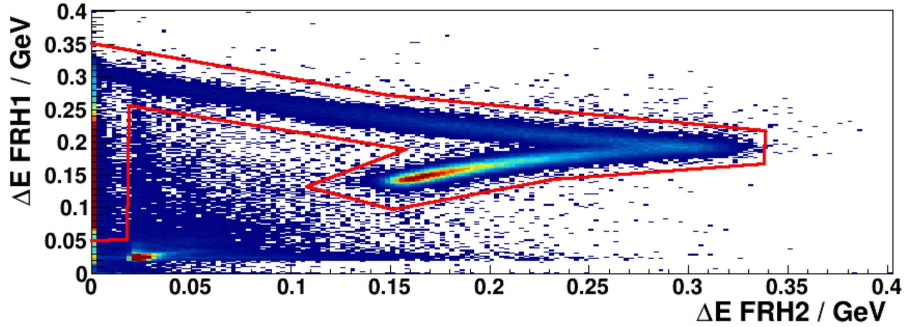
$$m_X = |\mathbb{P}_X| = |\mathbb{P}_p + \mathbb{P}_d - \mathbb{P}_{^3He}|$$

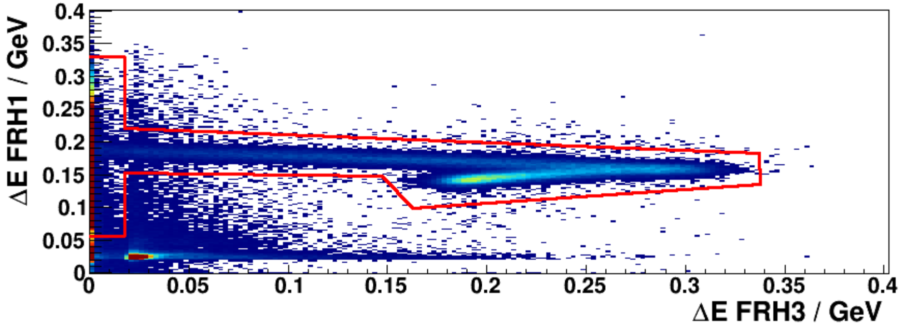
^{3}He identification - MC





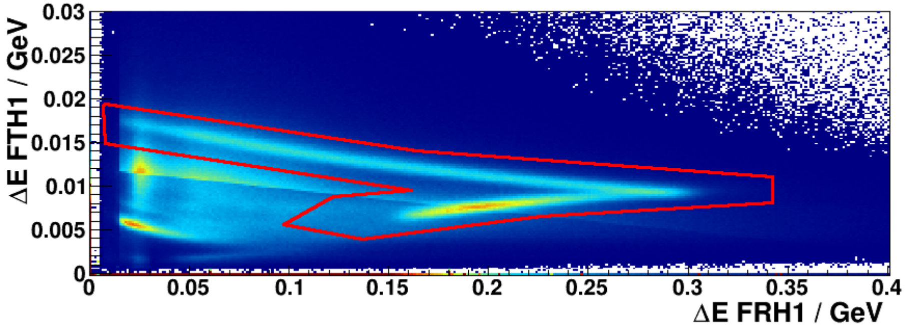


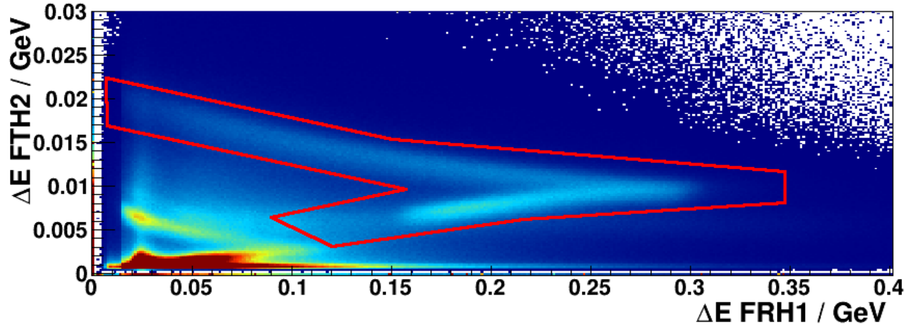


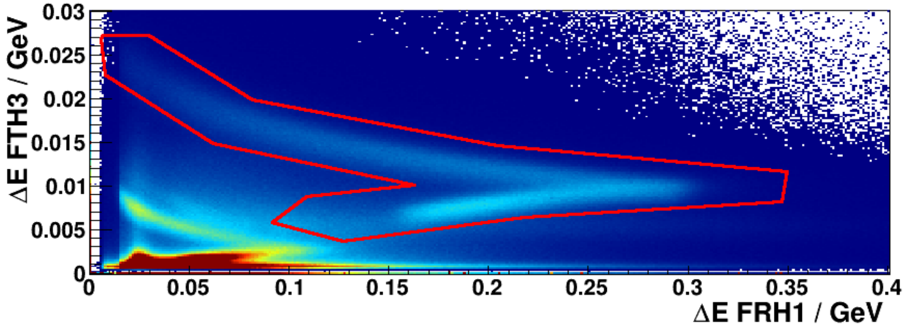


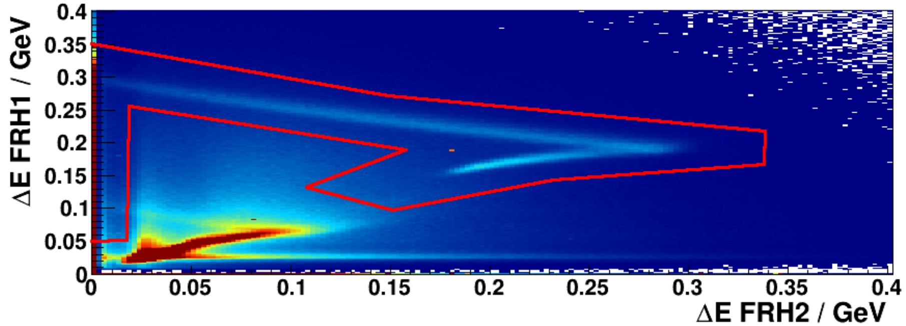
preliminary

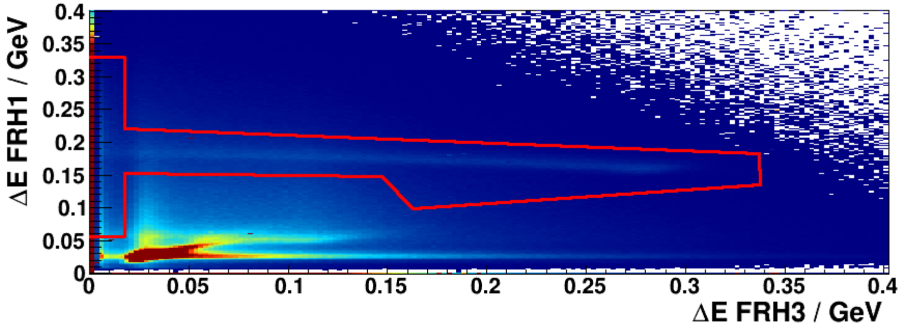
^{3}He identification - Data





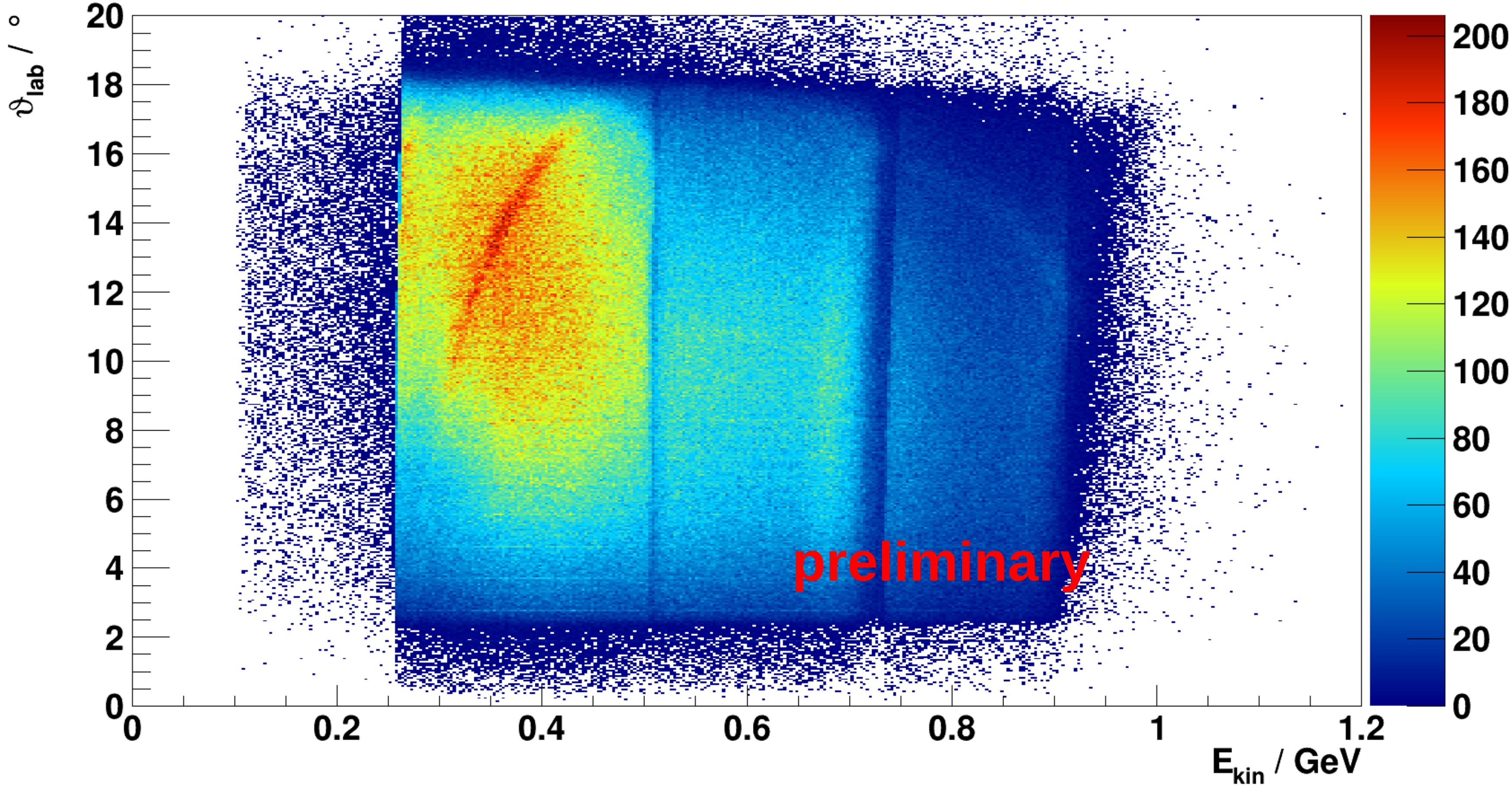




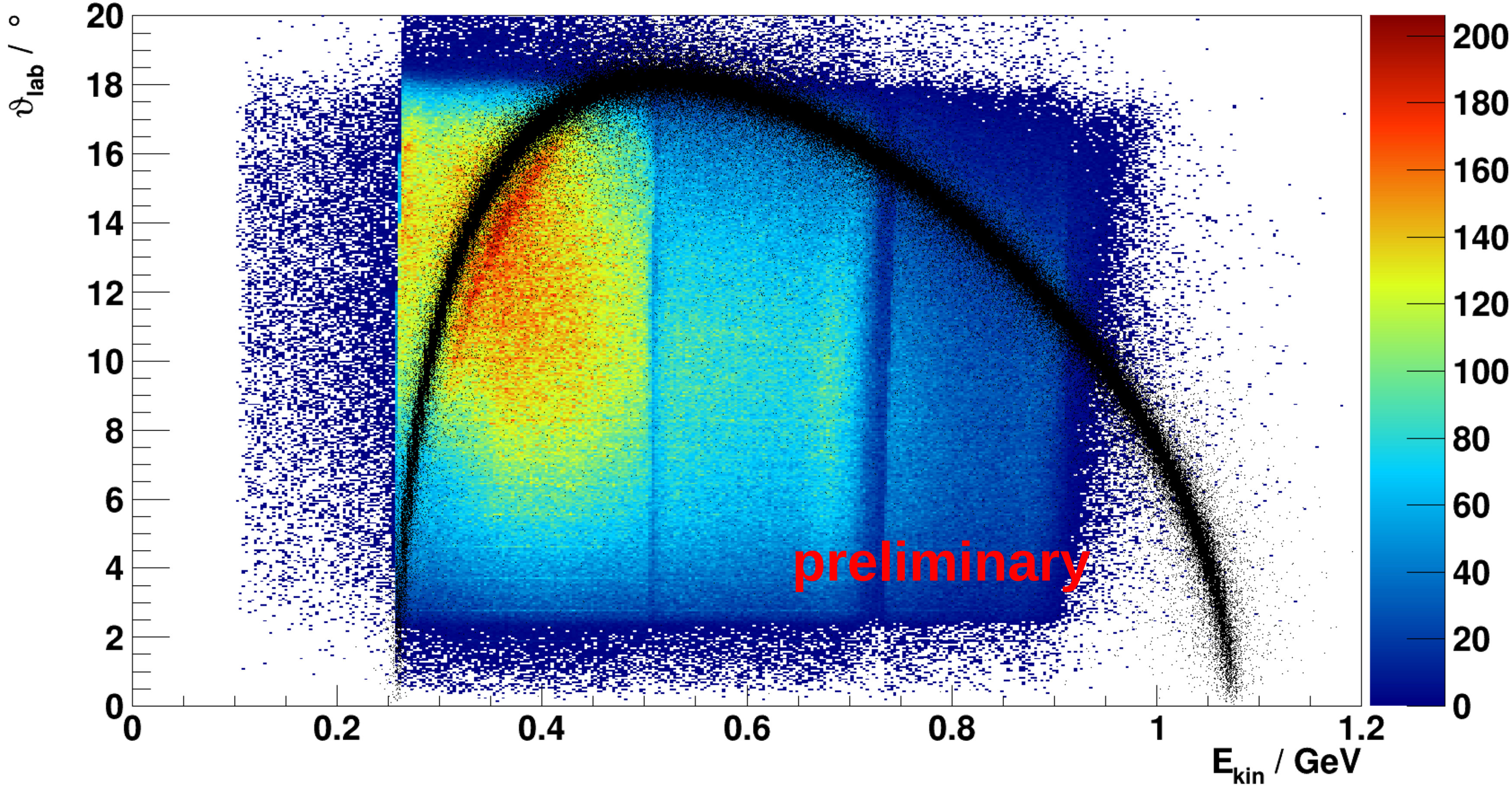


preliminary

- next step: fine tuning the calibration via $p + d \rightarrow {}^3He + \omega$

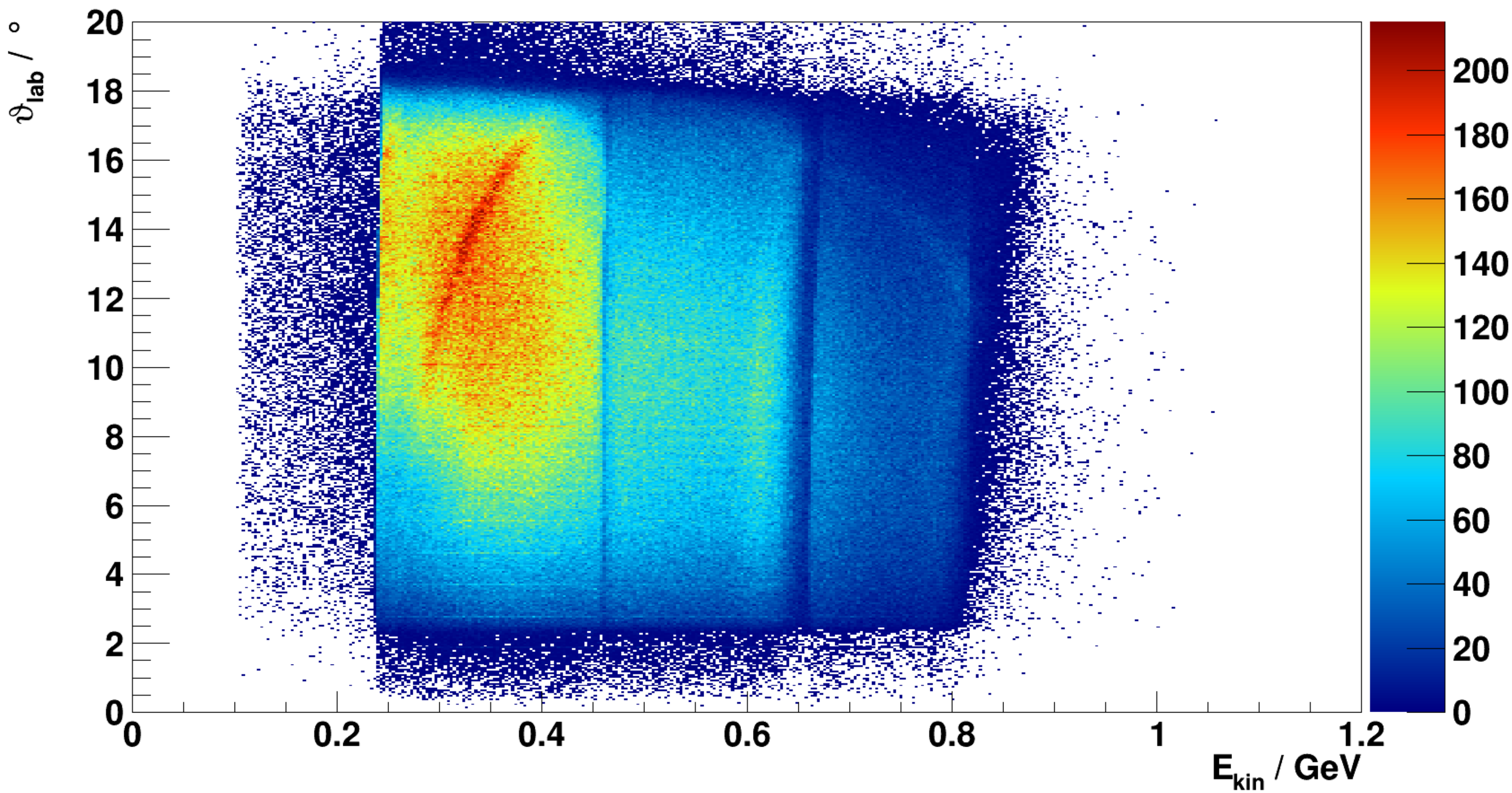


- offset between MC simulation and data



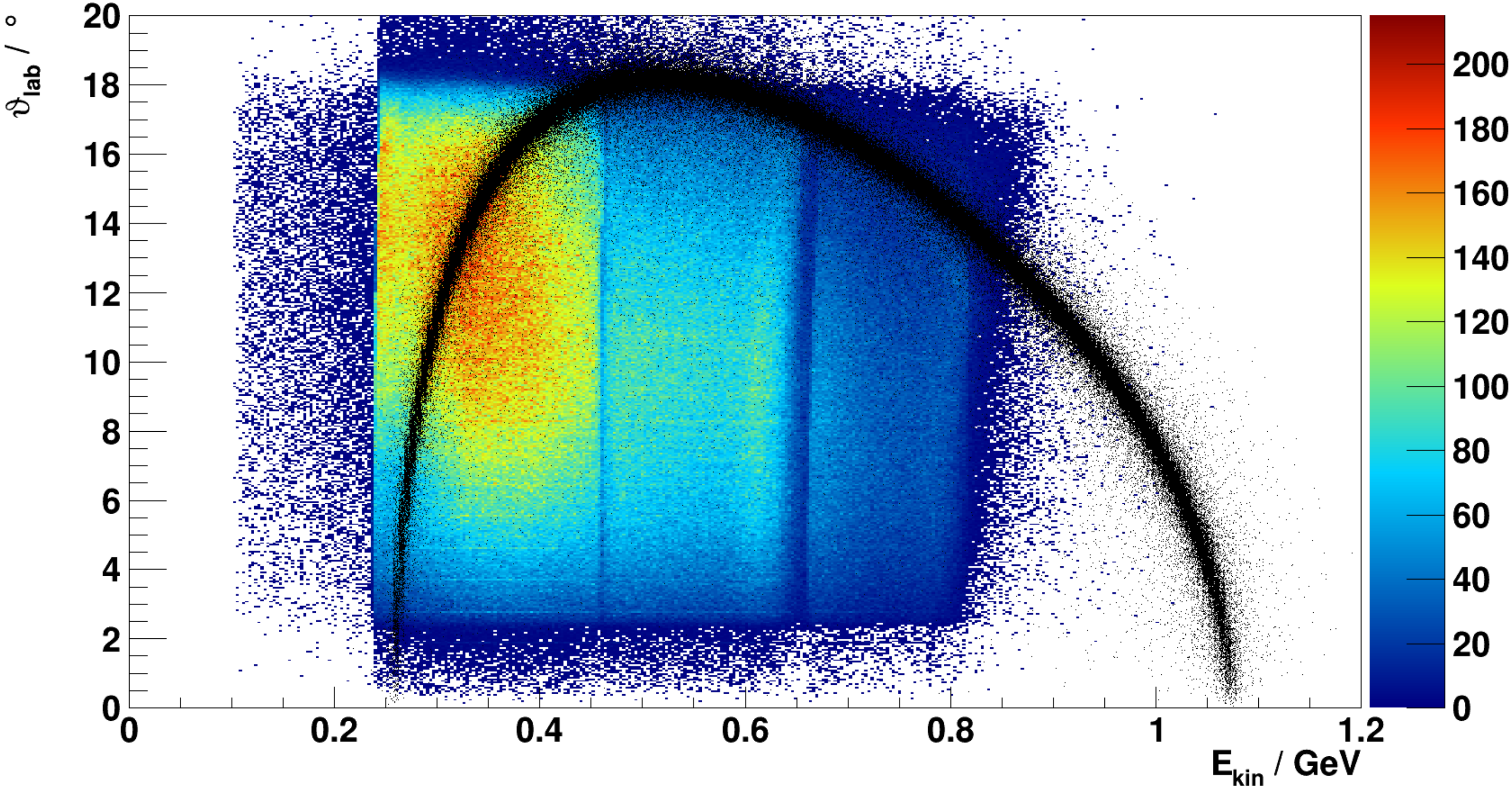
Fine tuning

- correct for this shift with a first order polynomial



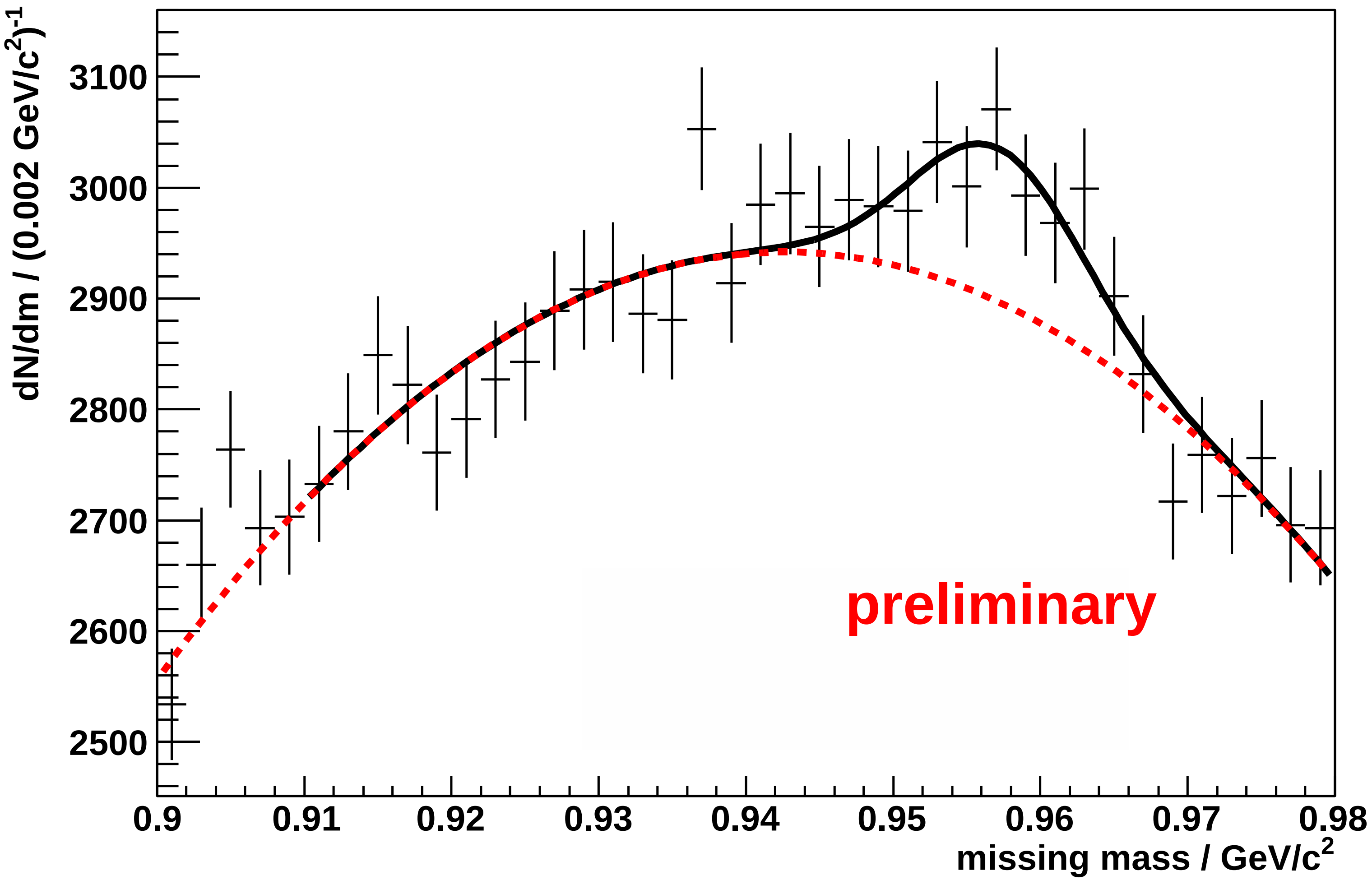
Fine tuning

- corrected values fit expected ones from MC



Missing Mass Analysis

T_P = 1800 MeV   -0.3 < cos(υ_{cm}) < 0.3



Missing Mass Analysis

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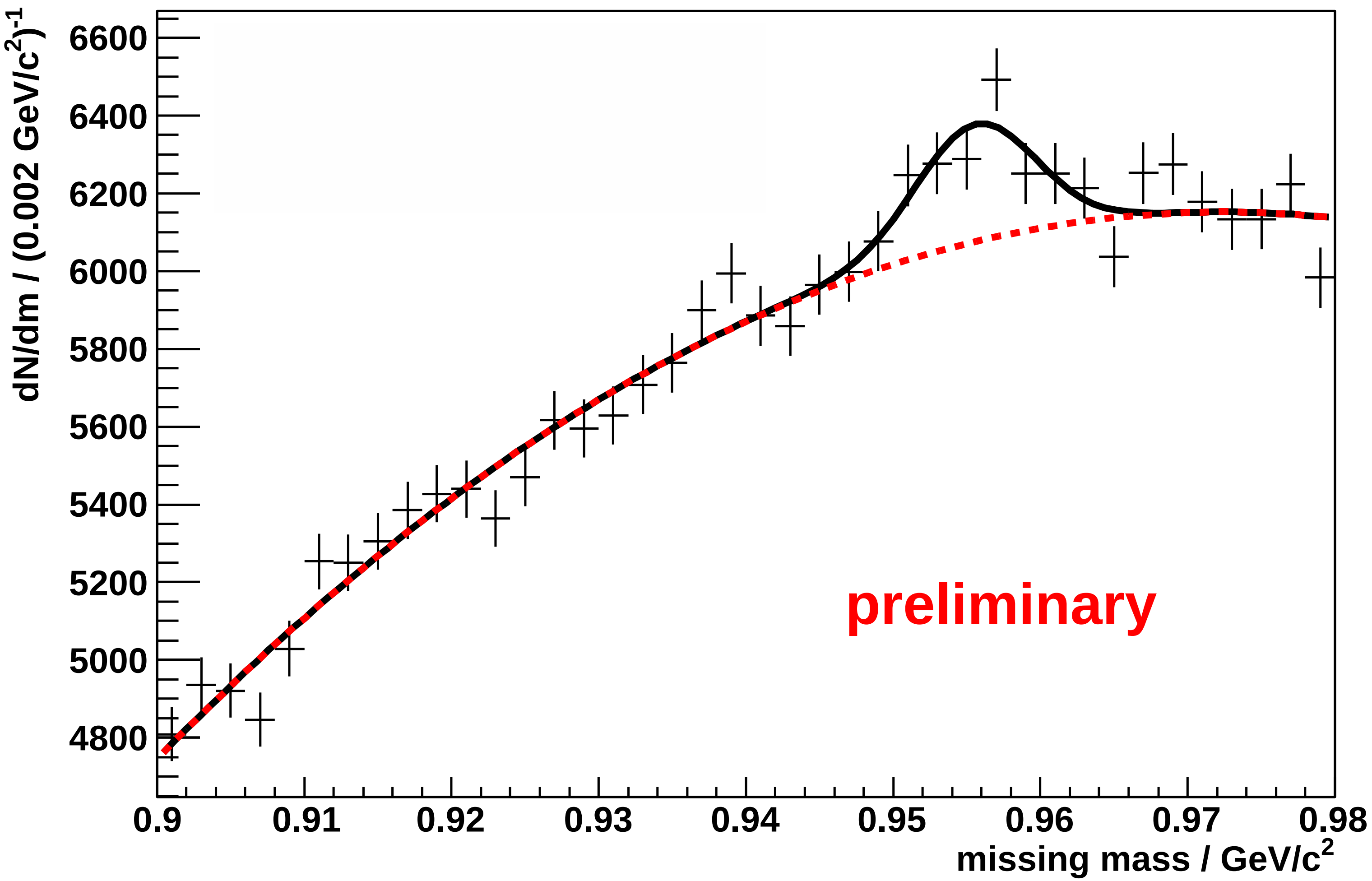
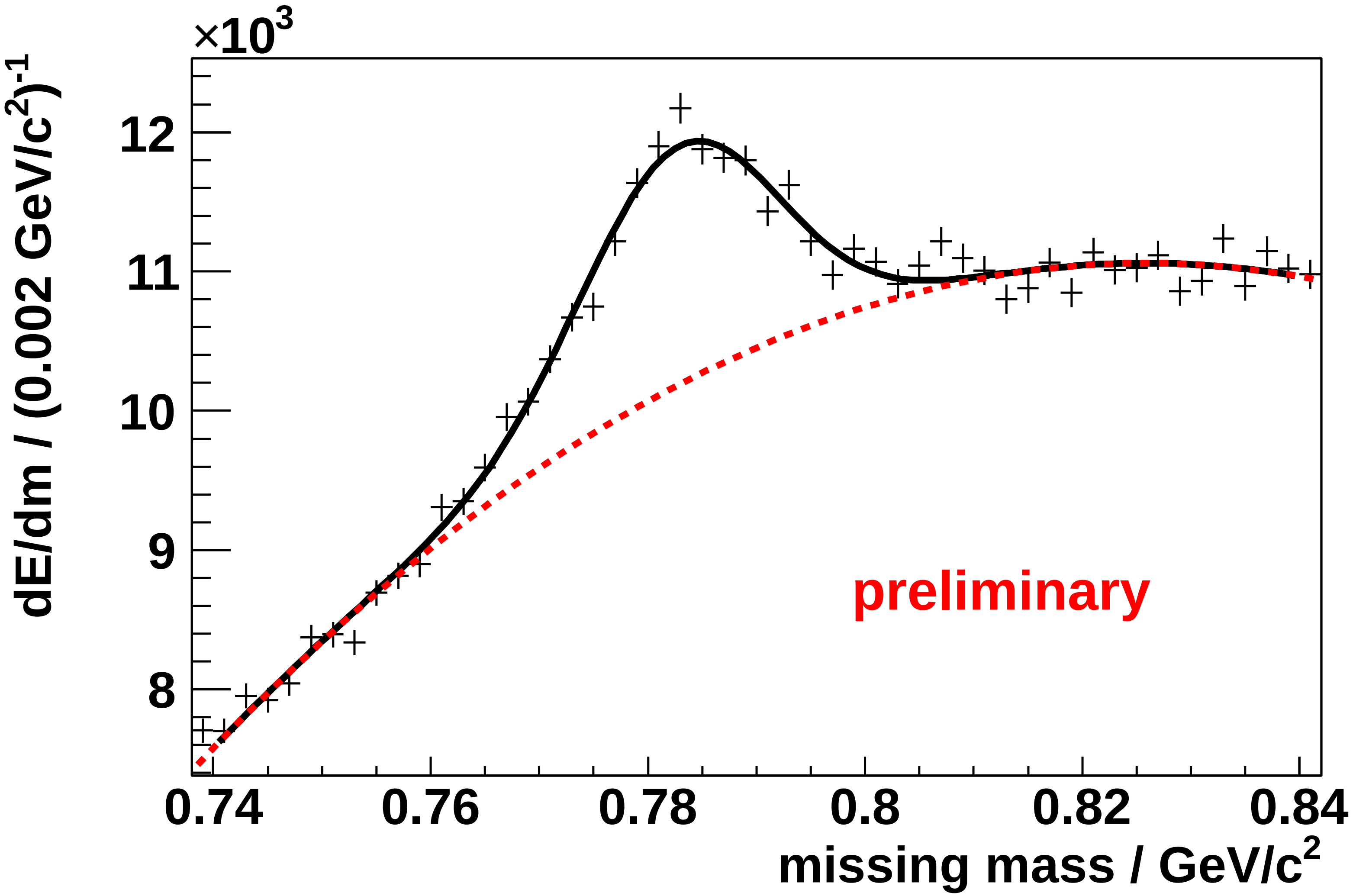
T_P = 1850 MeV   -0.3 < cos(υ_{cm}) < 0.3



Normalization via p+d→^{3}He+ω

T_P = 1800 MeV　　　-1.0 < cos(υ_{cm}) < -0.4



Normalization via p+d→^{3}He+ω

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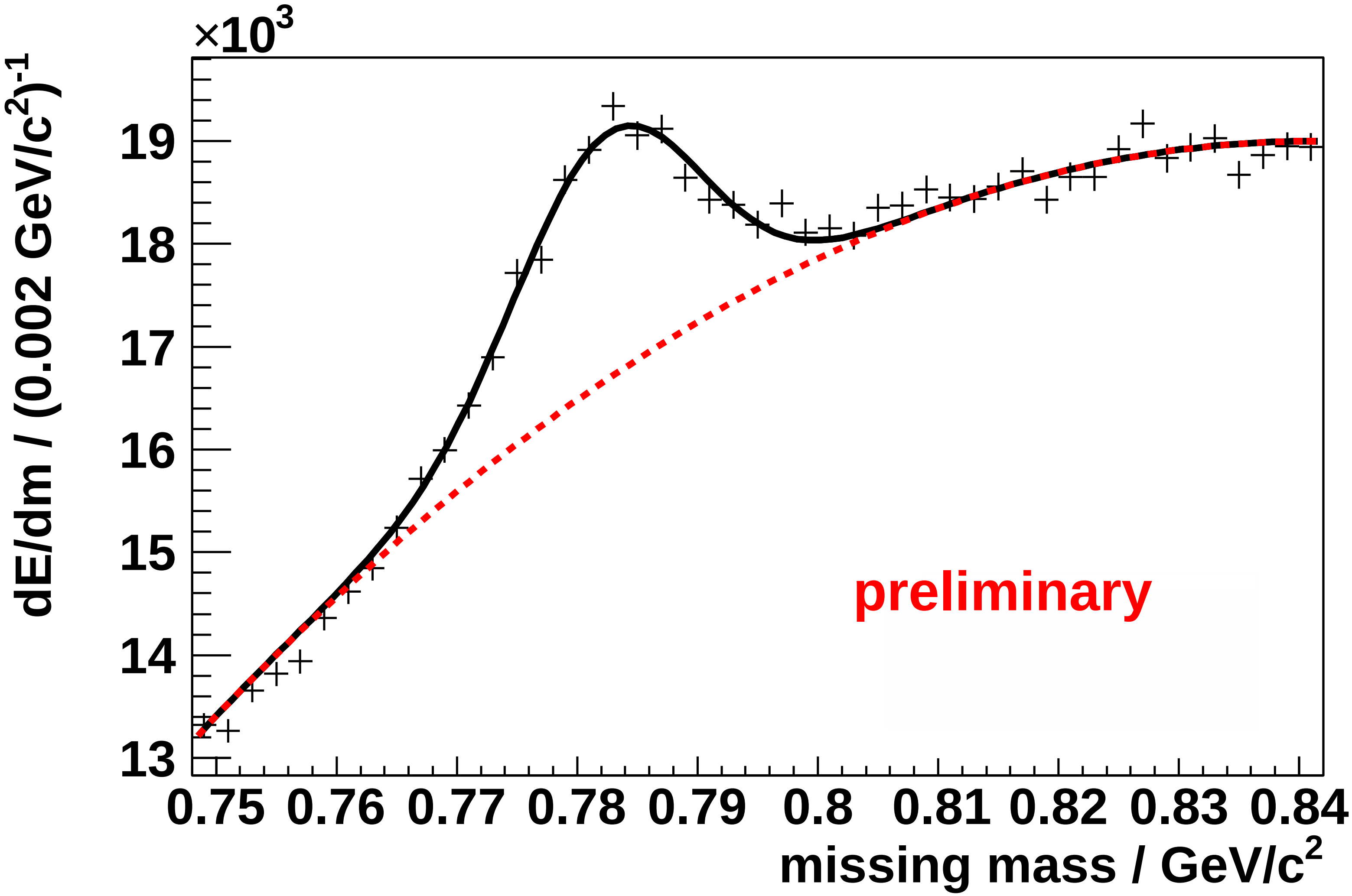
T_P = 1850 MeV -1.0 < cos(υ_{cm}) < -0.5

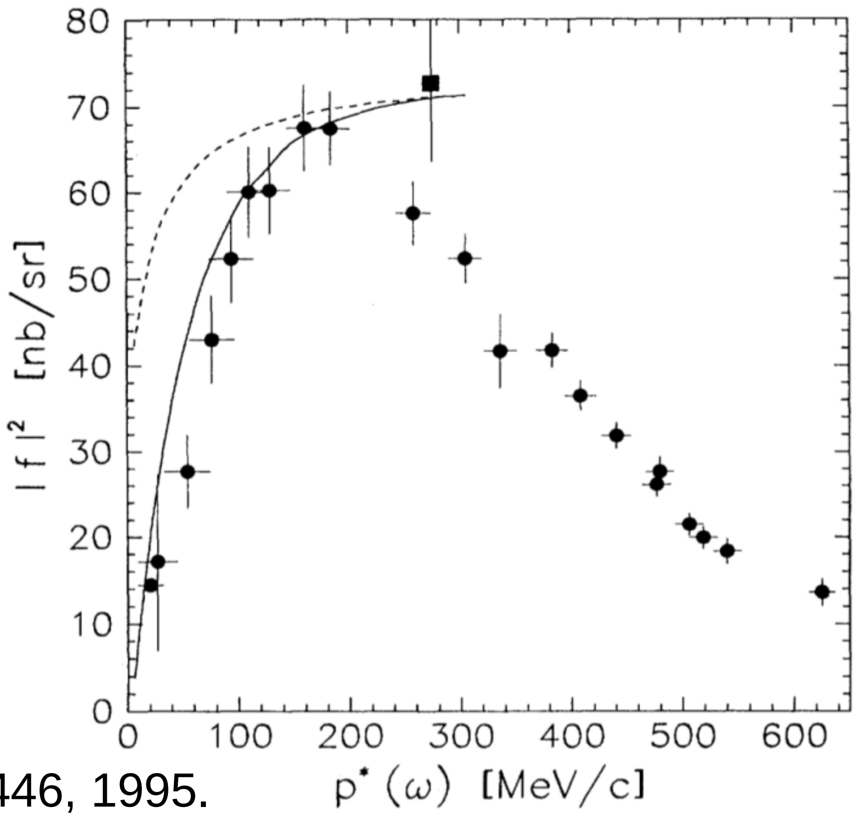


Normalization via $p+d \rightarrow {}^3He+\omega$

Outline:

- determine number of ${}^3He+\omega$ events per $\cos(\upsilon_{cm})$ to extract an angular distribution
- correct for the detector acceptance
- do a normalization via the $p+d \rightarrow {}^3He+\omega$ differential cross section as determined by Wurzinger et. al. for $\cos(\upsilon^{\omega}_{cm}) = -1$

➢ extract differential cross sections for
$p+d \rightarrow {}^3He+\omega$ (per $\cos(\upsilon_{cm})$-bin)
$p+d \rightarrow {}^3He+\eta'$ (assuming a flat distribution)



Wurzinger, R. et al., Physical Review C, 51:443446, 1995.

- the reaction $p+d \rightarrow {}^3He+\eta'$ is of interest because of its linkage to the $U_A(1)$ problem of QCD
- the database of cross sections for this reaction is small
- cross sections are expected to be well below 1 nb/sr

➢ two test beamtimes were done with WASA-at-COSY at T_P = 1800 MeV & T_P = 1850 MeV

➢ a missing mass signal of the $p+d \rightarrow {}^3He+\eta'$ reaction could be observed for both beam energies

➢ cross sections will be calculated based on a normalization to the $p+d \rightarrow {}^3He+\omega$ differential cross section as determined by Wurzinger et. al.

Thank you for your attention