Search for the η-^{4}He with the WASA-at-COSY detector

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for the WASA-at-COSY collaboration

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Outline

- Motivation,
- Idea of the measurement,
- WASA detector at the COSY accelerator,
- Data analysis,
- Summary.

Exotic nuclei

„classical" nucleus:

bound state of protons and neutrons.

Hypernuclei:

bound state of protons and neutrons

+hyperon Λ,Σ

Mesic nuclei:

bound state of protons and neutrons

+meson K, η, η' ω, ...

strong interaction + e-m interaction

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η-^{4}He case

strong interaction + ~~e-m interaction~~

Why η-mesic nuclei

- **New bound state of hadrons**

- **Investigation η-N interactions**

- **Studies of η quark structure**

  Binding energy and effective mass of η are sensitive to the gluon component of a flavour singlet function $|\eta_0>$

  (more gluon content → more attractive binding → higher binding energy)

  (*S.D. Bass, A.W. Thomas, Phys. Lett. B634 (2008)*)

- **Study of in-medium properties of N*(1535) resonance:**

  N-η system is strongly coupled with N*(1535) resonances. Eta-mesic nucleus as a probe for testing different N* models

History of η-mesic nuclei

- **1985: Bhalerao & Liu:**

  attractive interaction η-N

- **1986: Haider & Liu:**

  first predictions for η-mesic nuclei (for A>10)

- **Series of experiments (no conclusive results):**

  Chrien et al. (1998) $\pi^+ + {}^{16}O \rightarrow p + \eta\text{-}{}^{15}O$

  Johnson et al. (1993) $\pi^+ + {}^{18}O \rightarrow \pi^- + \eta\text{-}{}^{18}O$

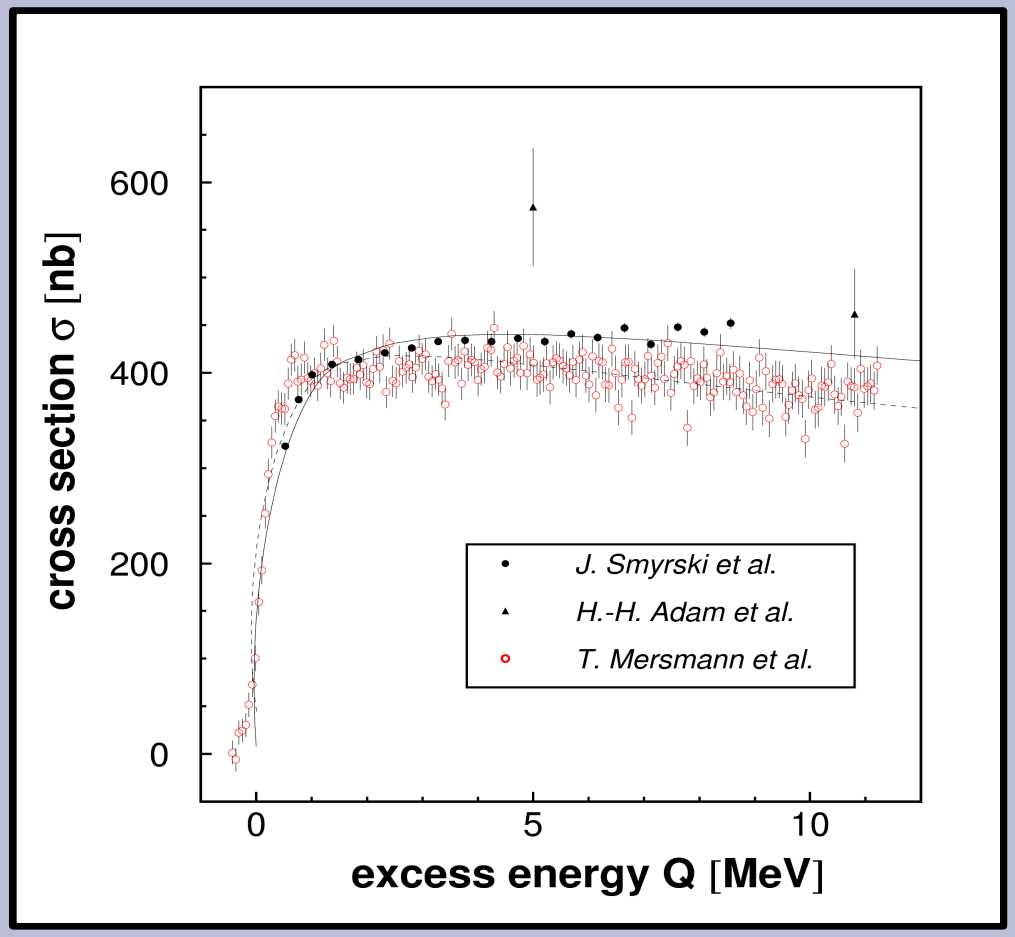
- **1993-2002 new data:**

  η-N scattering length much bigger than expected.

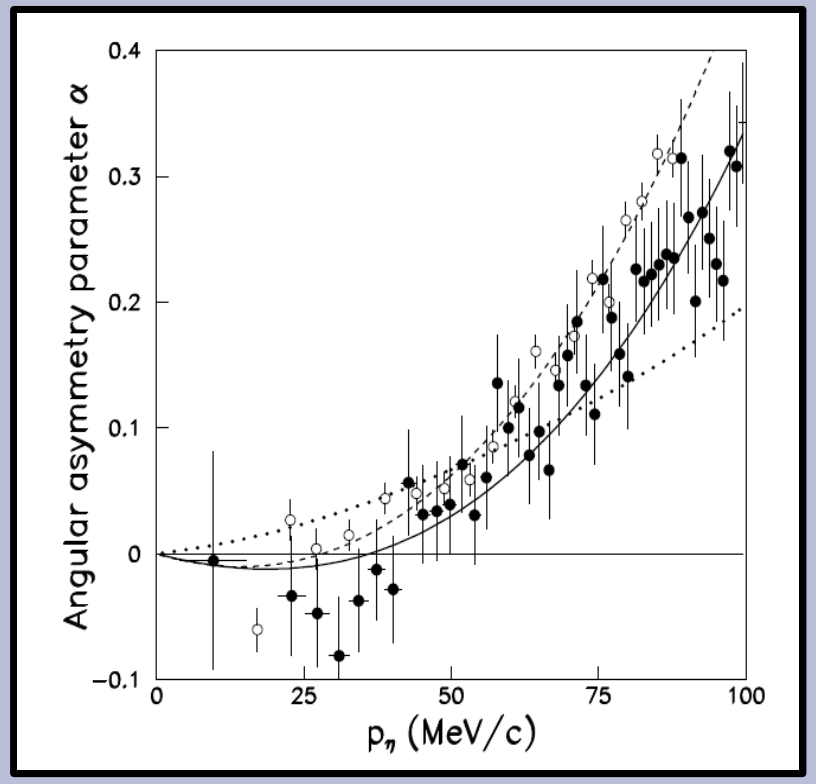
- **1991-2002 T. Ueda, C. Wilkin, S.A. Rakityansky and others:**

  new calculations and theoretical models which predict the existence of the η-mesic nuclei with light nuclei e.g. d-η, ^{3}He-η, ^{4}He-η, T-η

Experimental indications of the existence of a bound state in the η-He system



dp → ^{3}Heη



Full black squares: COSY-11

Empty red squares: COSY-ANKE

(*C.Wilkin et al. Phys.Lett. B654 (2007)*)

Full circles: COSY-ANKE

(T.Mersmann et al., Phys. Rev. Lett. 98 242301-1-4 (2007))

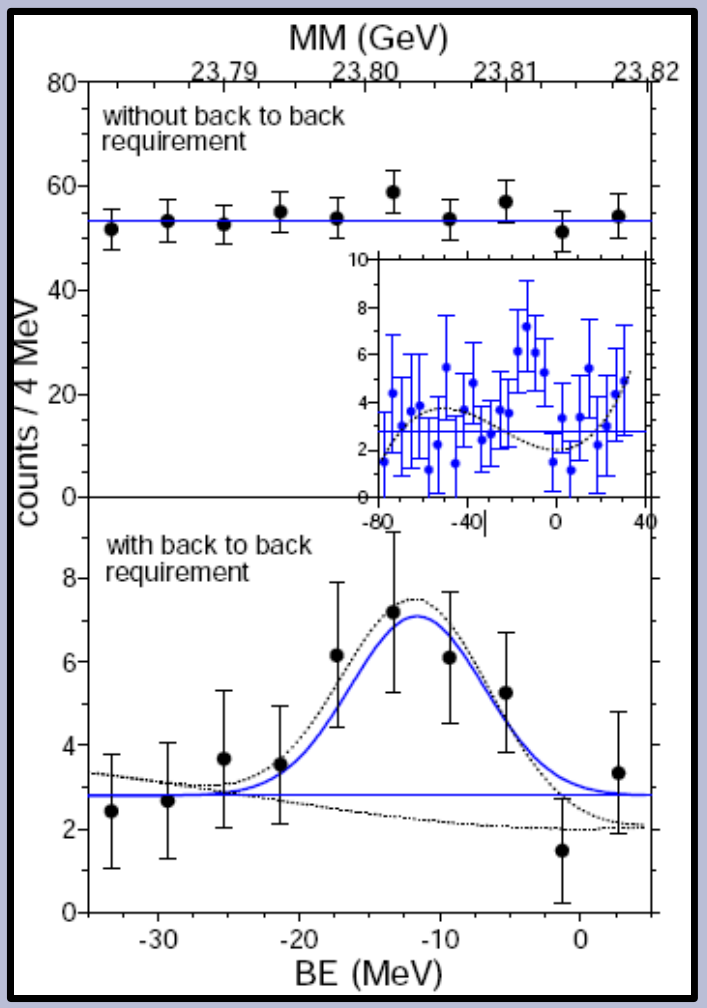
Empty circles: COSY-11

(J.Smyrski et al., Phys. Lett B 649 258-262 (2007))

- **Also total x-section $pd \rightarrow {}^3He\eta$ and $dd \rightarrow {}^4He\eta$**
  SPES-3 and SPES-4 @SATURNE
  N. Willis et al. Phys.Lett. B406(1997).

COSY-GEM results

$p+^{27}Al \rightarrow {}^{3}He+(\eta\,-{}^{25}Mg) \rightarrow {}^{3}He+\pi^{-}+p+X$

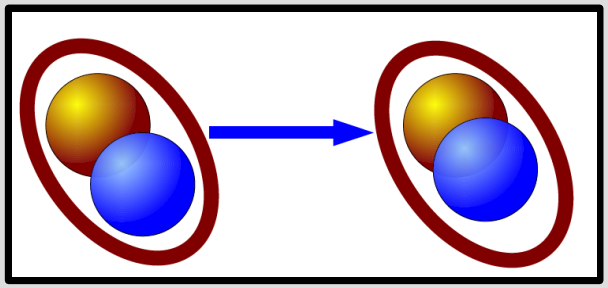


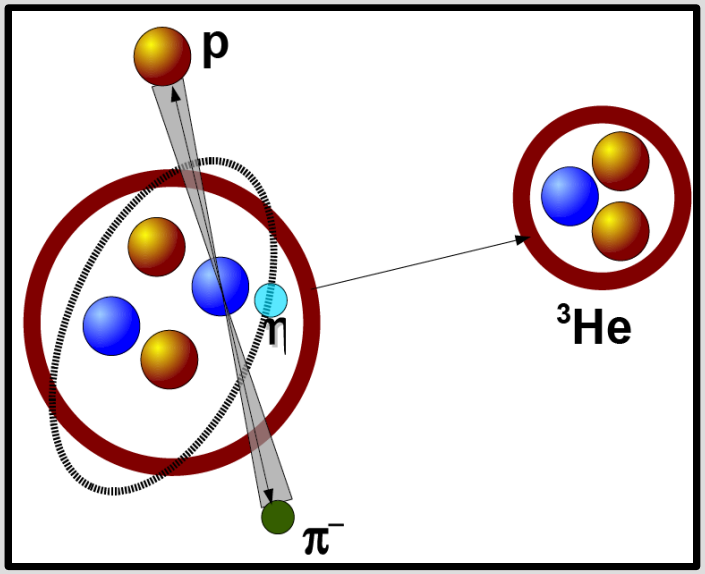
MM(3HE)

A. Budzanowski *et al.*, Phys Rev. C79 (2009).

Idea of the measurement

$$dd \rightarrow (\eta\text{-}^4He)_{bound} \rightarrow p + \pi^- + {}^3He$$



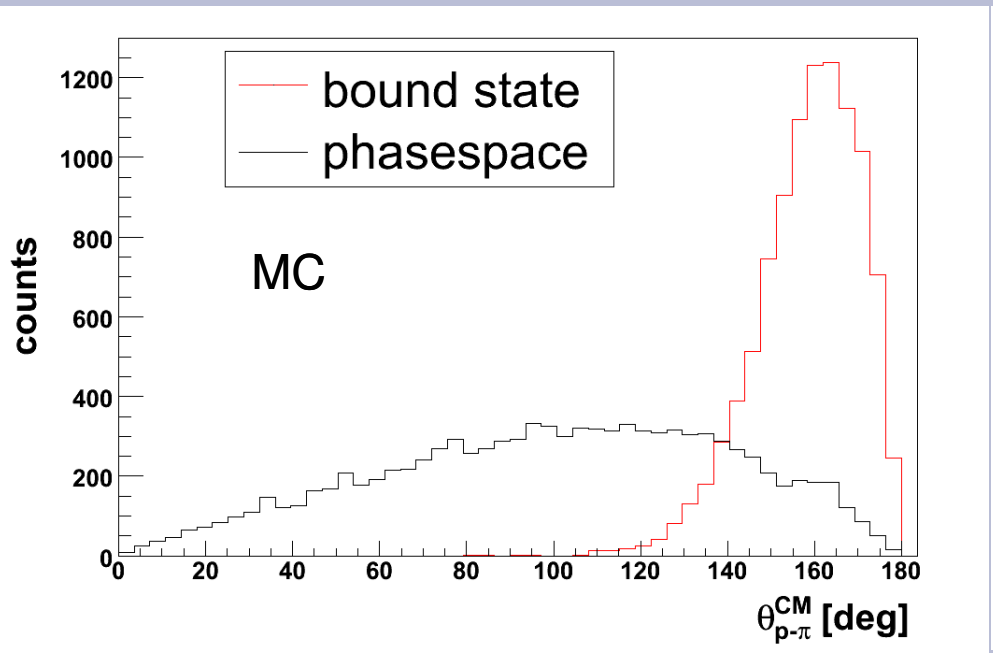


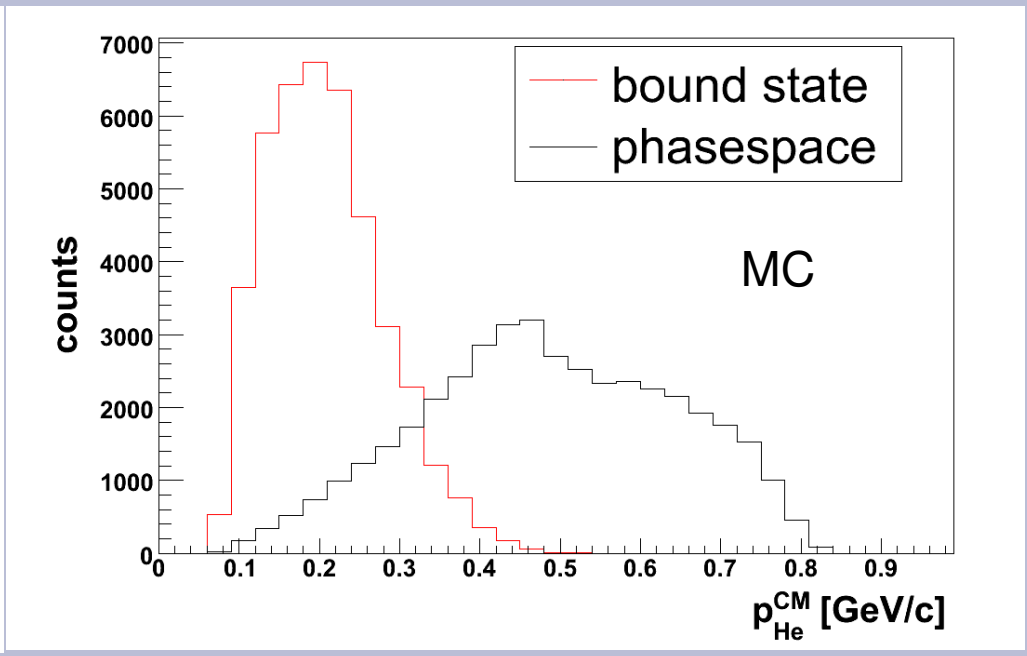
$\eta + p$ → N*(1535) → $p + \pi^-$

Relative p-π angle in the CM : $\theta_{cm} \sim 180^\circ$

Search for the resonance-like structure with the maximum below the η-^{4}He threshold

Signatures of the bound state



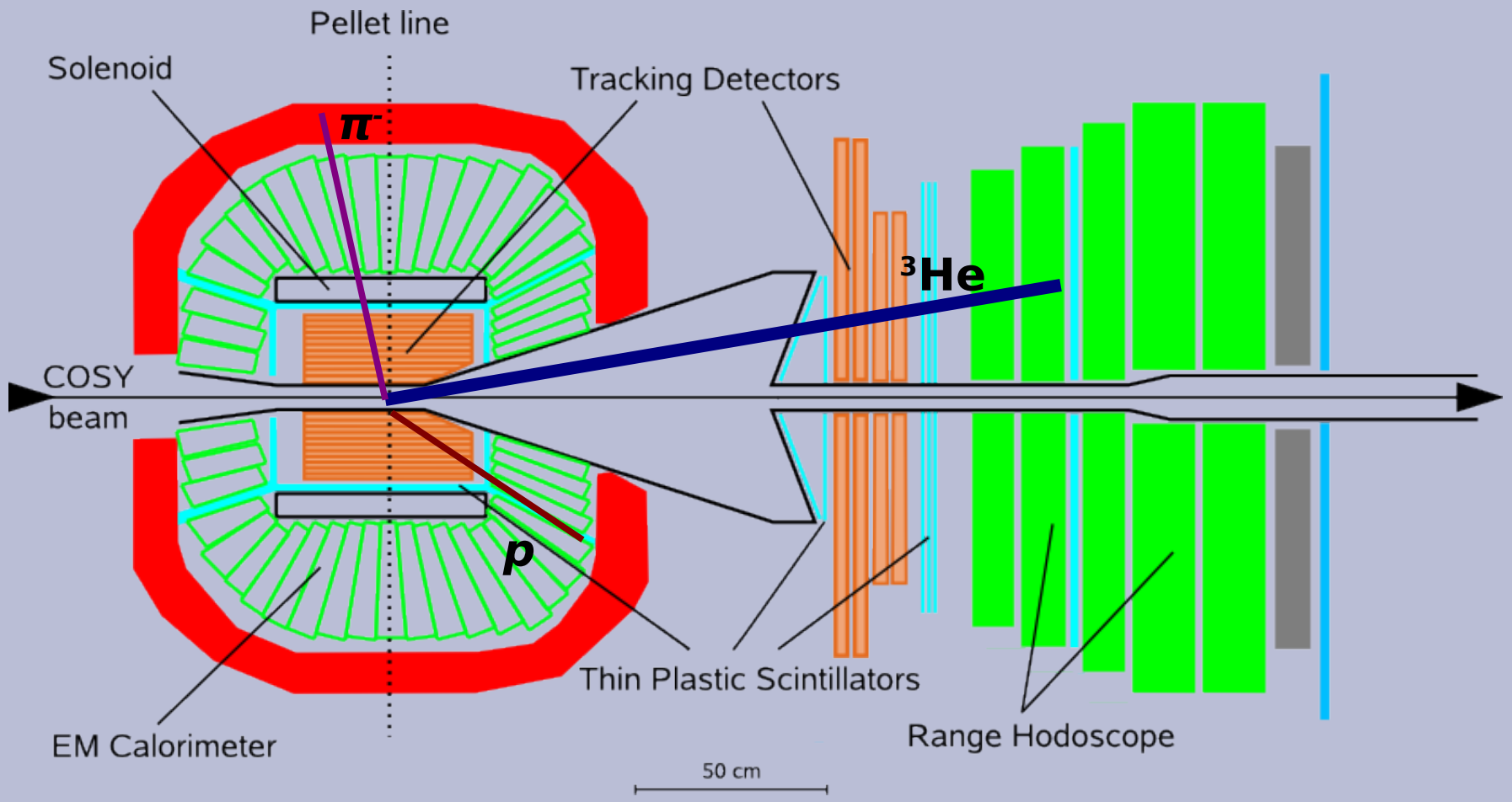


***p*-π opening angle in CM frame**

^{3}He momentum in CM frame

WASA detector at the COSY accelerator

WASA-at-COSY



$dd \rightarrow (\eta\text{-}{}^4He)_{bound} \rightarrow p\ \pi^-\ {}^3He$

Measurement in June 2008

Channels:

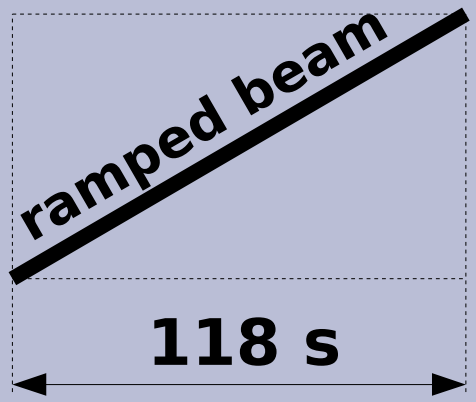
$dd \rightarrow {}^3He\,p\pi^-$

$dd \rightarrow {}^3He\,n$

- **Time: ~16 hours**

P_{beam} [GeV/c]

Q [MeV]



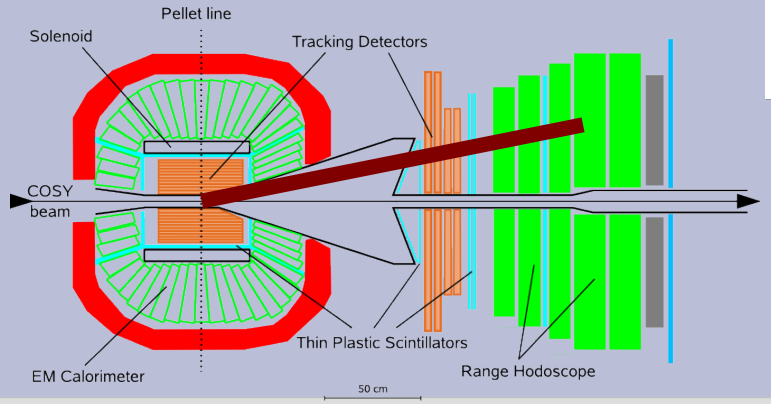
Q: -51 to 22 MeV

P: 2.185 to 2.4 GeV/c

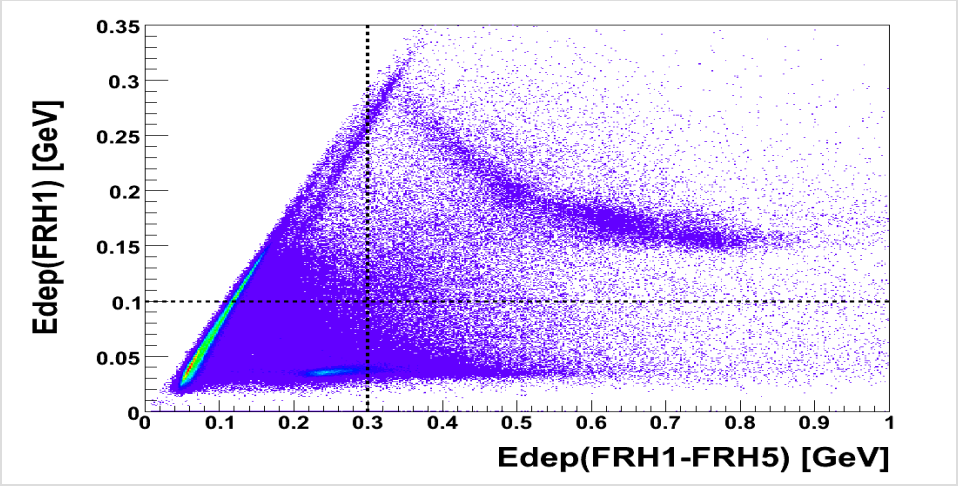
T: 1.005 to 1.171 GeV

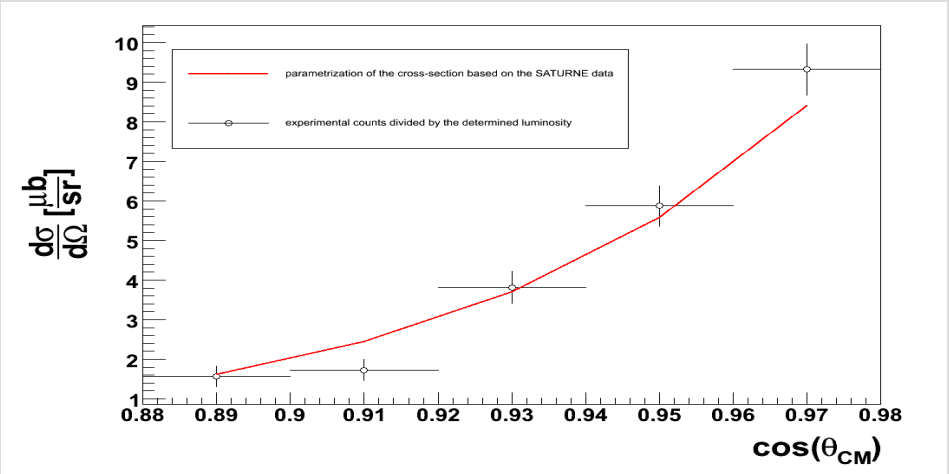
Luminosity I

Absolute normalization: dd → ^{3}He *n*

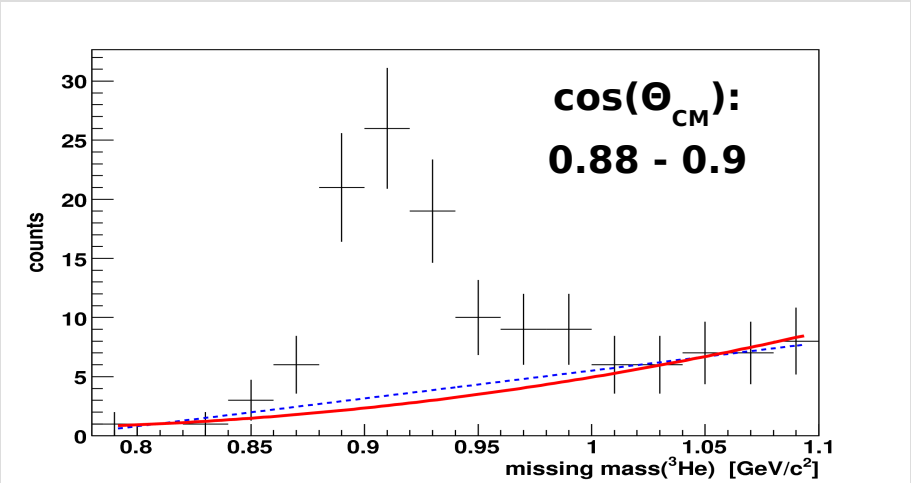


^{3}He selection





MM(^{3}He) -neutron

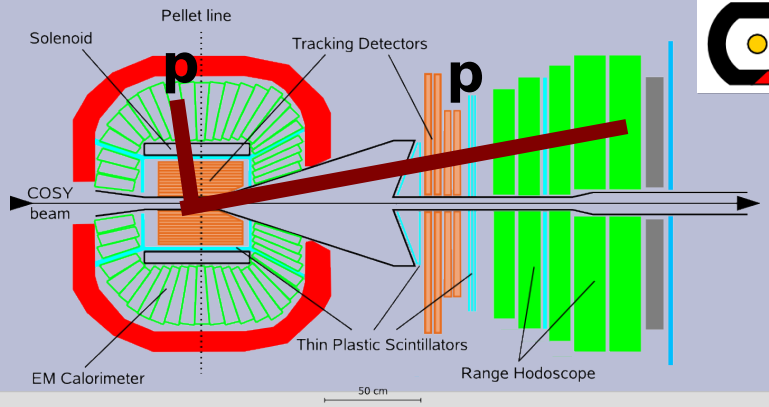


L=117.9 ±13.6 nb^{-1}

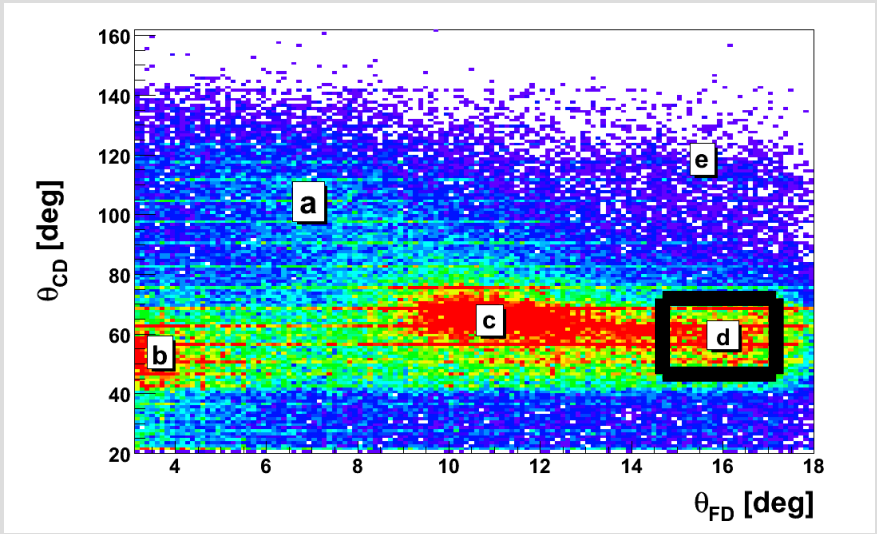
Comparison to SATURNE measurements: G.~Bizard et al., Phys. Rev. C 22 (1980) 1632.

Luminosity II (beam dependence)

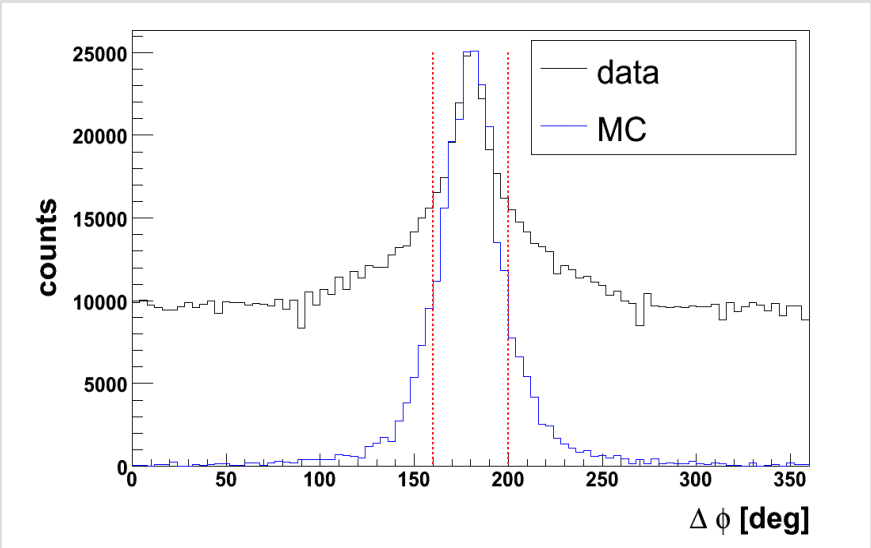
Quasi-elastic scattering: dd → pp (nn)$_{spec}$

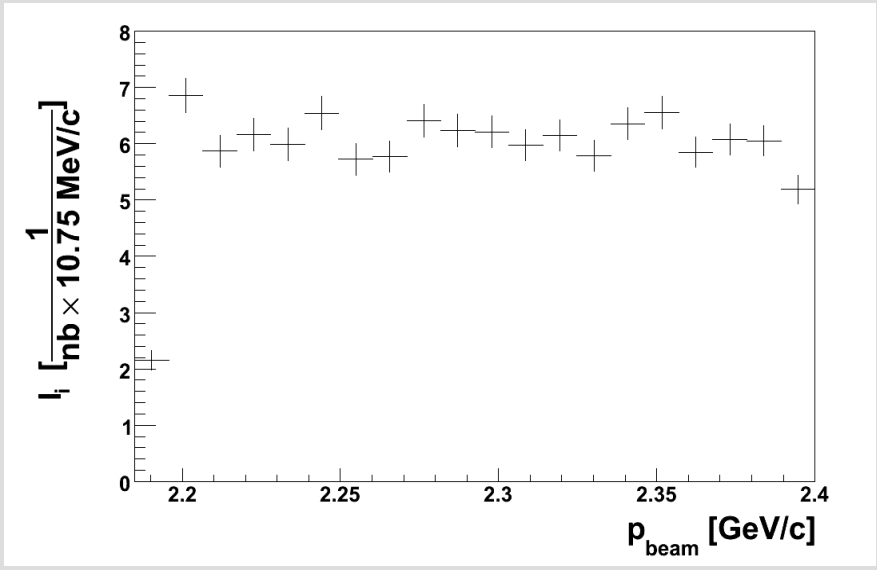


- One charged in FD && one charged in CD.
- Coplanarity condition **Δφ<20 deg.**
- Cuts on E in the scintillator barrel (elimination of π).



Coplanarity cut

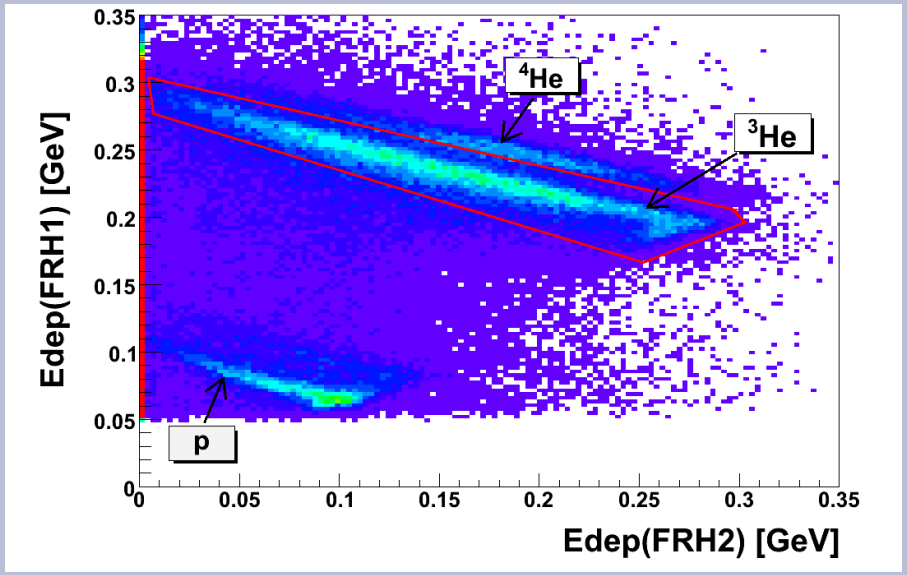




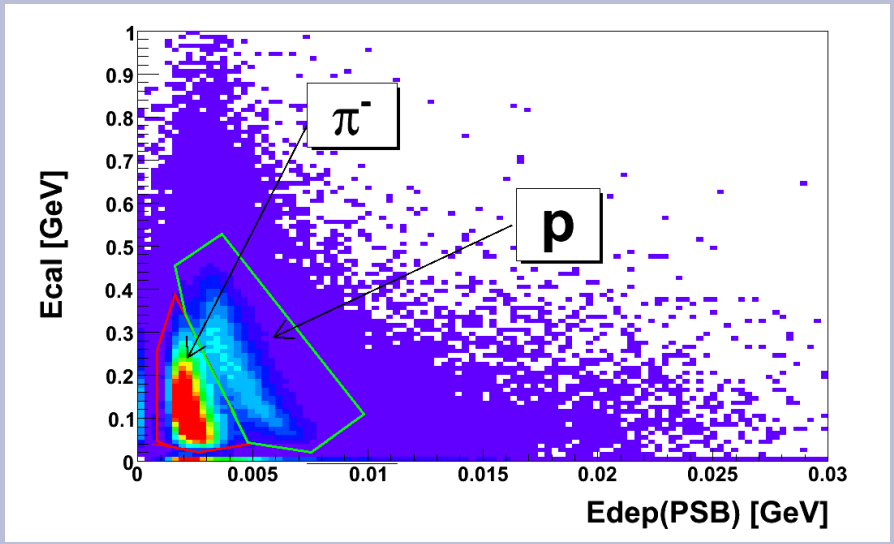
Analysis of

$$dd \rightarrow (\eta\text{-}^{4}He)_{bound} \rightarrow {}^{3}He\ p\ \pi^{-}$$

PID

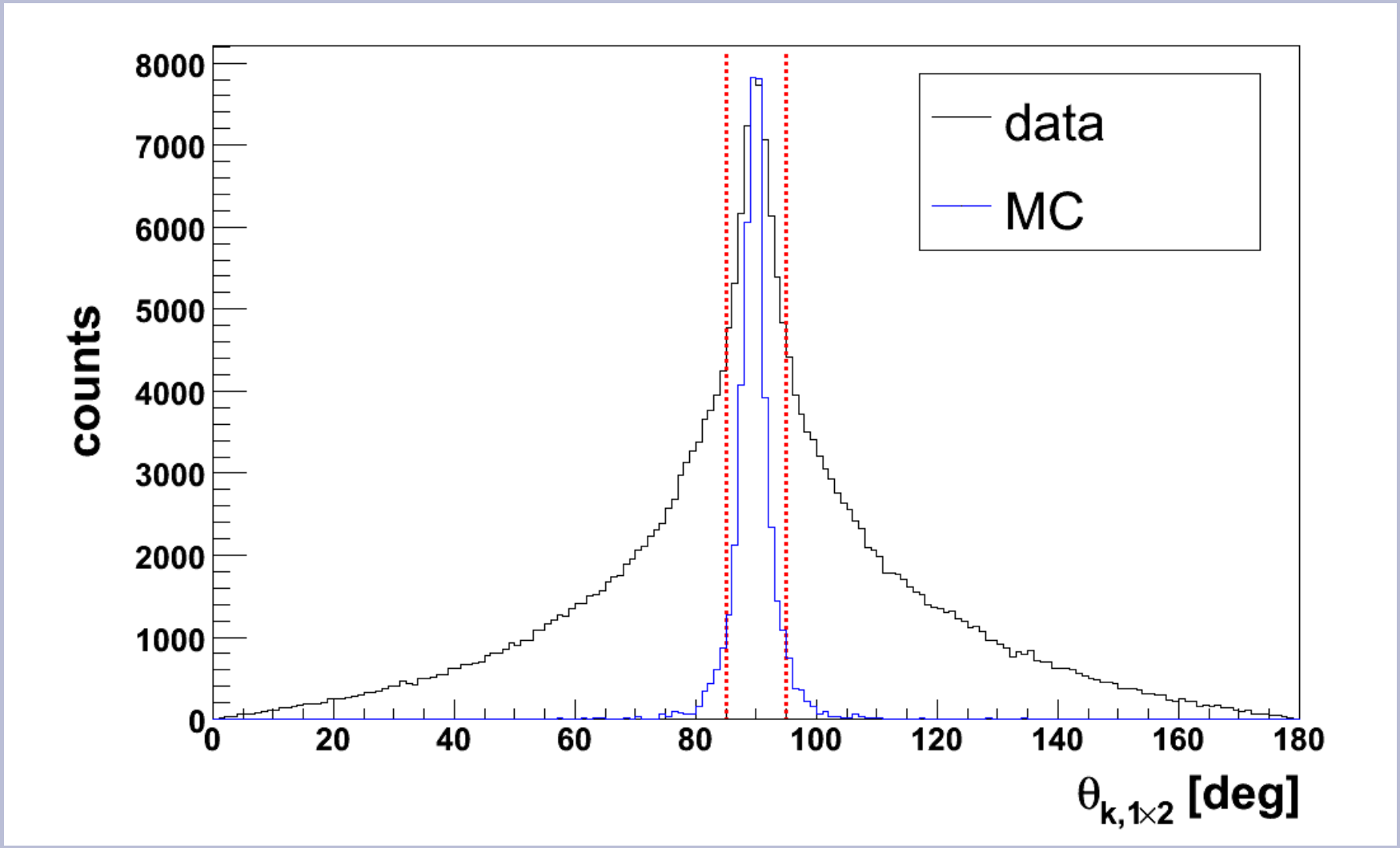


^{3}He identification in the “forward” detector

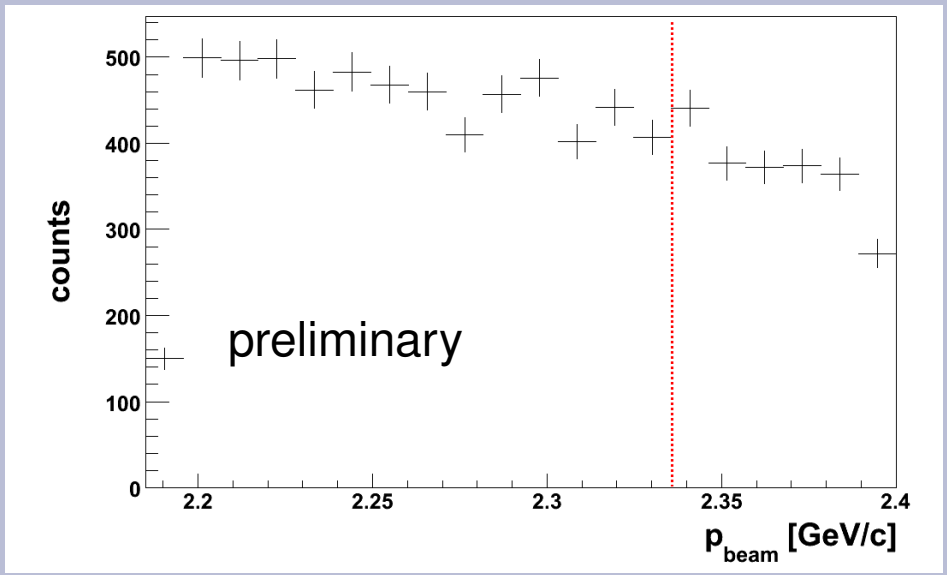


p-π^- identification in CD detector

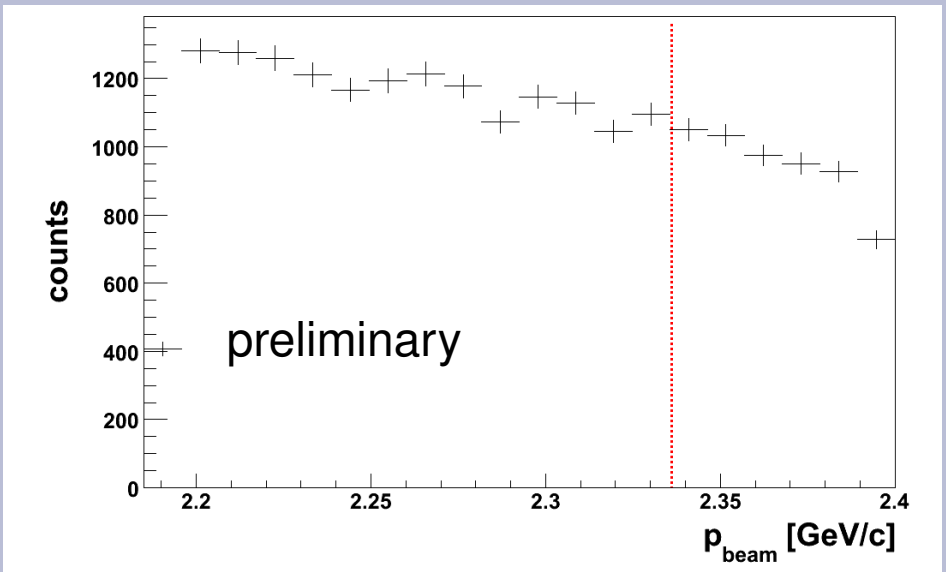
Three-particle coplanarity cut



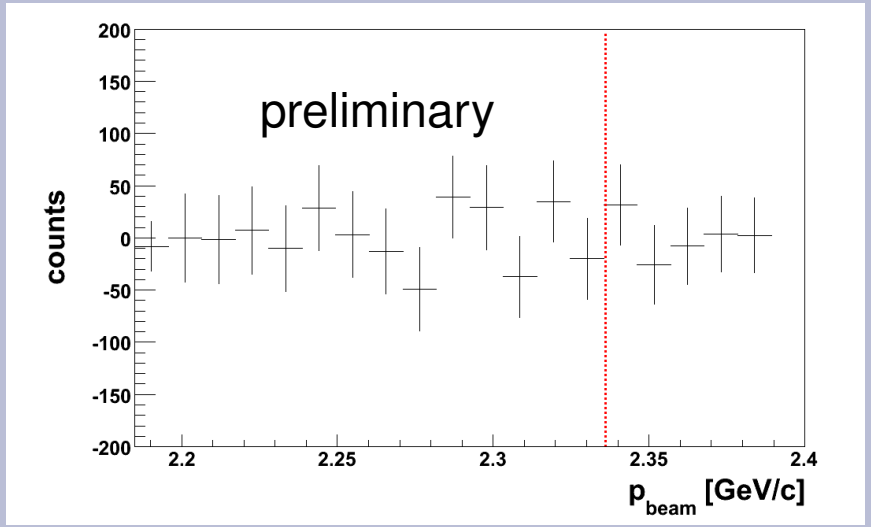
Excitation functions



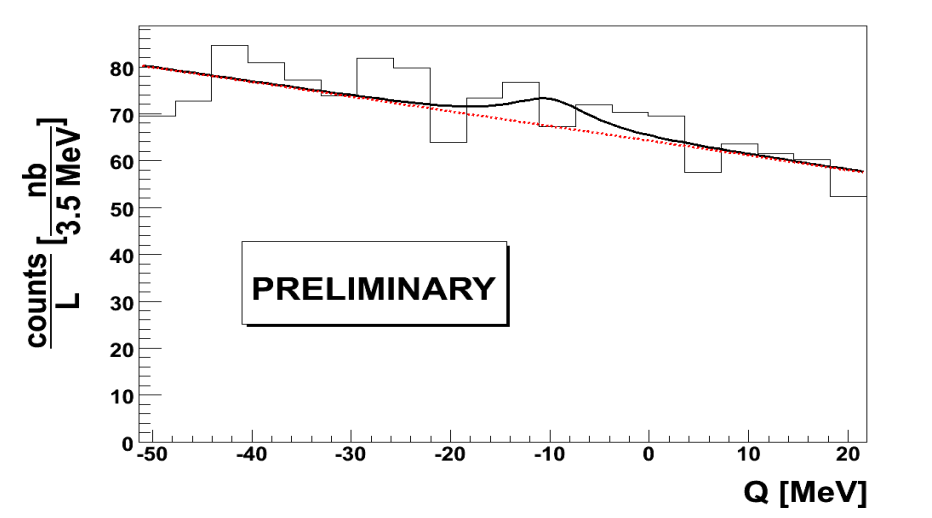
“Signal-rich” region
(P_{HE}^{CM} <0.3 GeV/c)



“Signal-poor” region
(P_{HE}^{CM} >=0.3 GeV/c)



difference



normalized excitation function

Summary

- Exclusive measurement with the ramped beam of the reaction

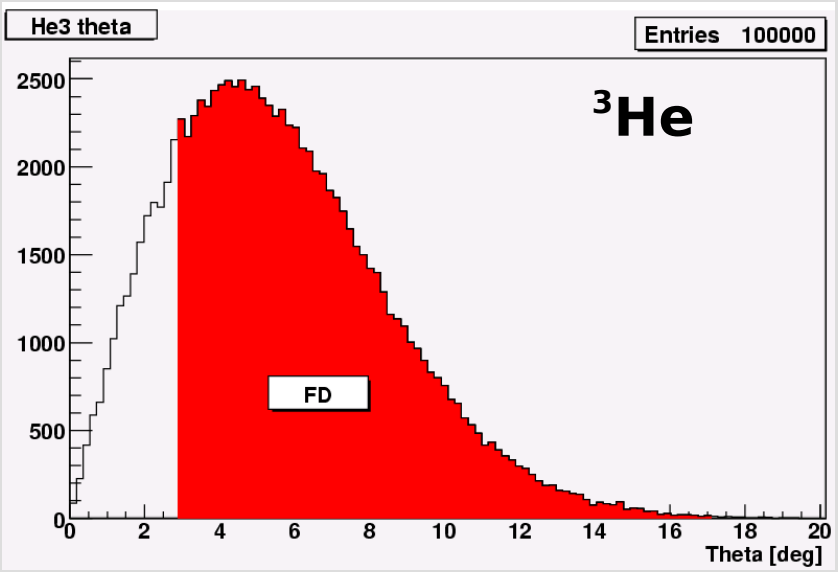
  dd → ^{3}He p π^{-} ,

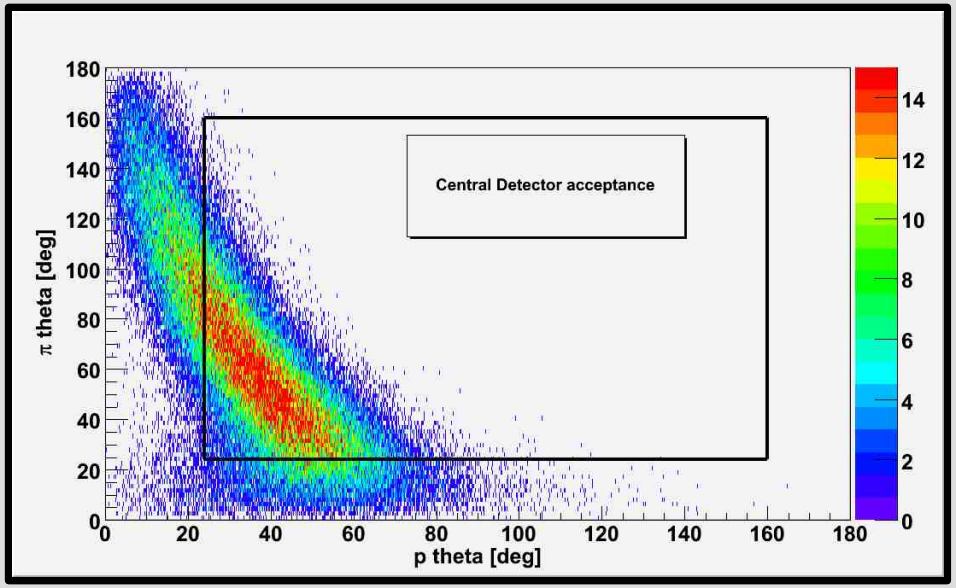
- No η-^{4}He bound state observed in current analysis,
- New data : December 2010

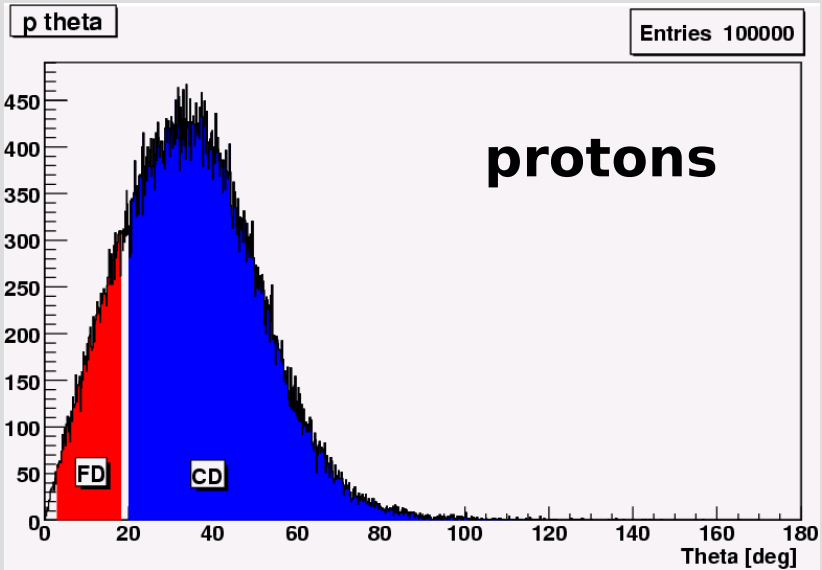
  (~20 x statistics, magnetic field, additional channel ^{3}He n π^{0}).

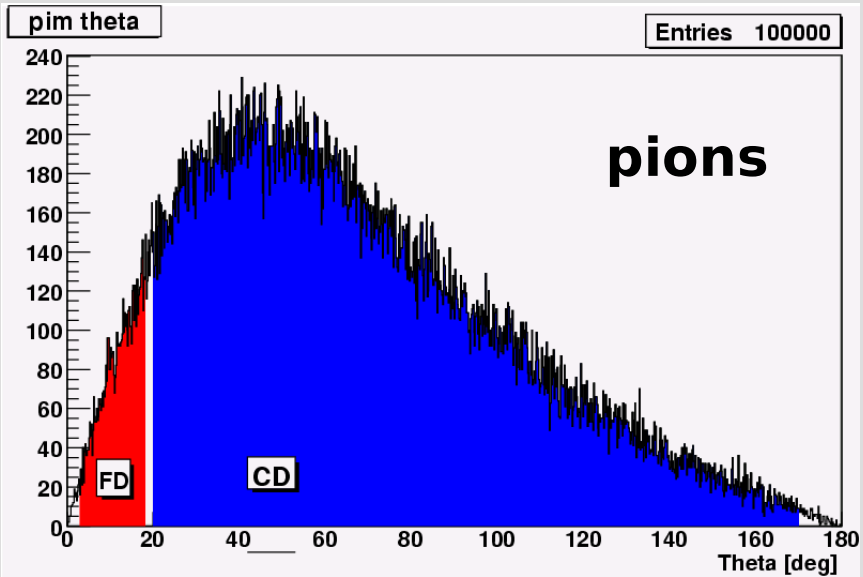
Thank you

Acceptance for dd → $(\eta\text{-}^4\mathrm{He})_{\mathrm{bound}}$ → $^3\mathrm{He}\ p\ \pi^-$

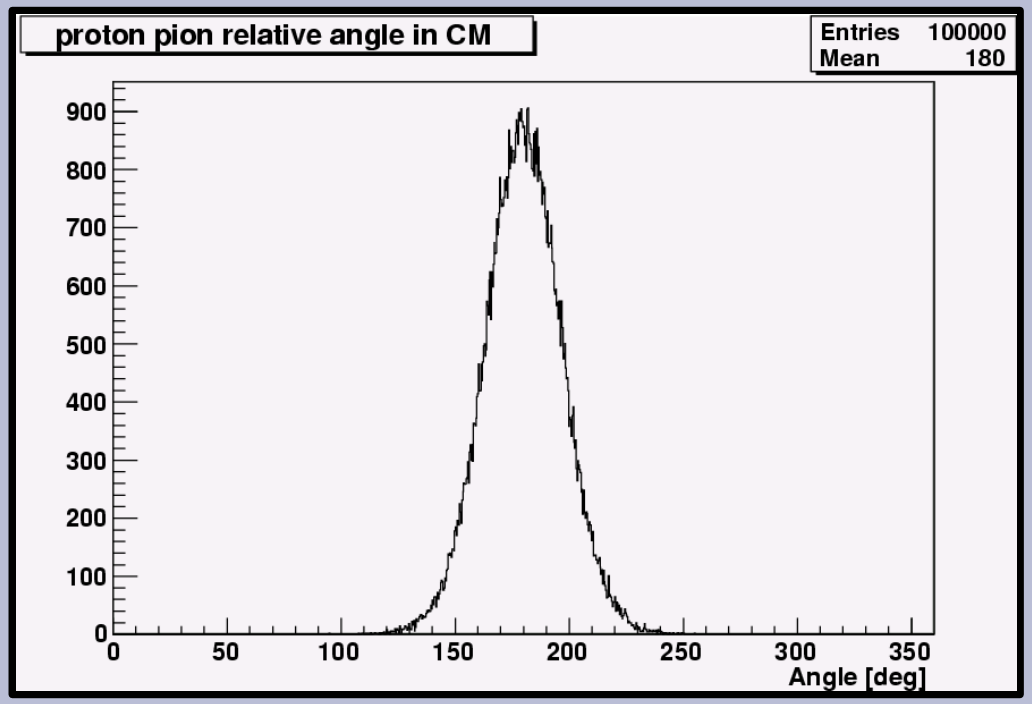


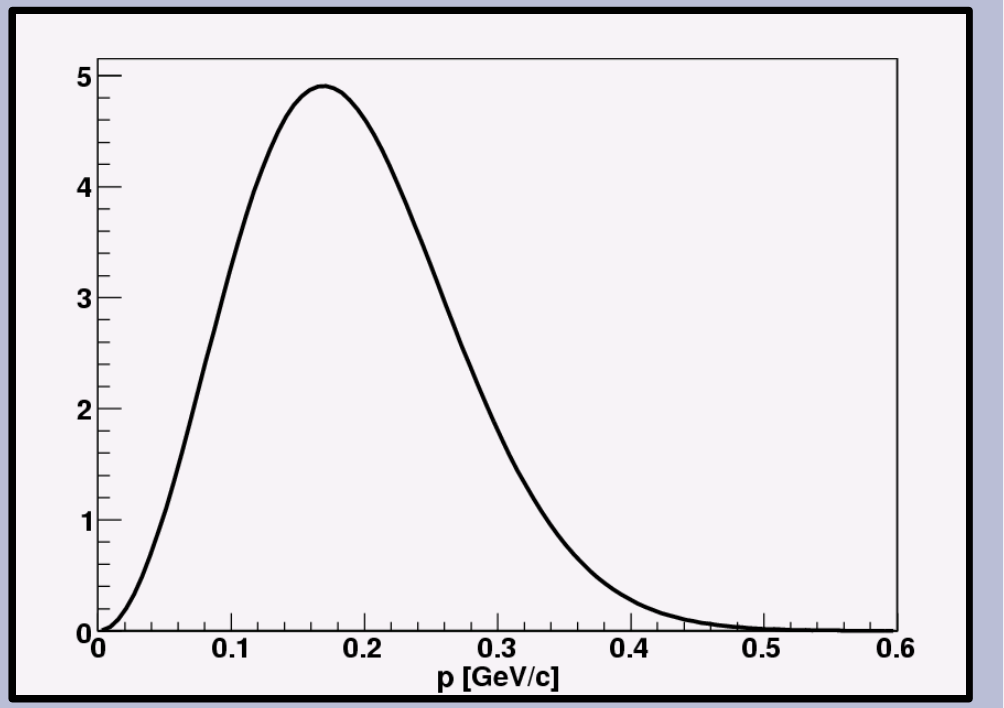






Smearing of proton-pion relative angle

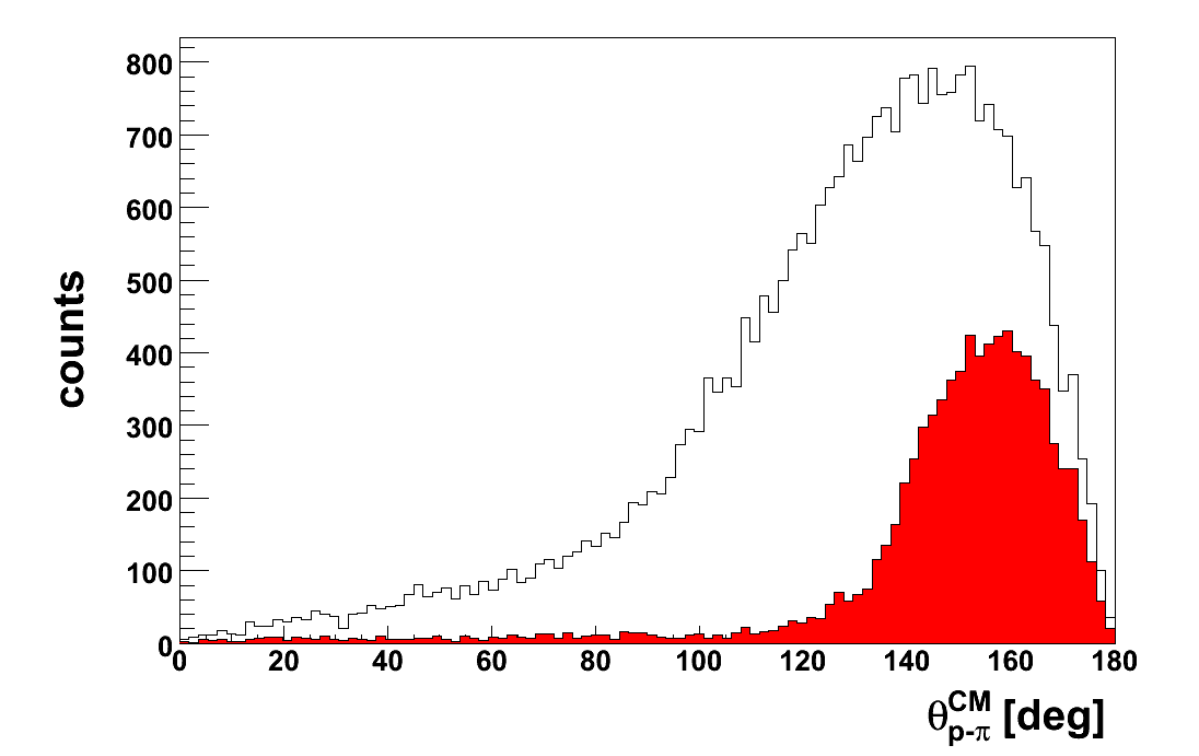




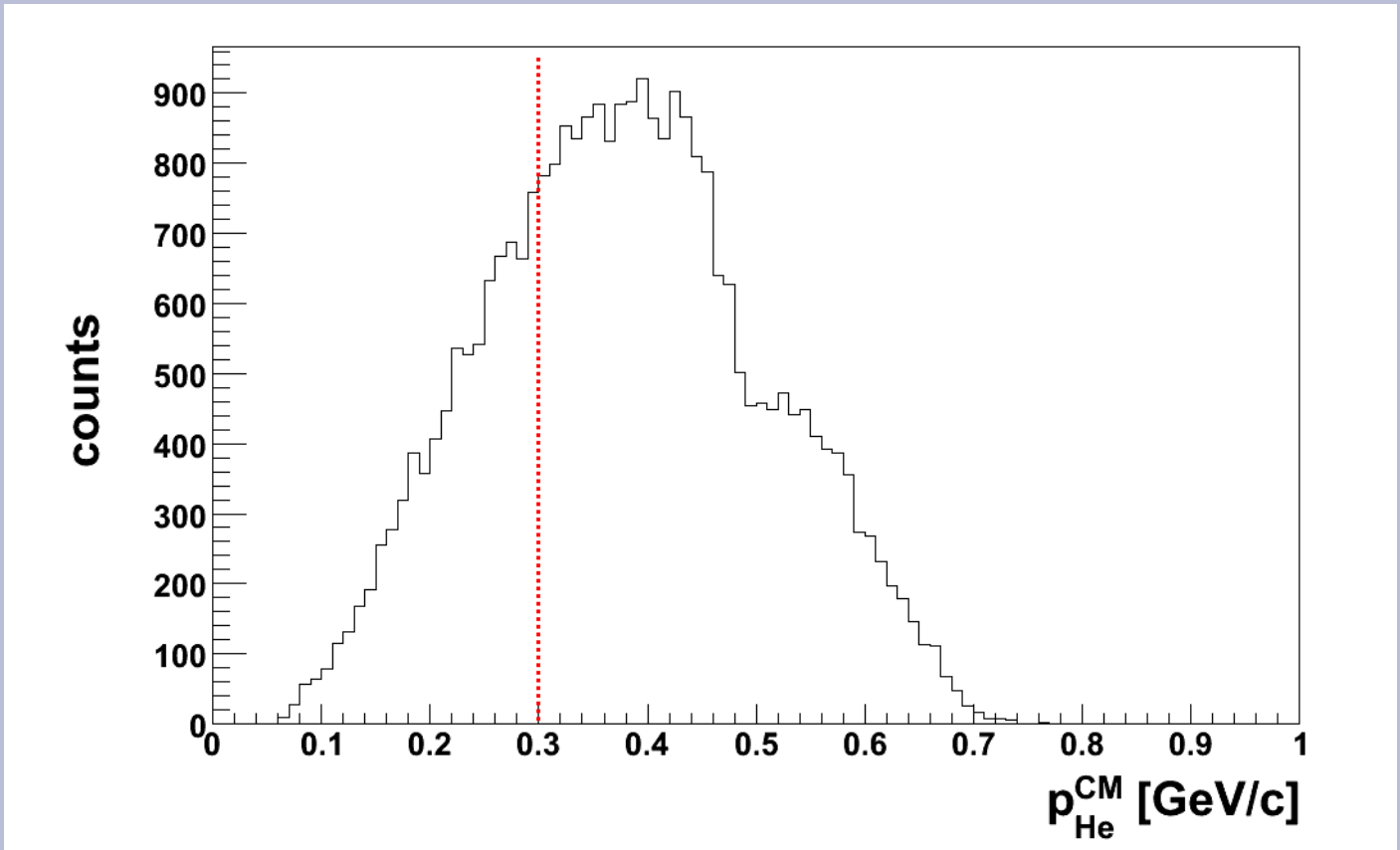
proton-pion relative angle in c.m. frame

Fermi momentum distribution in ^{4}He

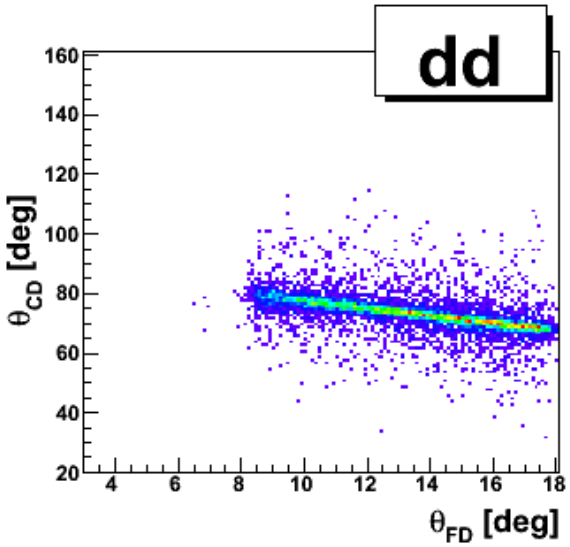
Back-to-back after He3 momentum cut in CM

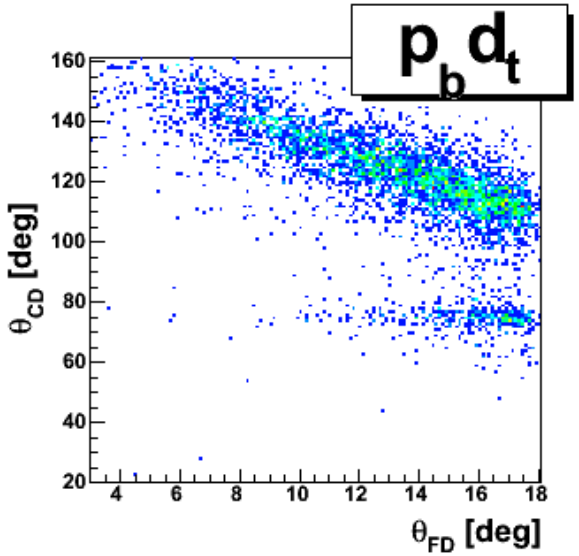


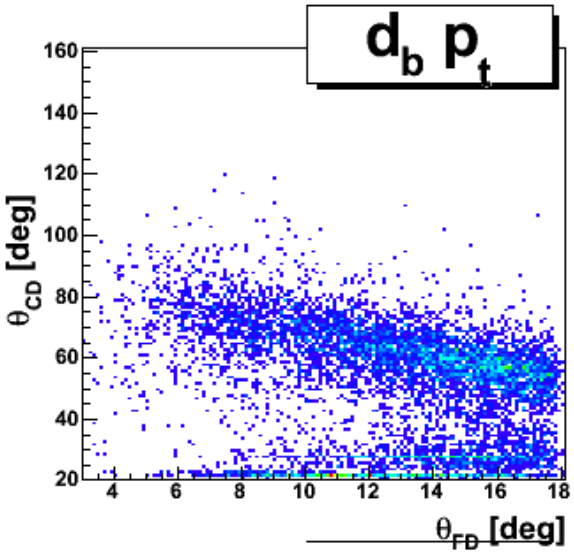
Experimental distribution of He momentum in CM

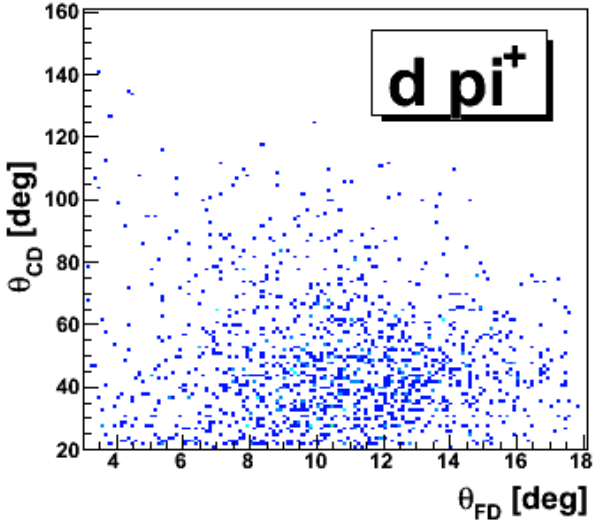


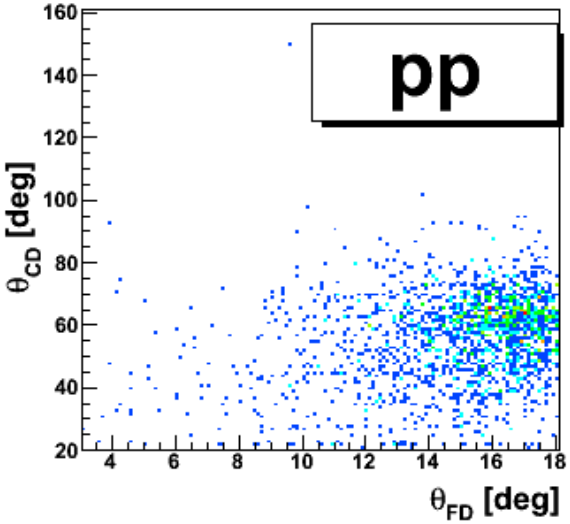
Quasi-elastic MC simulations





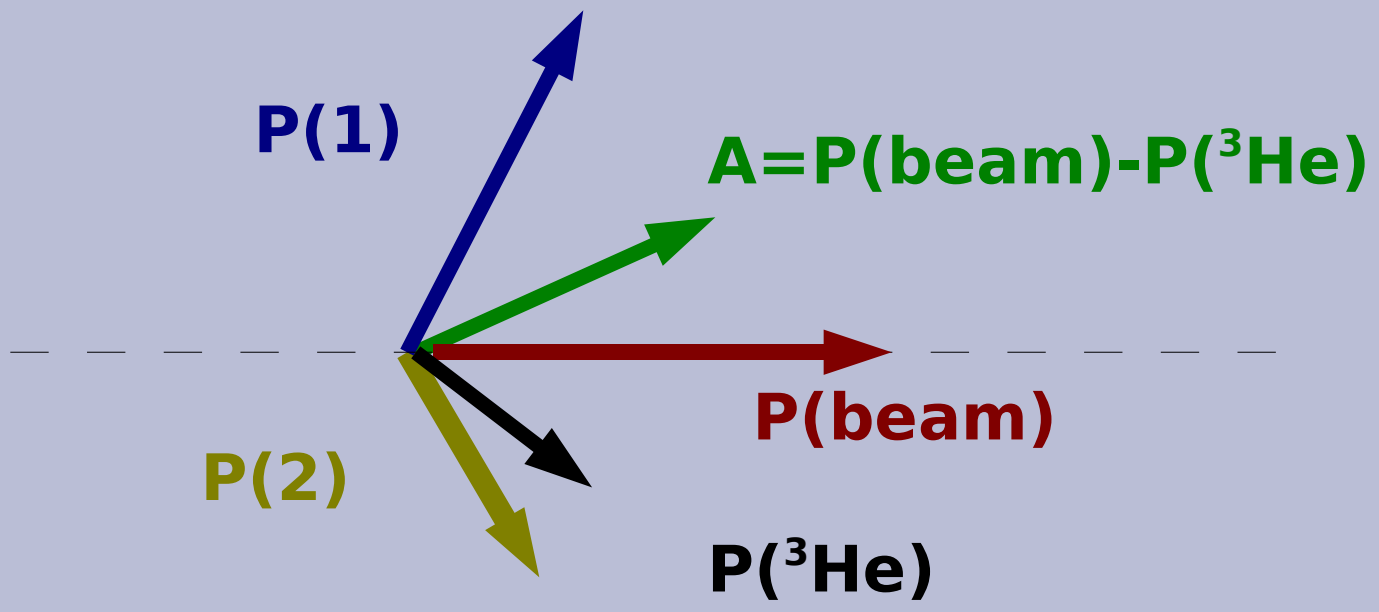






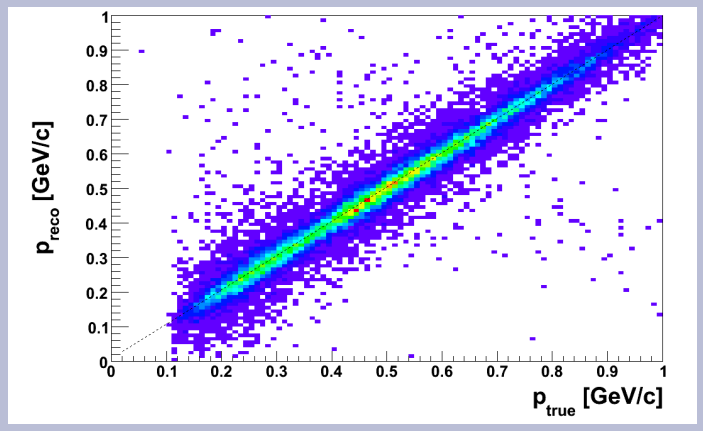
Momentum reconstruction for CD tracks

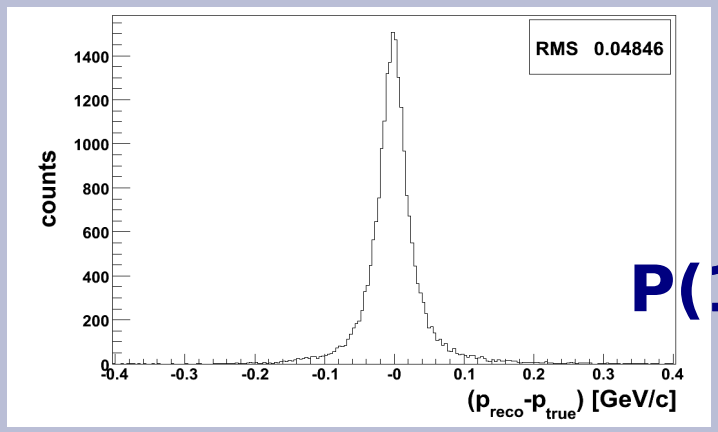
- No magnetic field available during measurements.

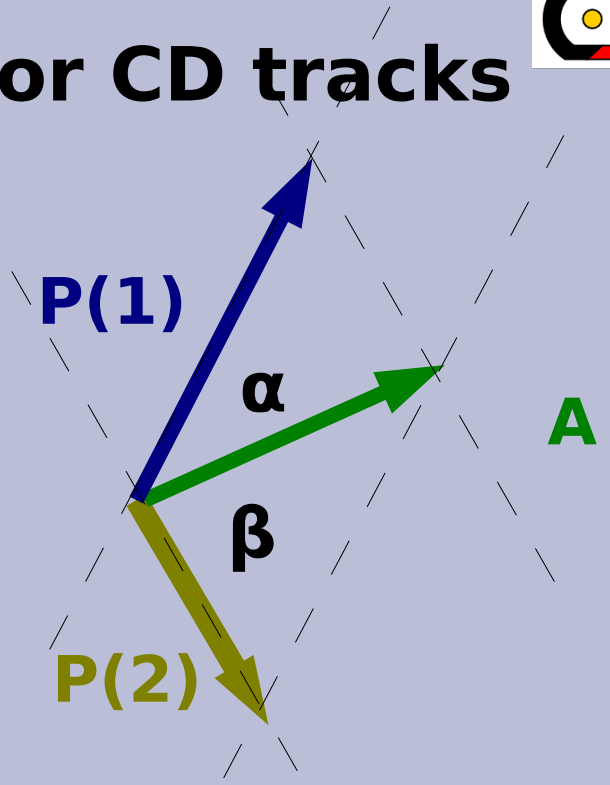


P(beam)=P(³He)+P(1)+P(2)

Momentum reconstruction for CD tracks







$$A = P(1) + P(2)$$