The ABC Effect and its Energy Dependance in the Double-Pionic Fusion to ^{4}He

Annette Pricking
University of Bonn / Tübingen

for the WASA-at-COSY Collaboration

MESON 2010
Krakow, June 14th 2010

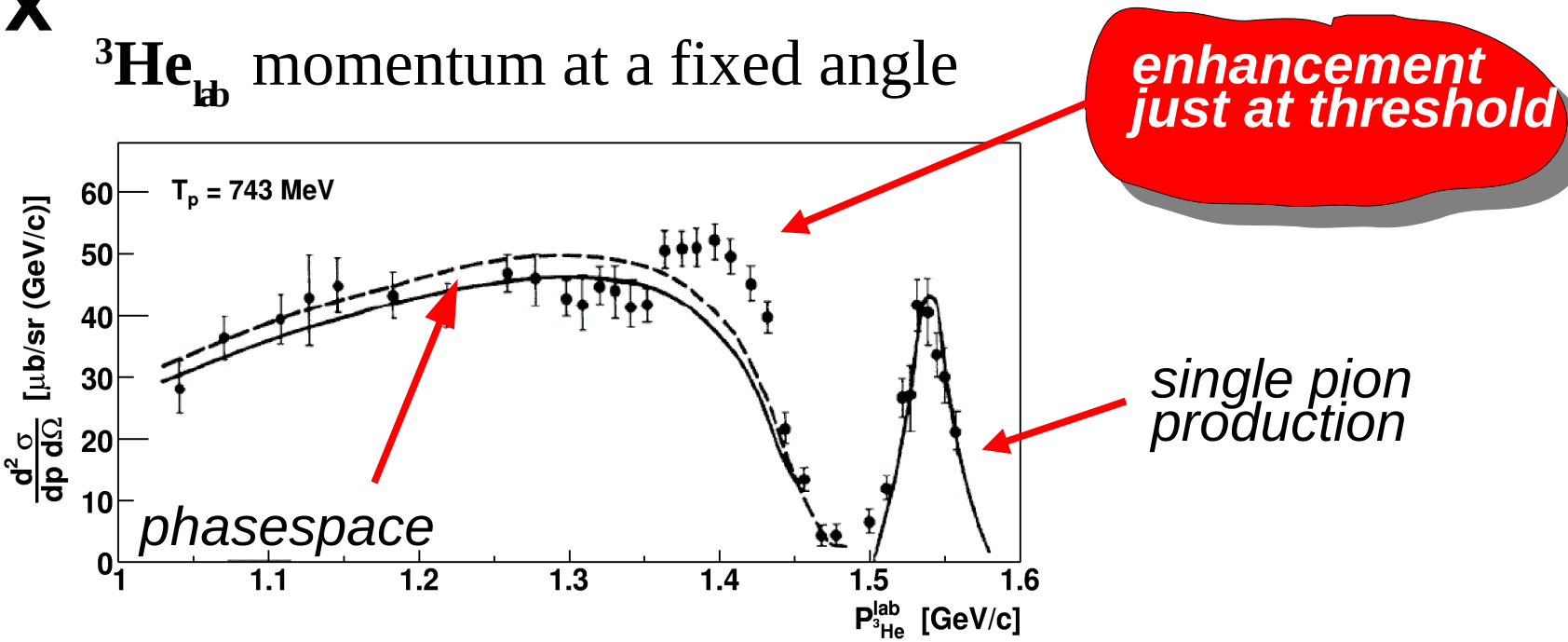
supported by COSY FFE, BMBF, Europ. Grad.School

What is the ABC Effect ?

Abashian, **B**ooth, **C**rowe, Phys. Rev. Lett. **5**, 258 (1960)

pd → ^{3}He X

^{3}He$_{lab}$ momentum at a fixed angle

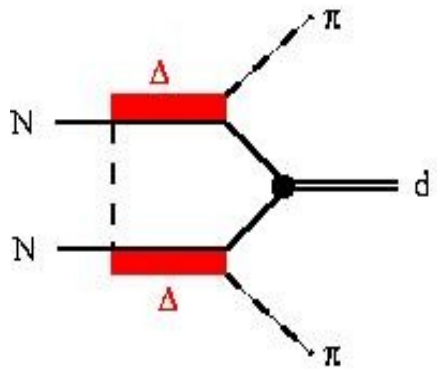


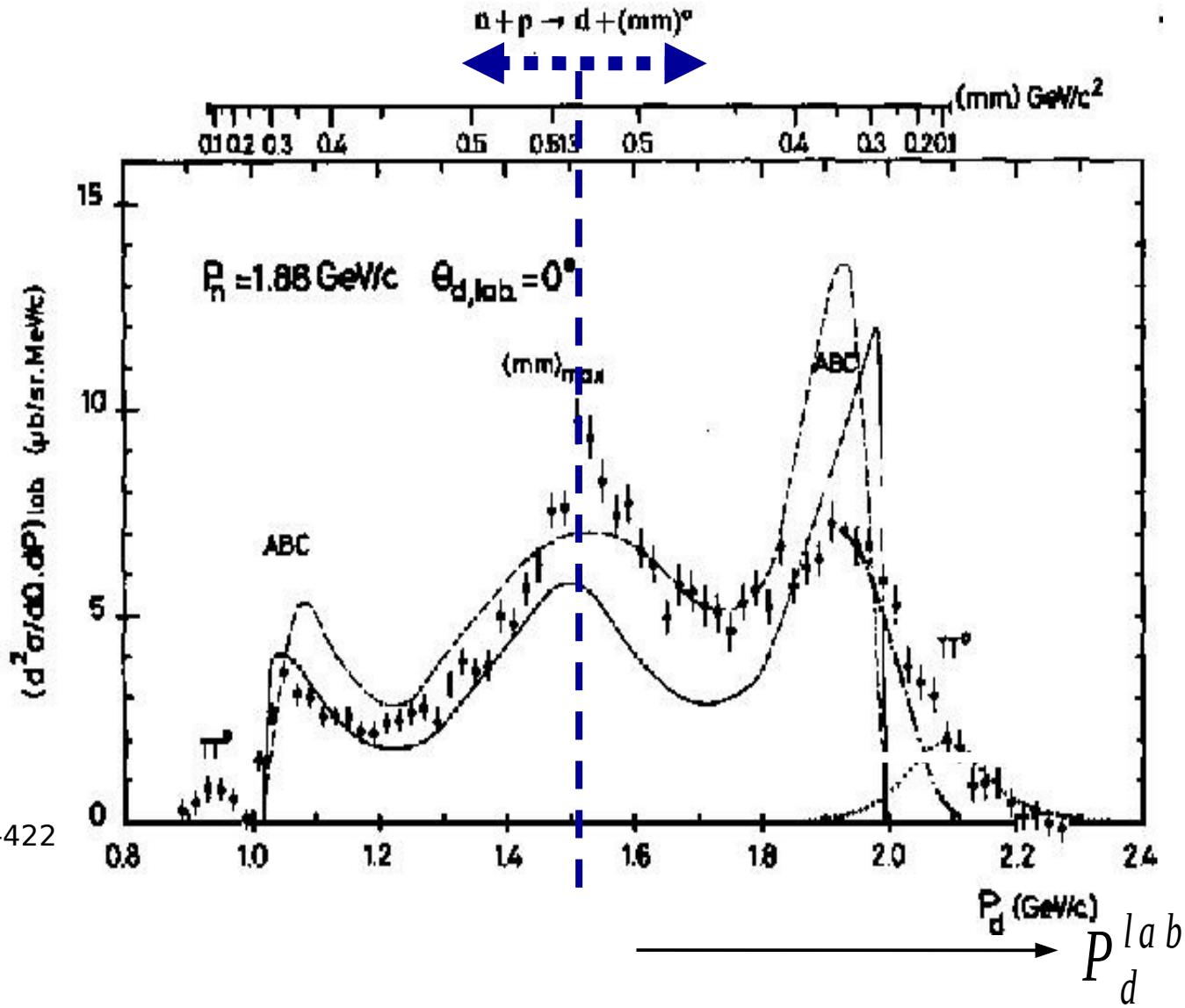
- two pion production in nuclear fusion reactions to d, ^{3}He, ^{4}He
- X isoscalar and neutral
- inclusive measurements

How to explain it ?

pn → d X

t-channel $\Delta\Delta$





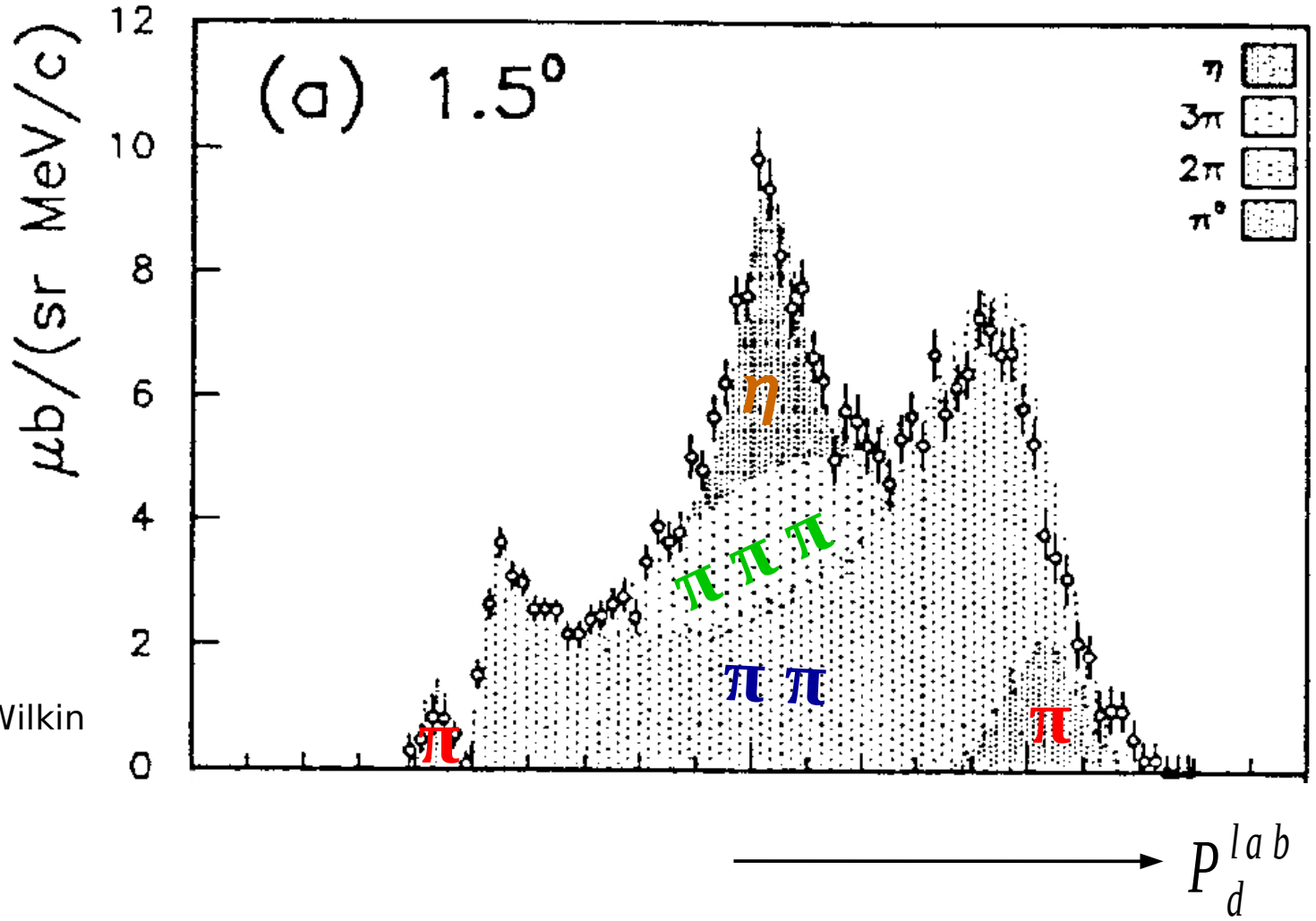
F. Plouin et. al.

Nucl. Phys. **A302** (1978), 413-422

How to explain it ?

pn → d X

Only inclusive measurements !



F. Plouin, P. Fleury, C. Wilkin

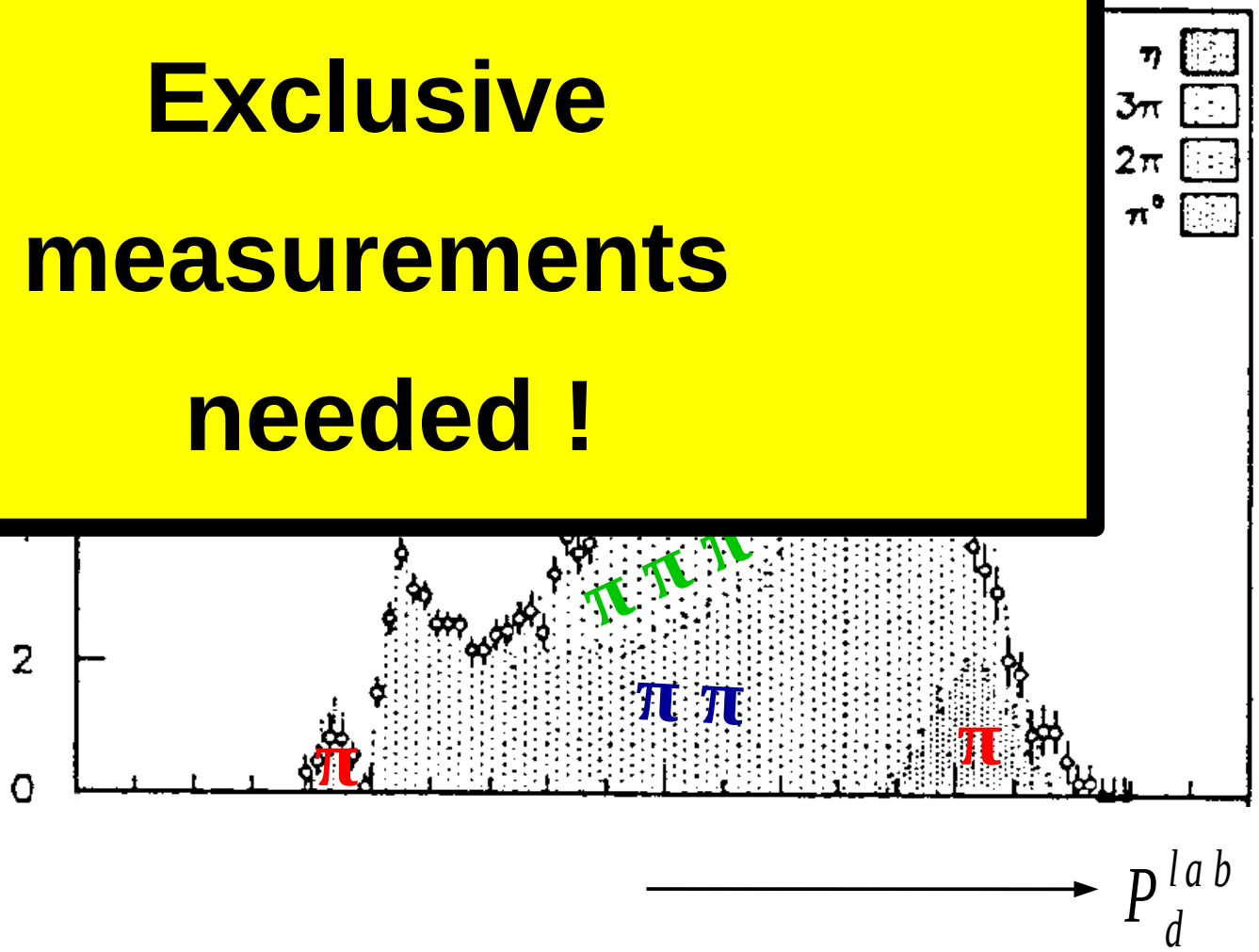
PRL **65** (1990) 692

How to explain it ?

pn → d X

Only inclusive measurements !

Exclusive measurements needed !



F. Plouin, P. Fleury, C. Wilkin

PRL **65** (1990) 692

Experiments with WASA-at-COSY

exclusive, kinematically complete, high statistics

start with CELSIUS-WASA, continued with WASA-at-COSY

pn → d $\pi\pi$ → paper in preparation M. Bashkanov

pd → ^{3}He $\pi\pi$ → first results on the way E. Perez del Rio

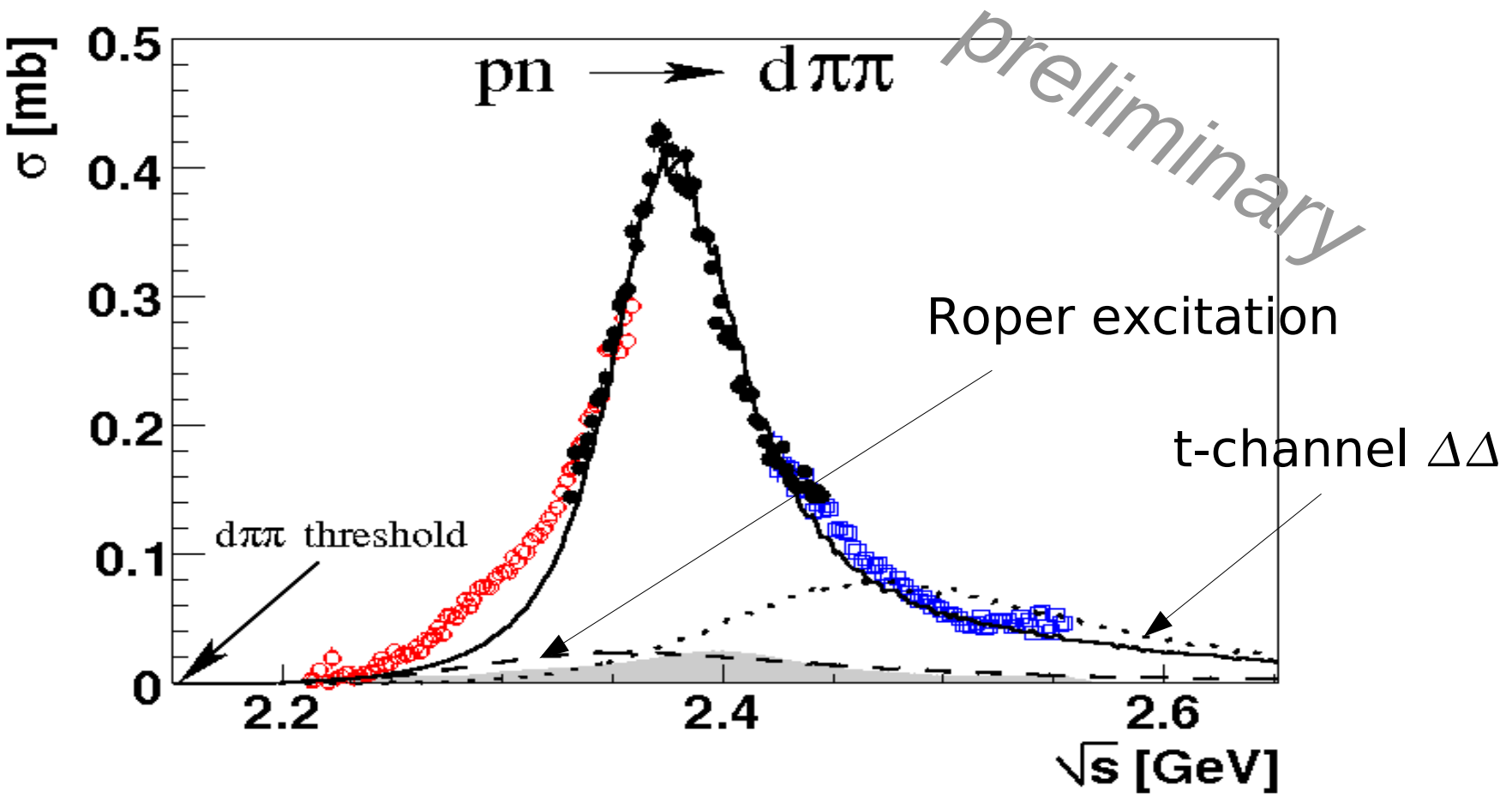
dd → ^{4}He $\pi\pi$ → this talk

Experiments with WASA-at-COSY

exclusive, kinematically complete, high statistics

pn → d $\pi\pi$ → paper in preparation M. Bashkanov

(see also poster #4)

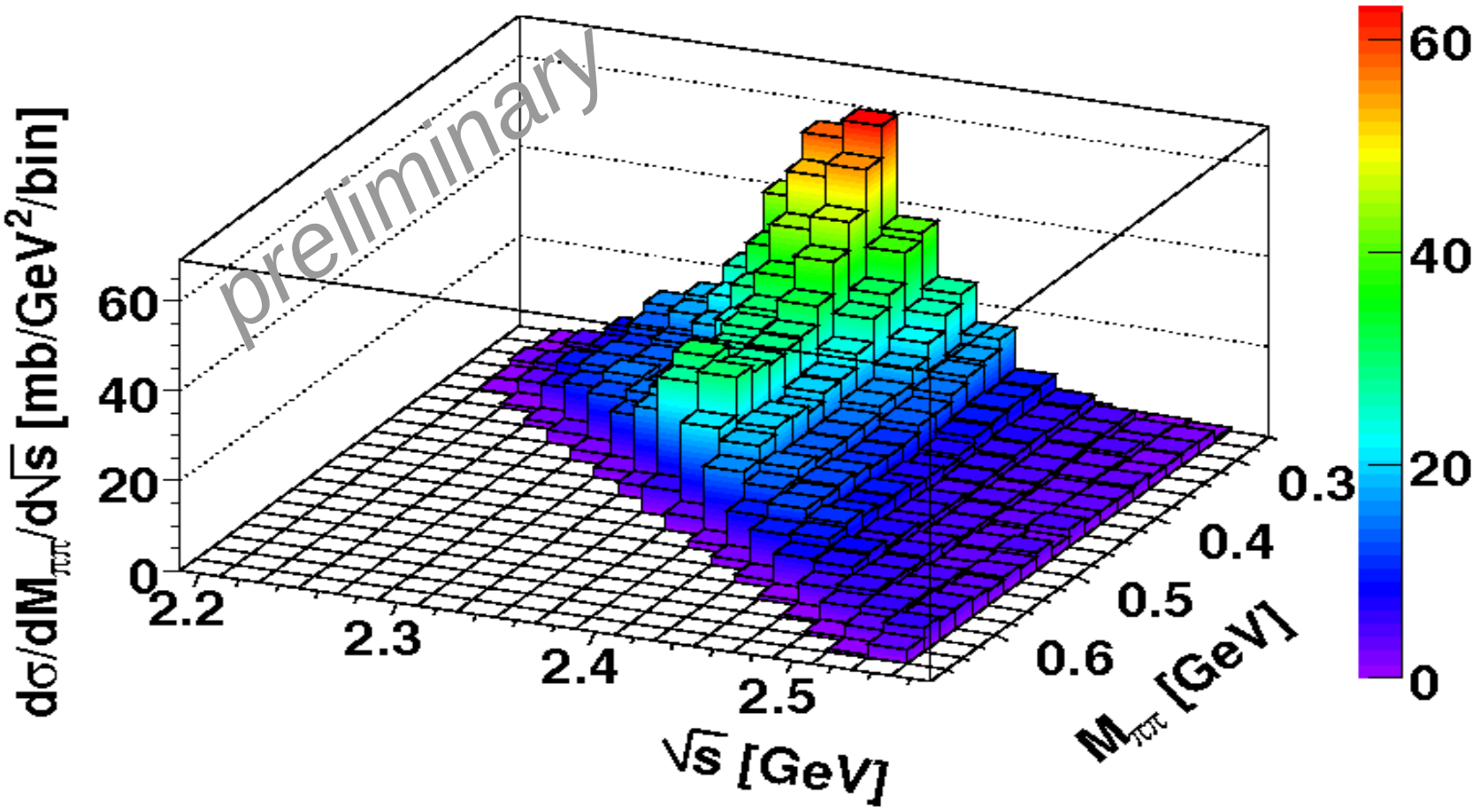


Experiments with WASA-at-COSY

exclusive, kinematically complete, high statistics

pn → d $\pi\pi$ → paper in preparation M. Bashkanov

(see also poster #4)



Experiments with WASA-at-COSY

exclusive, kinematically complete, high statistics

start with CELSIUS-WASA, continued with WASA-at-COSY

pn → d $\pi\pi$ → paper in preparation M. Bashkanov

pd → ^{3}He $\pi\pi$ → first results on the way E. Perez del Rio

dd → ^{4}He $\pi\pi$ → this talk

September and December 2007:

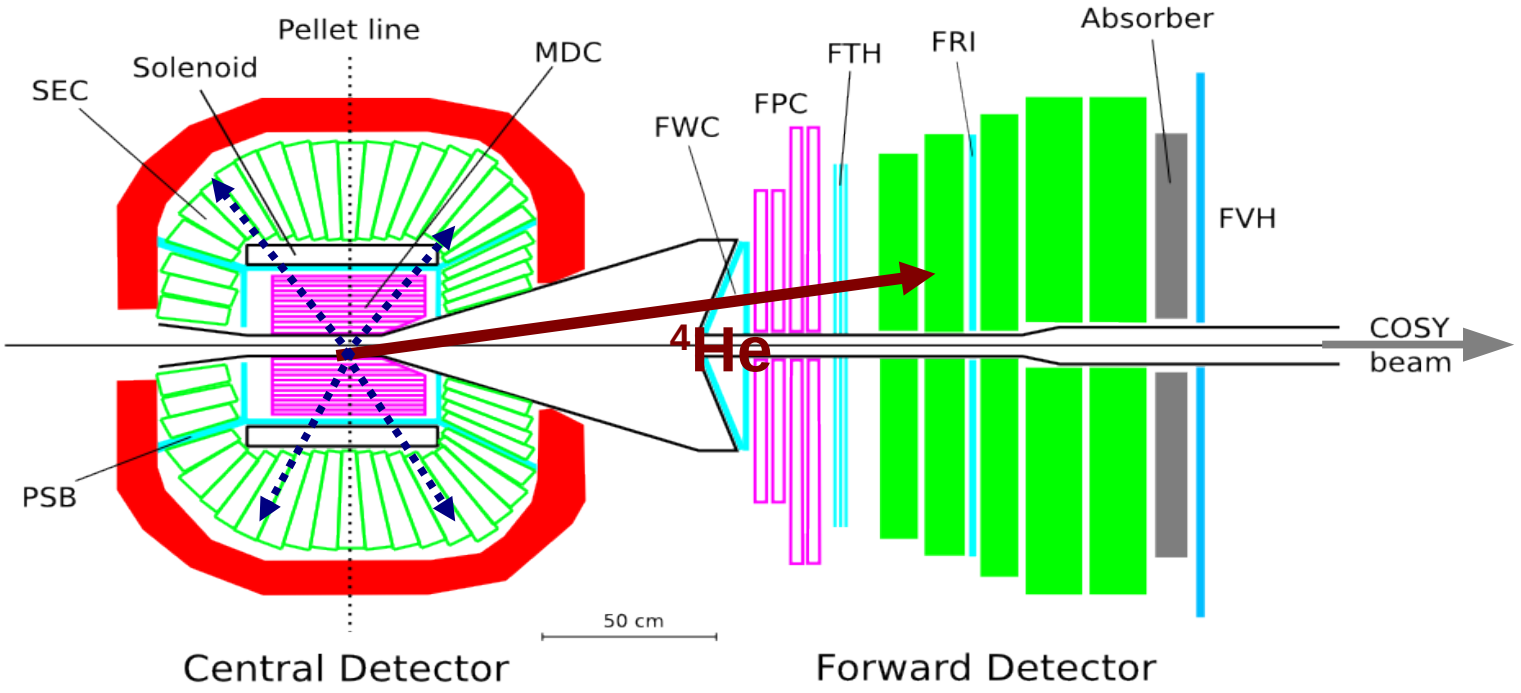
9 beam energies

1.0 GeV 1.2 GeV (two weeks commissioning beamtime, September)

0.8 GeV 0.9 GeV 1.05 GeV 1.117 GeV
1.25 GeV 1.320 GeV 1.4 GeV

(two weeks dedicated beamtime, December)

$dd \rightarrow {}^4He\ \pi^0\pi^0$

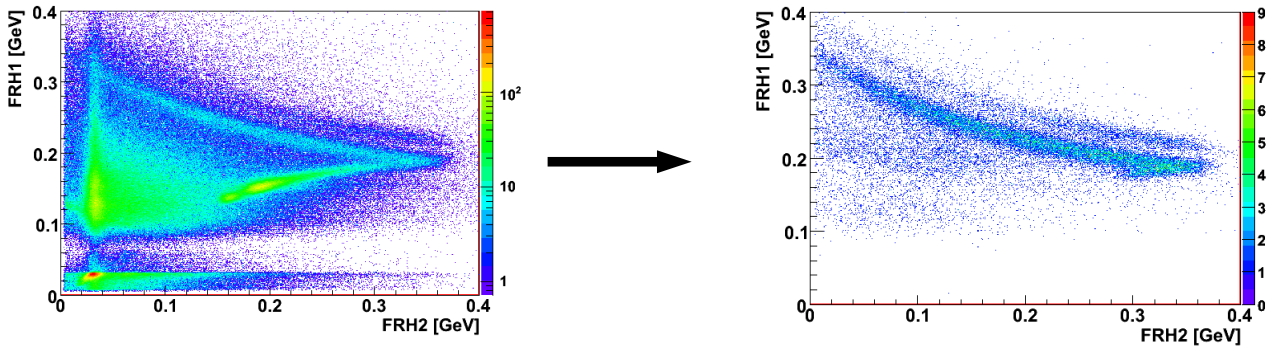


- deuteron beam, deuteron pellets
- ^{4}He stopping in first 3 thick layers of the forward detector
- π^0 decays in 2 γ $\rightarrow$ detect 4 neutral tracks in central detector

Analysis

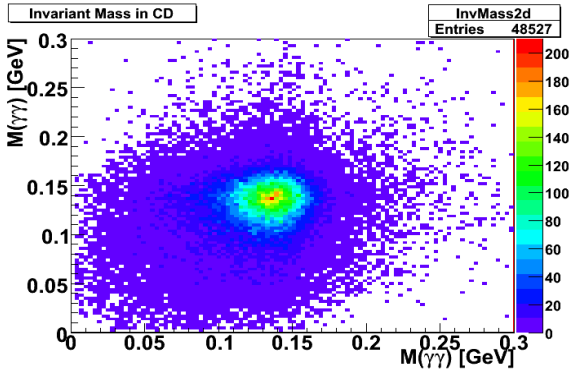
Identify the He

ΔE-E Plots



Identify the two π^0

Find the best combination of
4 γ which form two π^0



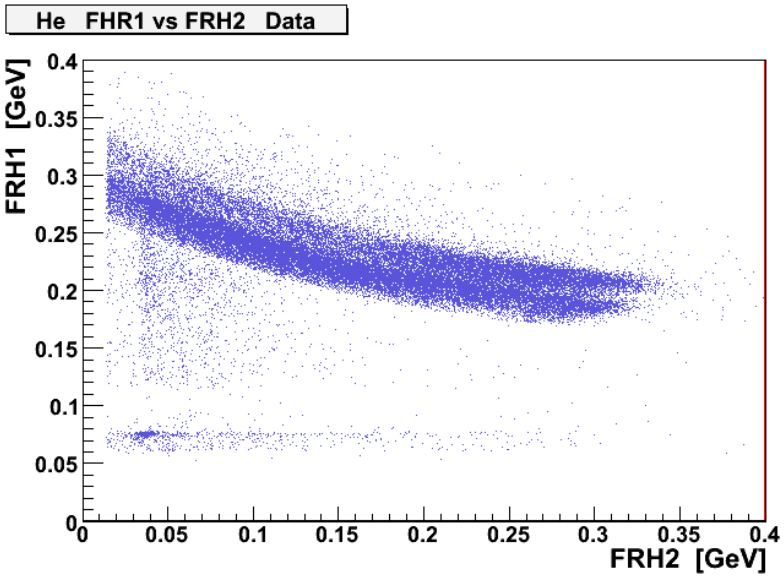
Kinematic Fit with 6 overconstraints

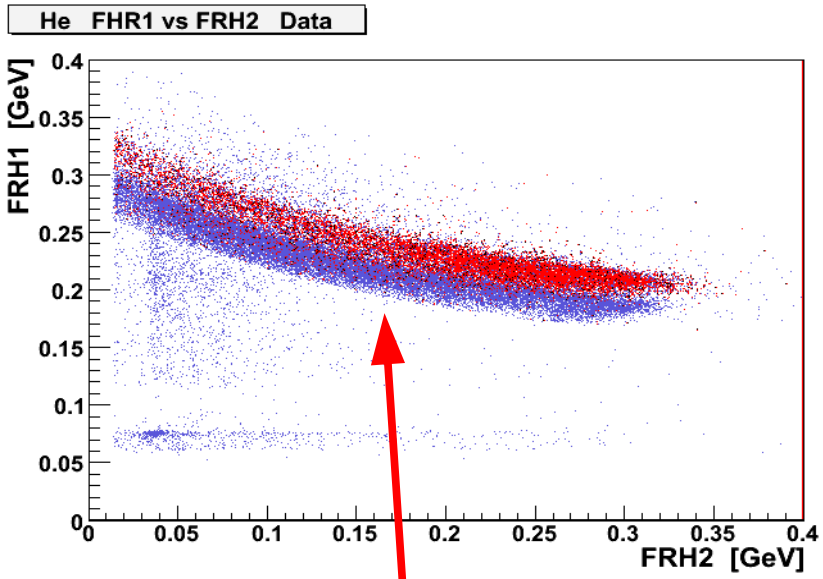
- improve resolution
- find best $\gamma\gamma \leftrightarrow \pi^0$ combination
- ^{3}He / ^{4}He separation

Efficiency and acceptance corrections

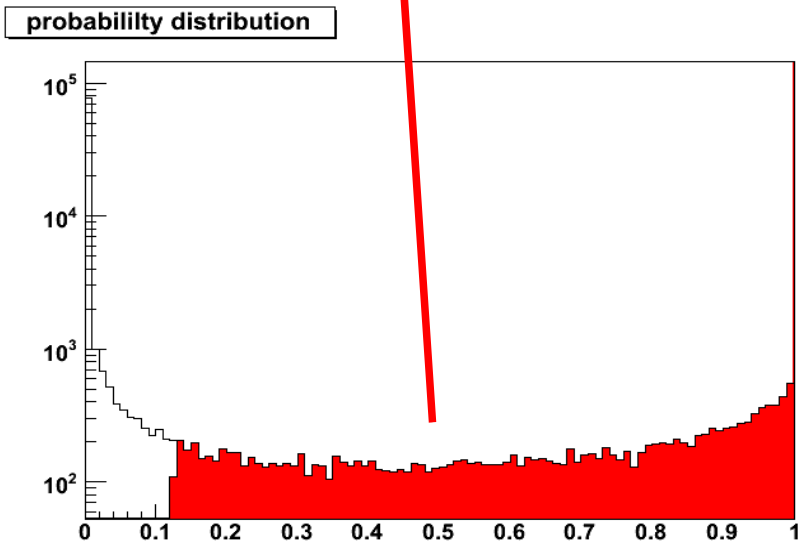
^3He / ^4He Separation with Kinematic Fit

all He which have $2\pi^0$



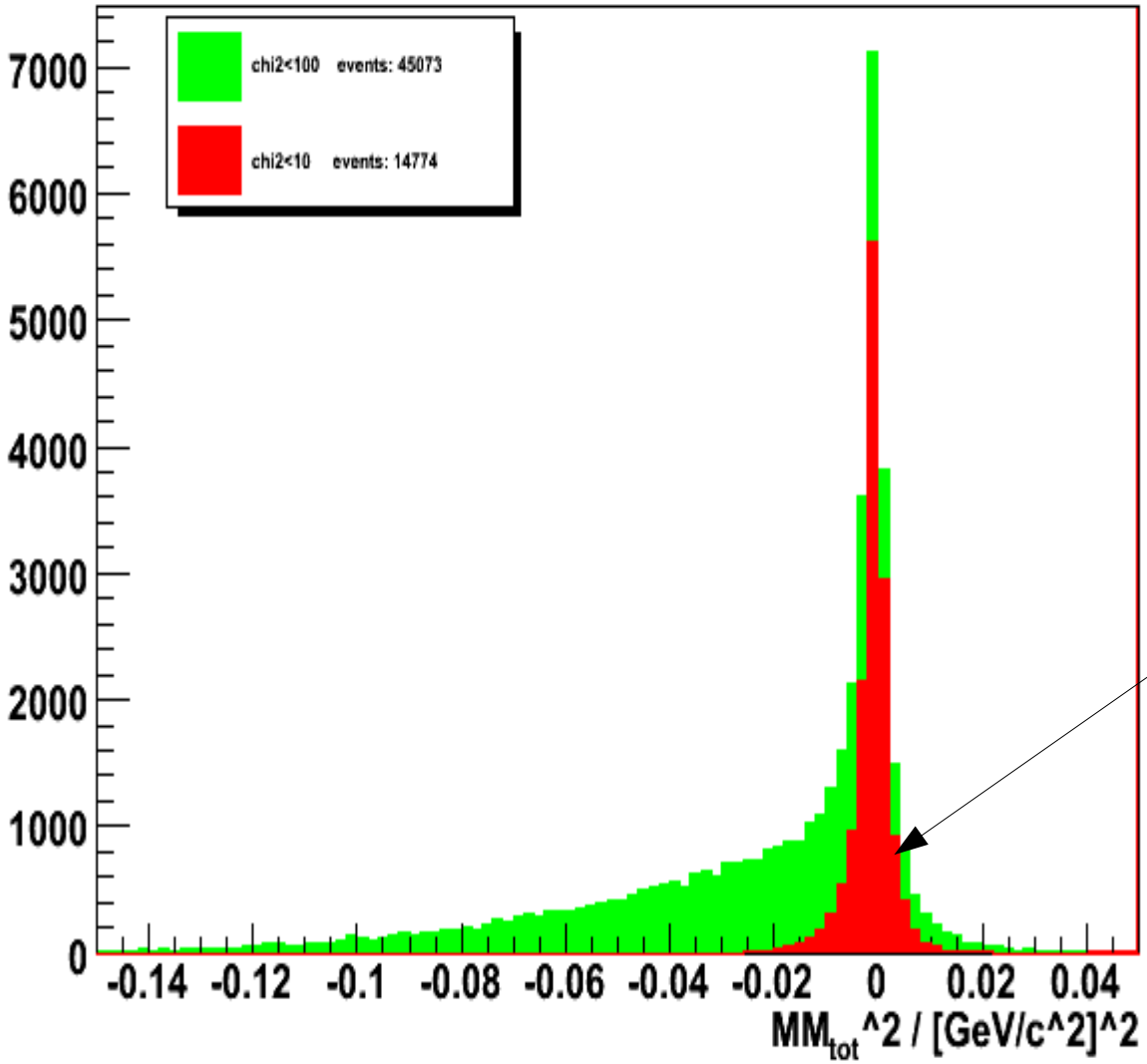


kinematic fit
assuming the He to be ^4He



Check ^{3}He / ^{4}He Separation

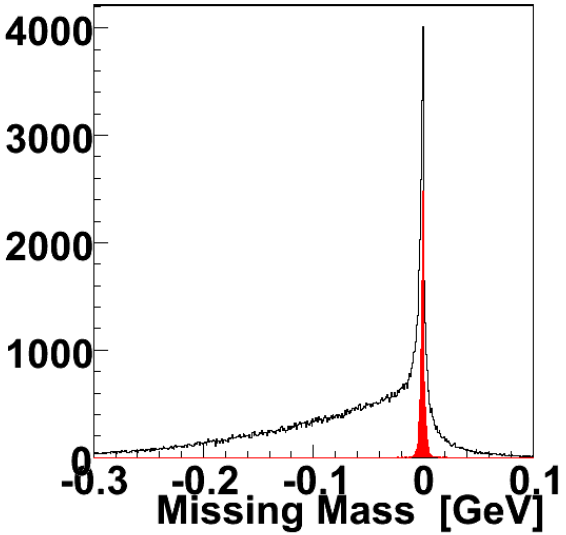
Missing Mass of the Total System



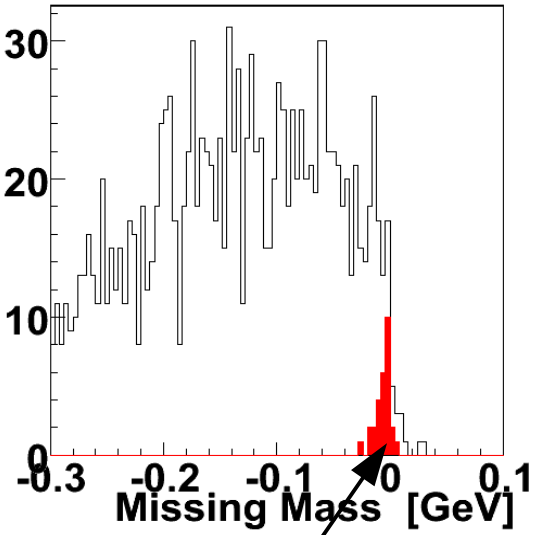
selected events

Check ^{3}He / ^{4}He Separation

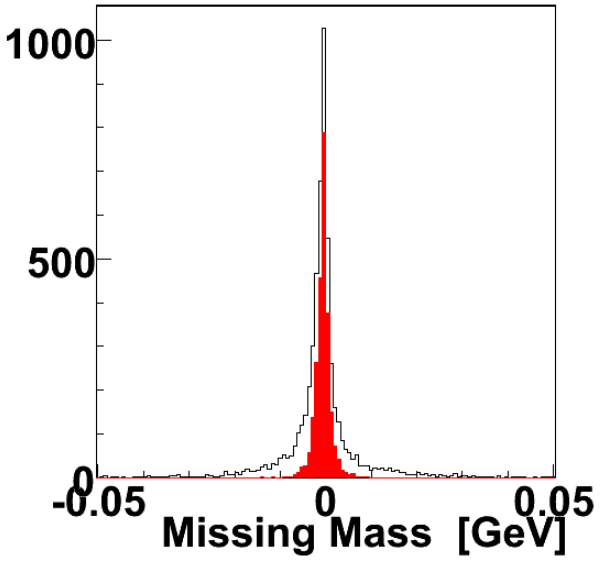
experimental data



MC dd→ ^{3}He n $2\pi^0$



MC dd→ ^{4}He $2\pi^0$

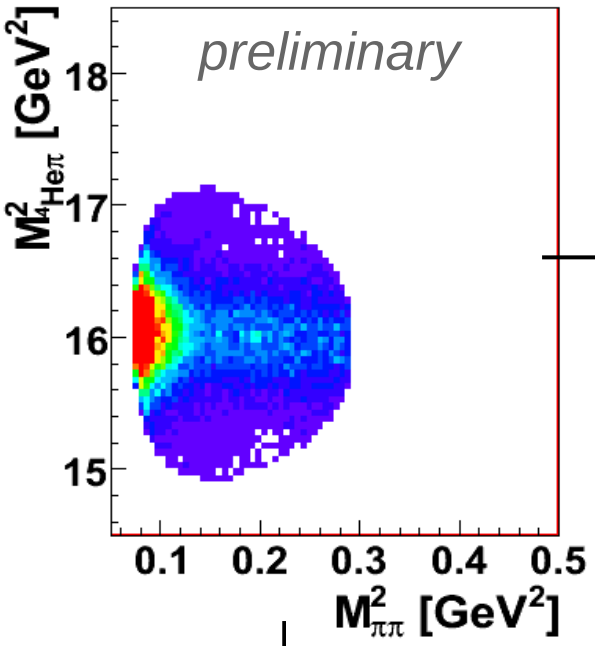


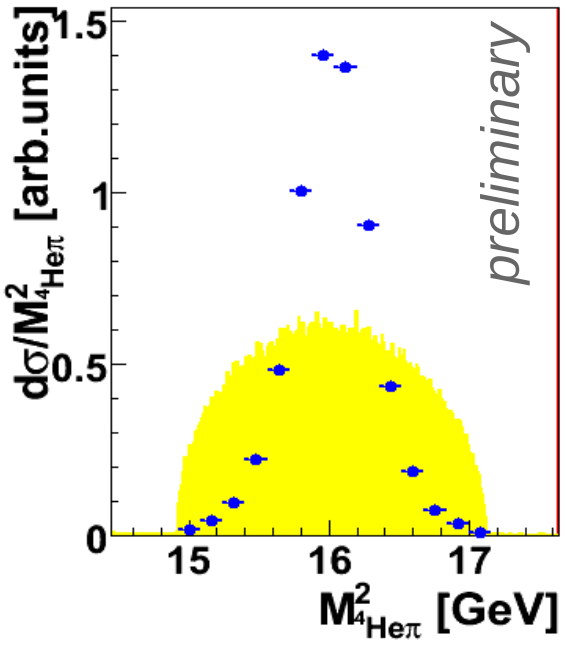
$2.8 \cdot 10^{-4}$ of all ^{3}He n $2\pi^0$ survive the kinfit

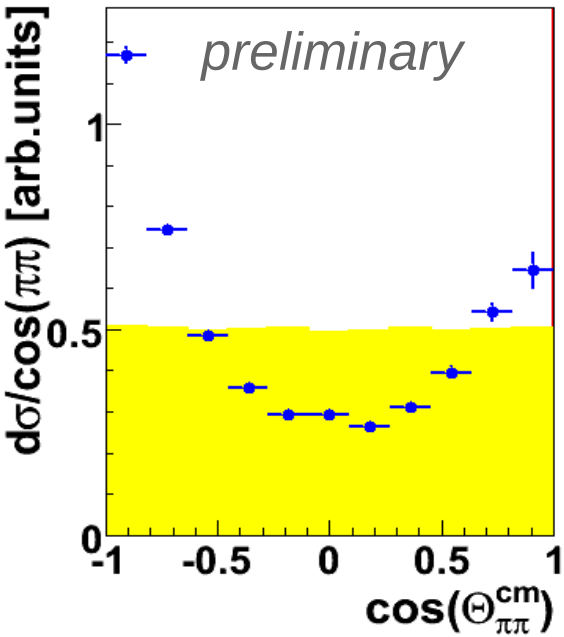
Results:

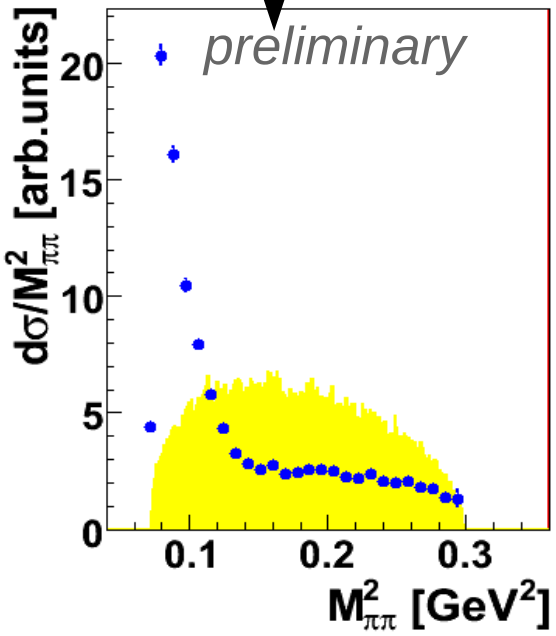
differential cross sections

1.117 GeV



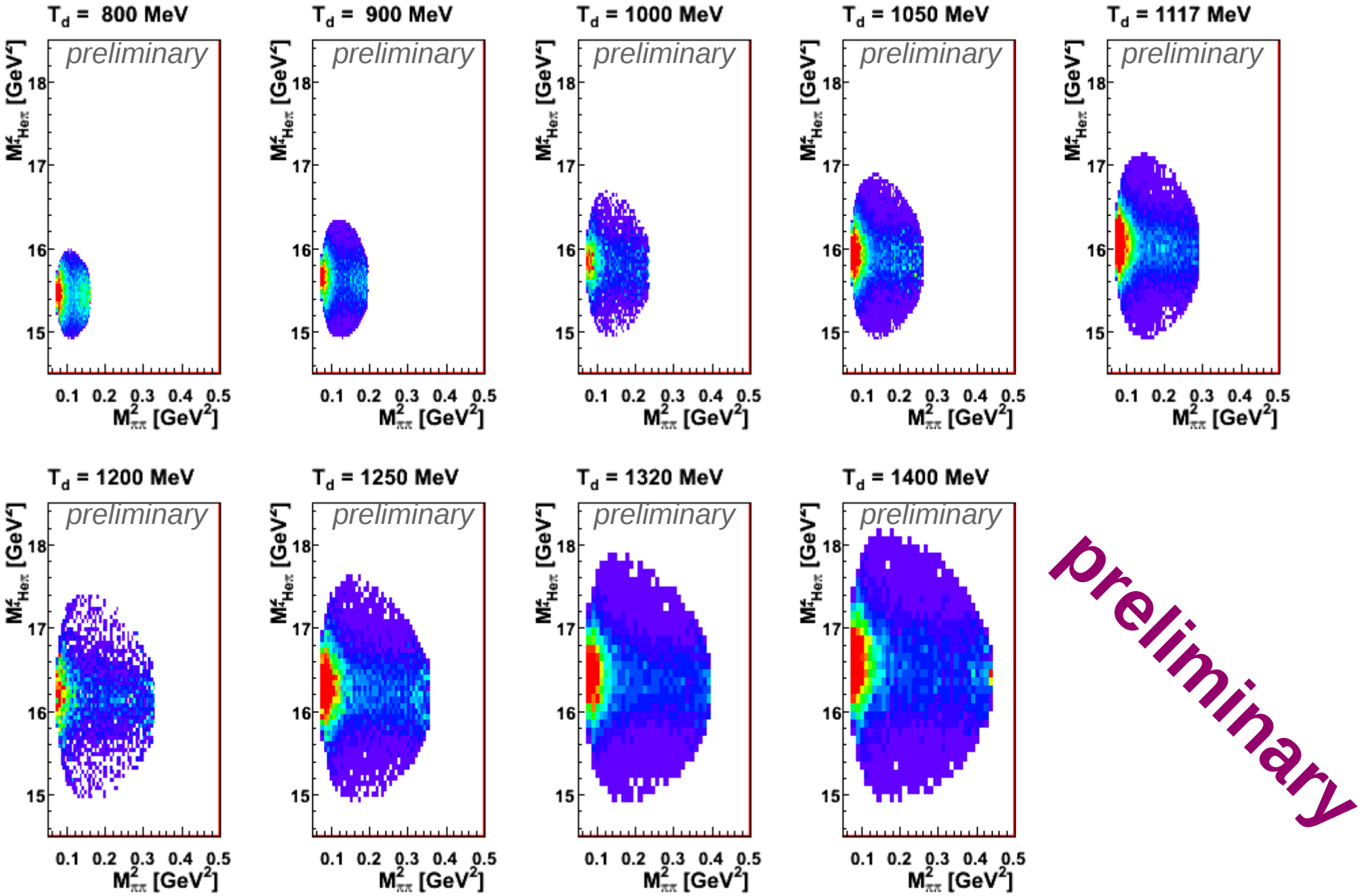






- low-mass enhancement in the $\pi^0\pi^0$ invariant mass spectrum
- clear signal of $\Delta\Delta$ in $^4He\pi^0$ invariant mass
- strong angular dependence

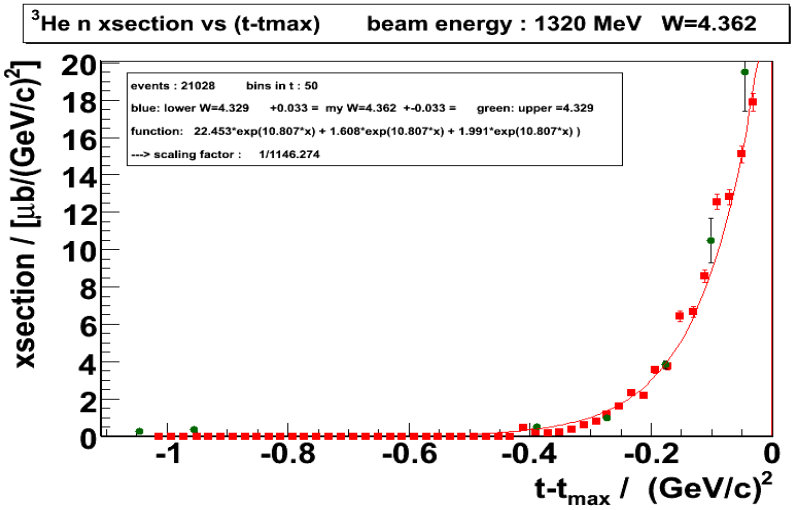
Dalitz Plots



preliminary

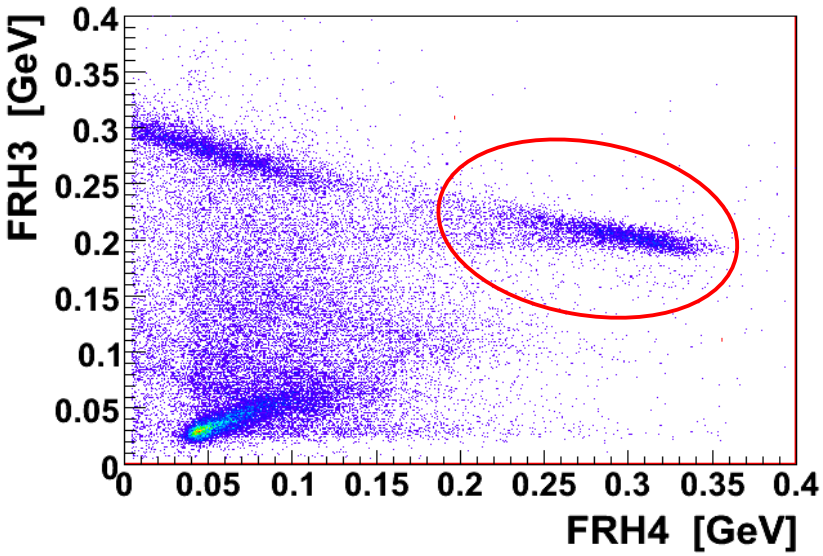
Total Cross Section

- Absolute normalization with **dd→ ^{3}He n**
- Easy to separate from other reactions
- Same trigger as dd → ^{4}He $\pi^0\pi^0$
- Saclay data available Bizard et al. PhysRevC.22.1632

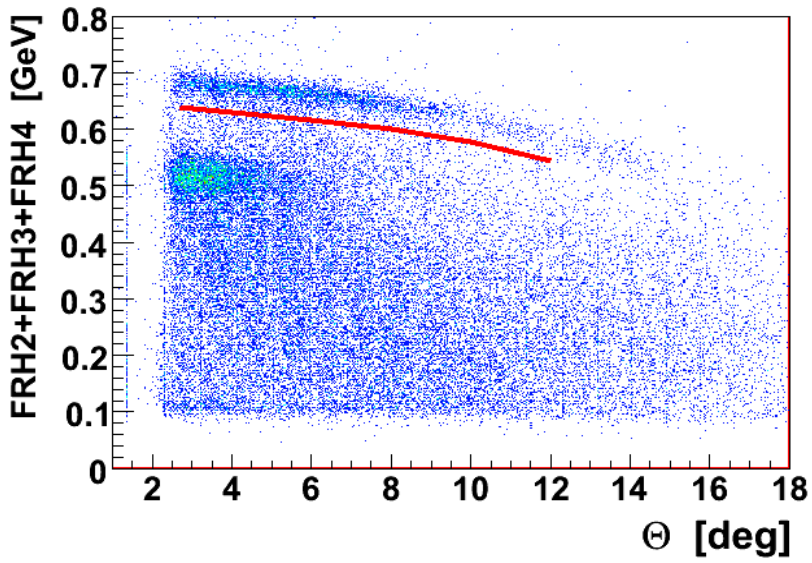


1117 MeV

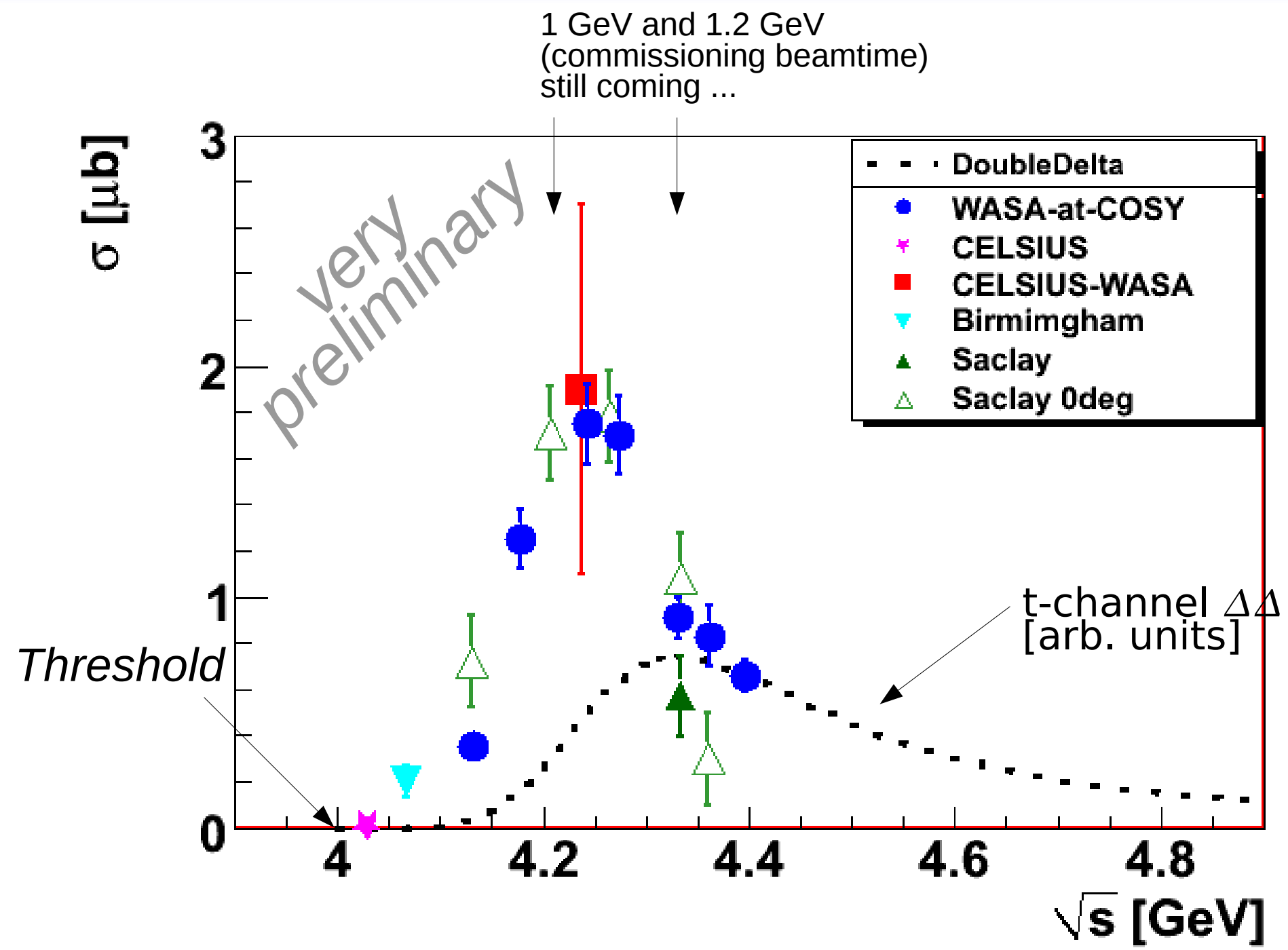
ΔE vs E



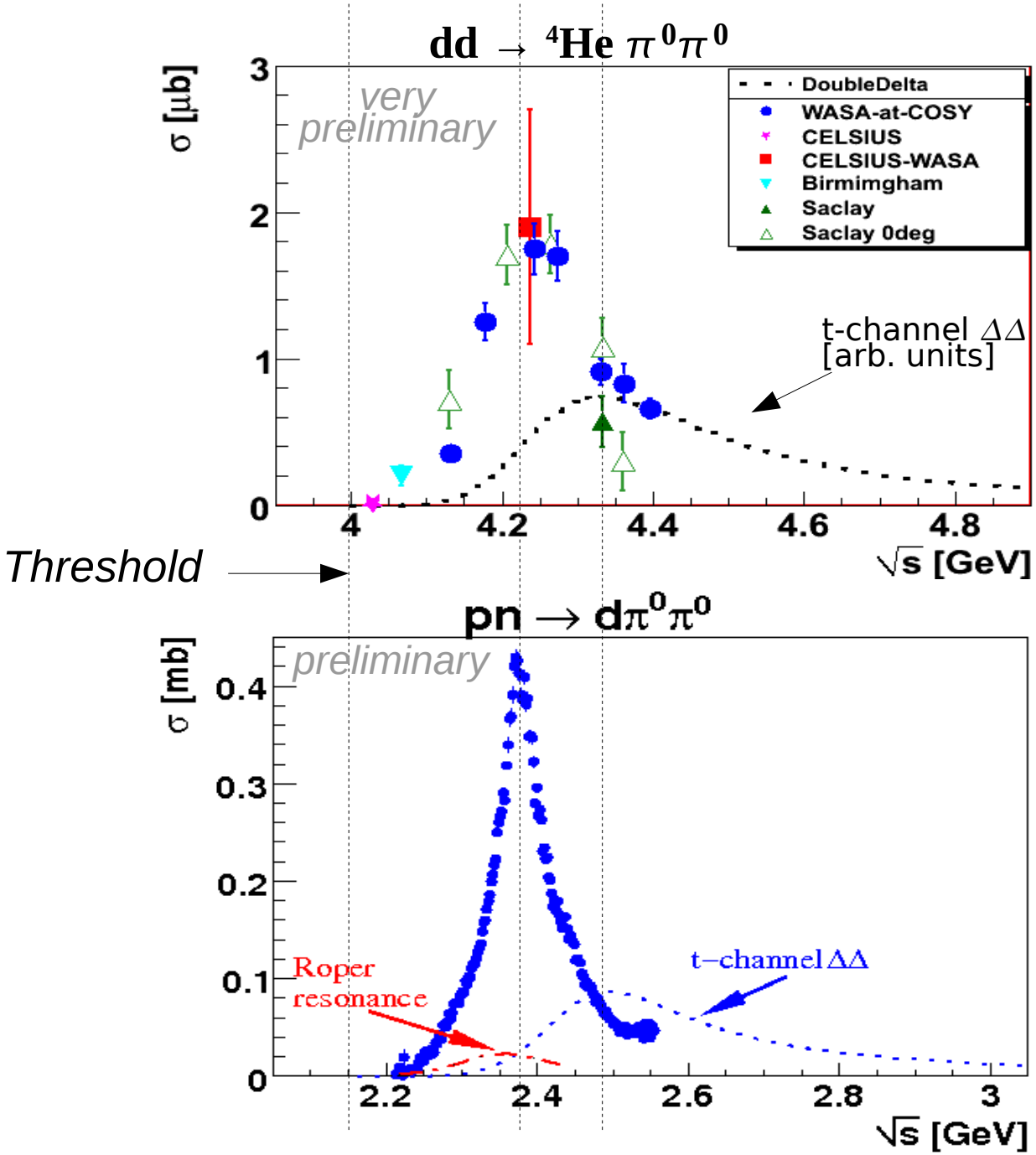
E vs θ



Total Cross Section



Total Cross Section



M. Bashkanov
paper in preparation

Summary

- exclusive data of dd → ^{4}He ππ were taken at 9 different energies
- preliminary results for $\pi^0\pi^0$
  - pronounced low-mass enhancement in the $\pi^0\pi^0$ invariant mass spectrum
  - clear signal of $\Delta\Delta$ in ^{4}Heπ^0 invariant mass / Dalitz plot
  - strong angular dependence
  - strong energy dependence in total cross section
  - t-channel $\Delta\Delta$ model at variance with data

Summary and Outlook

- exclusive data of dd → ^{4}He ππ were taken at 9 different energies
- preliminary results for $\pi^0\pi^0$
  - pronounced low-mass enhancement in the $\pi^0\pi^0$ invariant mass spectrum
  - clear signal of $\Delta\Delta$ in ^{4}Heπ^0 invariant mass / Dalitz plot
  - strong angular dependence
  - strong energy dependence in total cross section
  - t-channel $\Delta\Delta$ model at variance with data

- still: finalize analysis
- try to understand the result ...
  - ABC group at COSY: experimentalists and theorists

(ANKE, WASA ...)

Summary and Outlook

exclusive data of dd → ^{4}He $\pi\pi$ were taken at 9 different energies

preliminary results for $\pi^0\pi^0$

pronounced low-mass enhancement in the $\pi^0\pi^0$ invariant mass spectrum

clear signal of $\Delta\Delta$ in ^{4}Heπ^0 invariant mass / Dalitz plot

strong angular dependence

strong energy dependence in total cross section

t-channel $\Delta\Delta$ model at variance with data

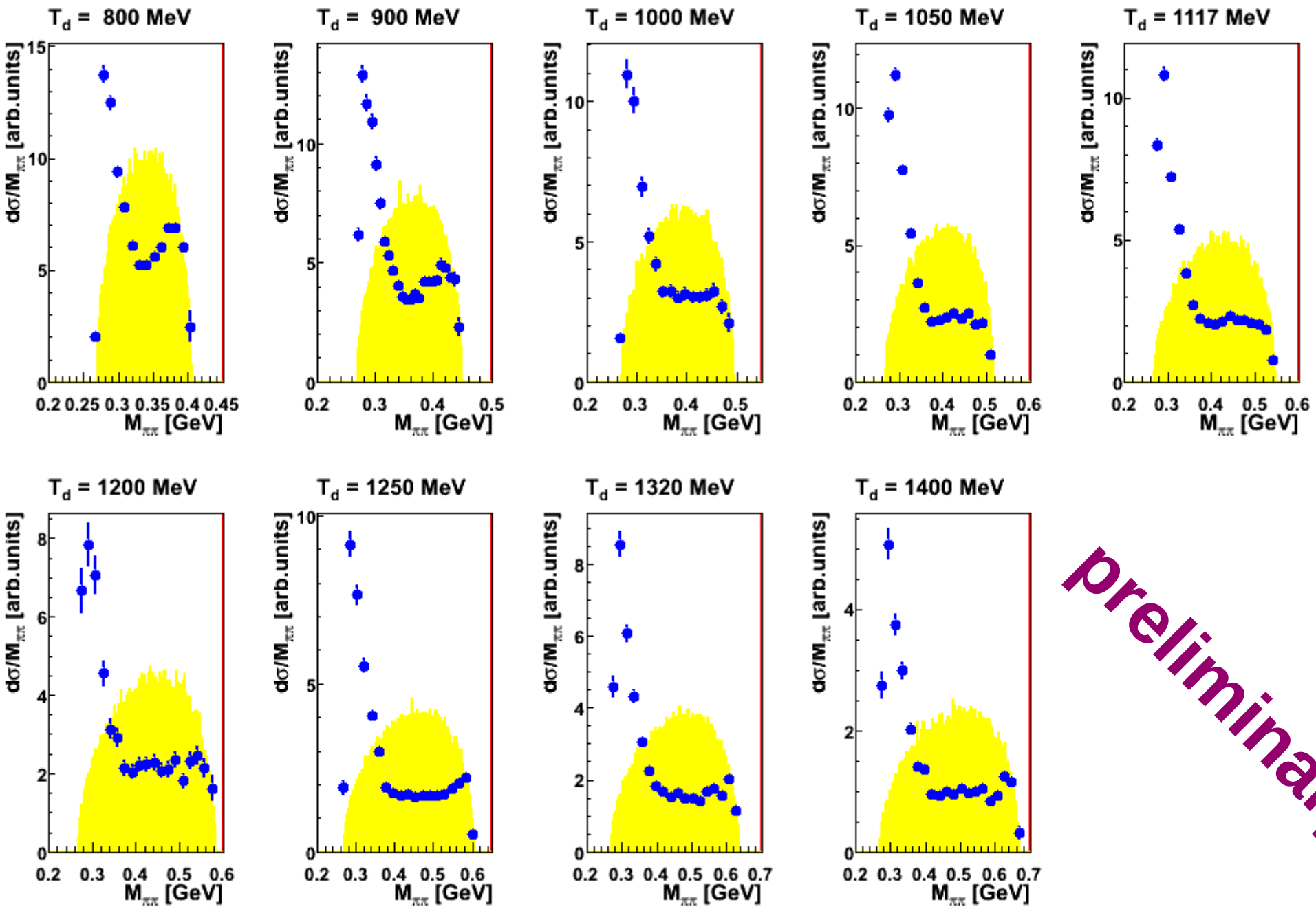
still: finalize analysis

try to understand the result ...

ABC group at COSY: experimentalists and theorists

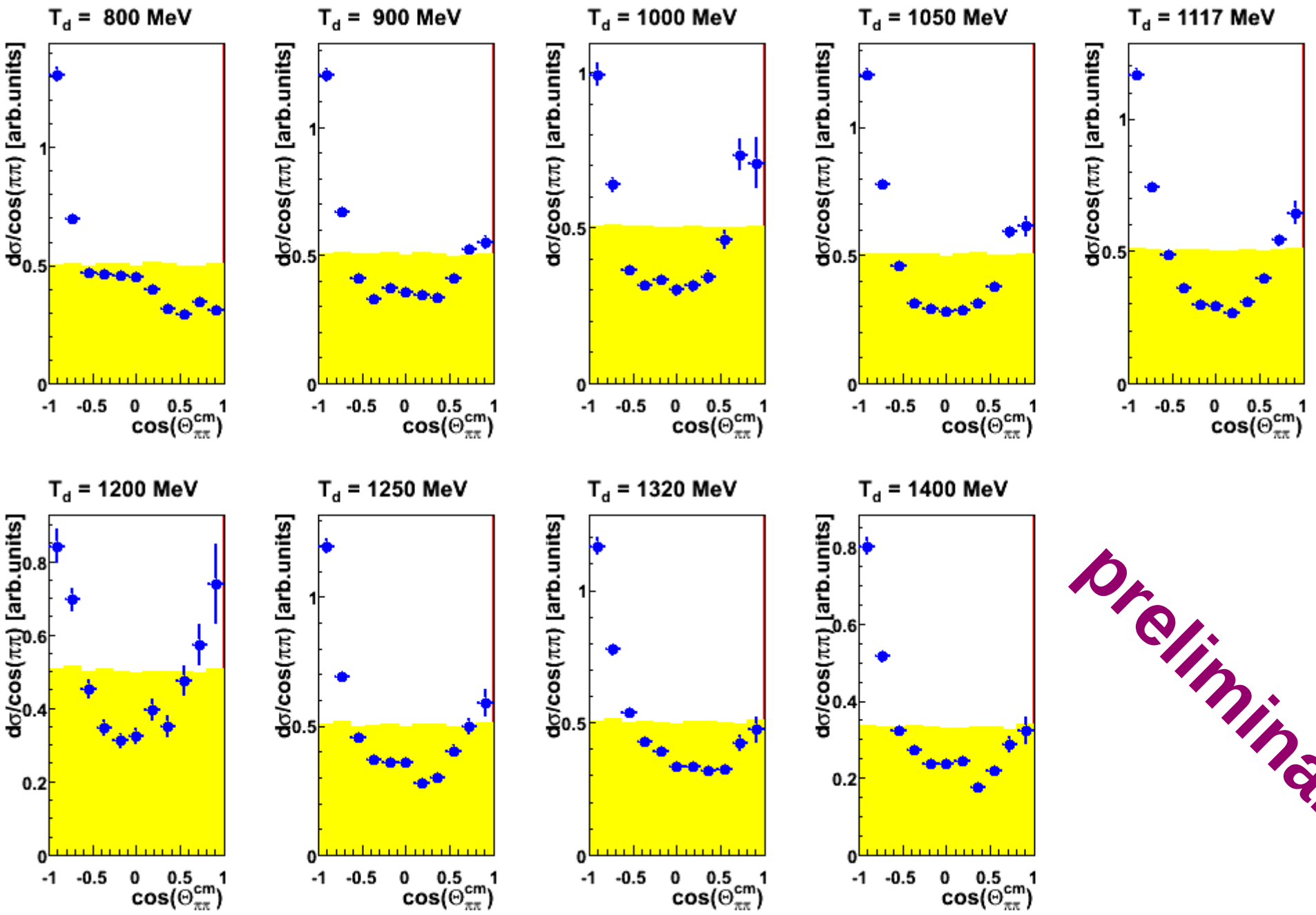
(ANKE, WASA ...)

$M_{\pi^0\pi^0}$



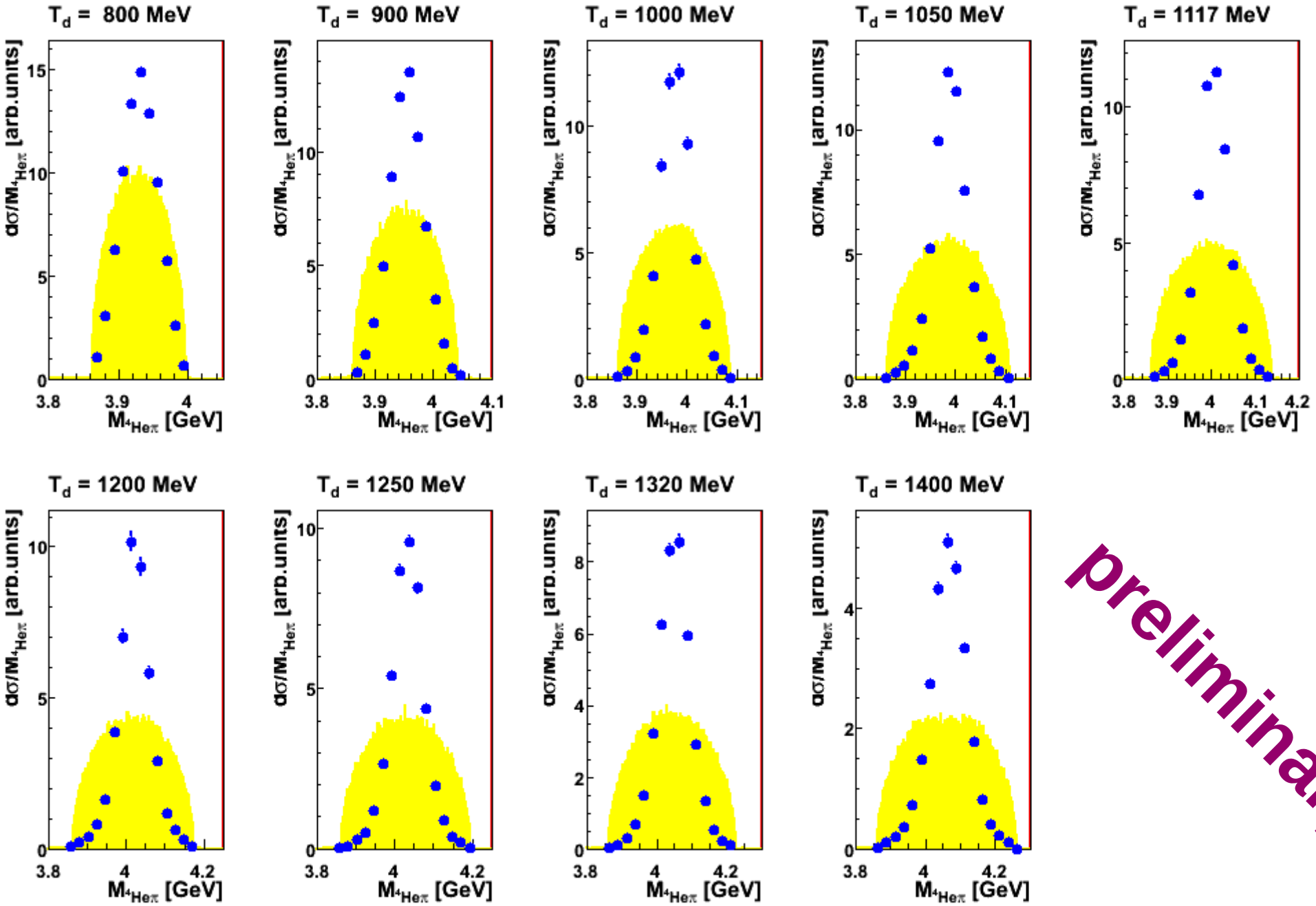
preliminary

$cos(\theta_{\pi^0\pi^0})$



preliminary

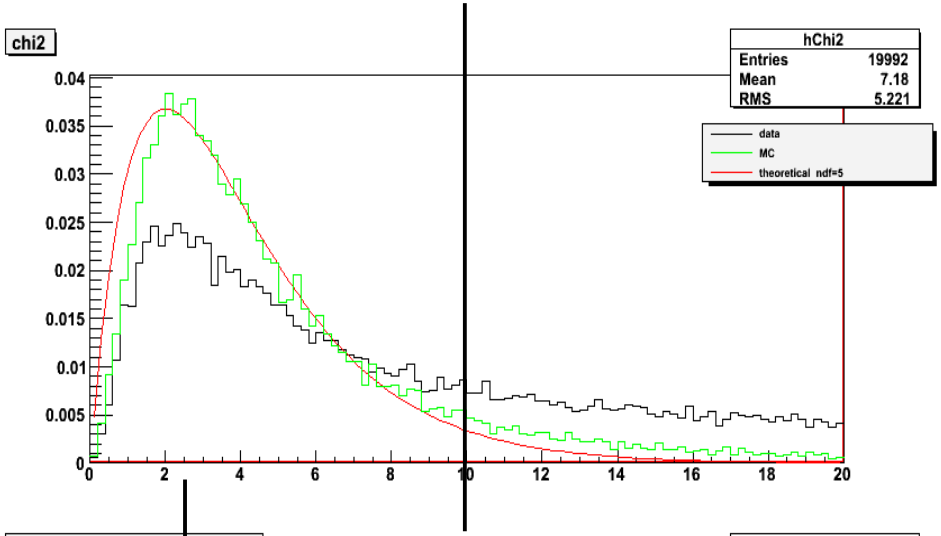
$M_{^4He\pi^0}$

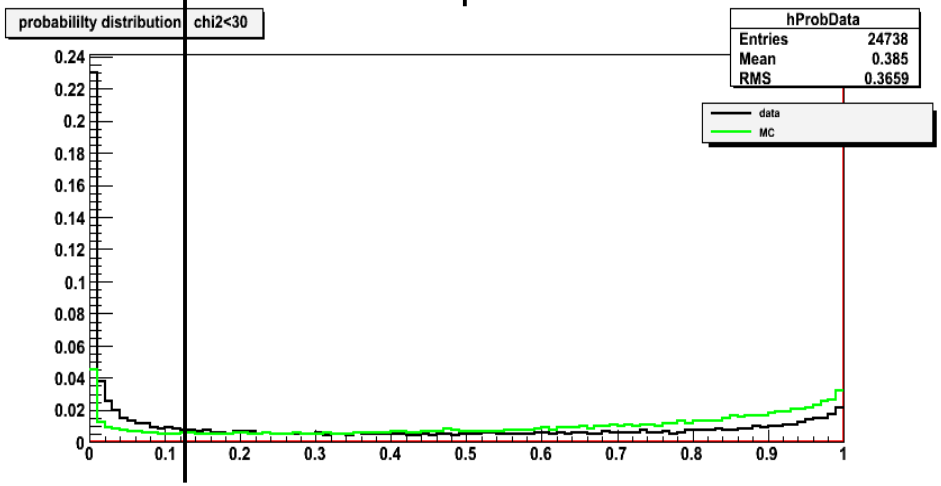


preliminary

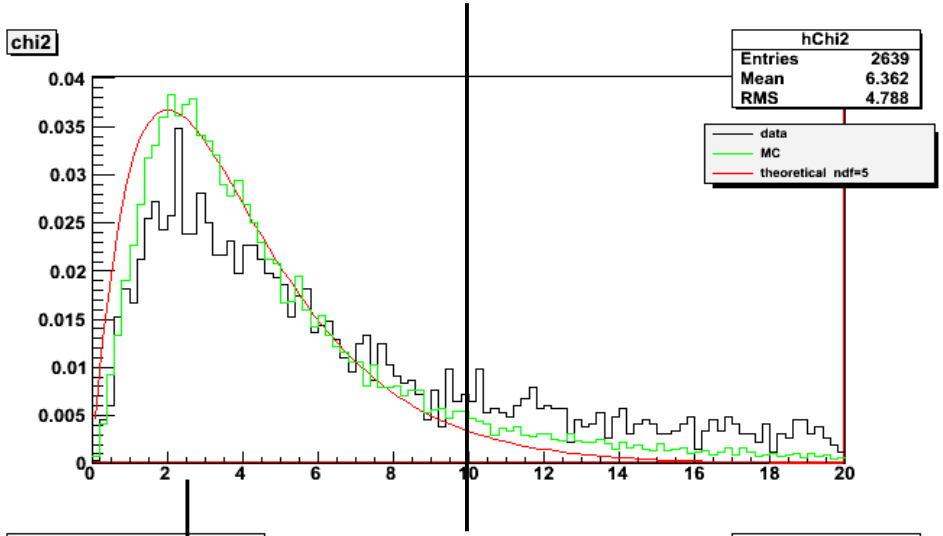
KinFit

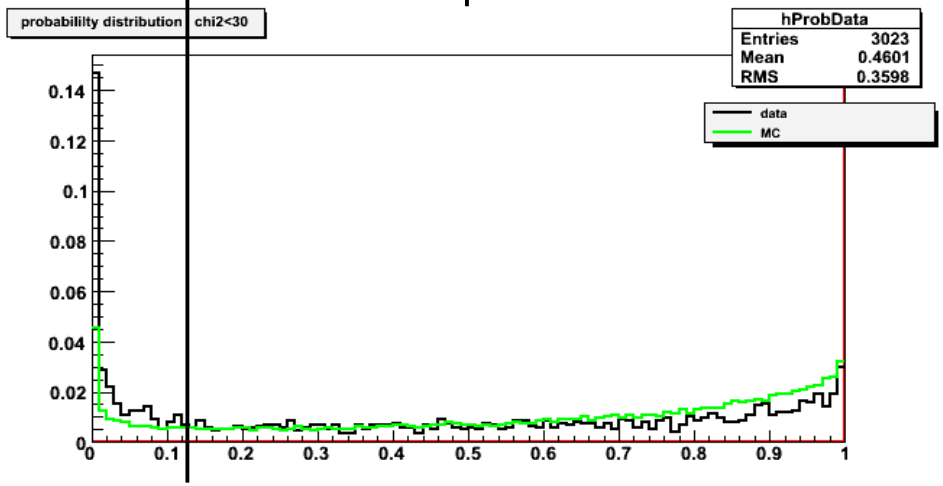
- now do kinematic fit assuming the forward particle to be ^{4}He
- perform one fit for each combination of gammas





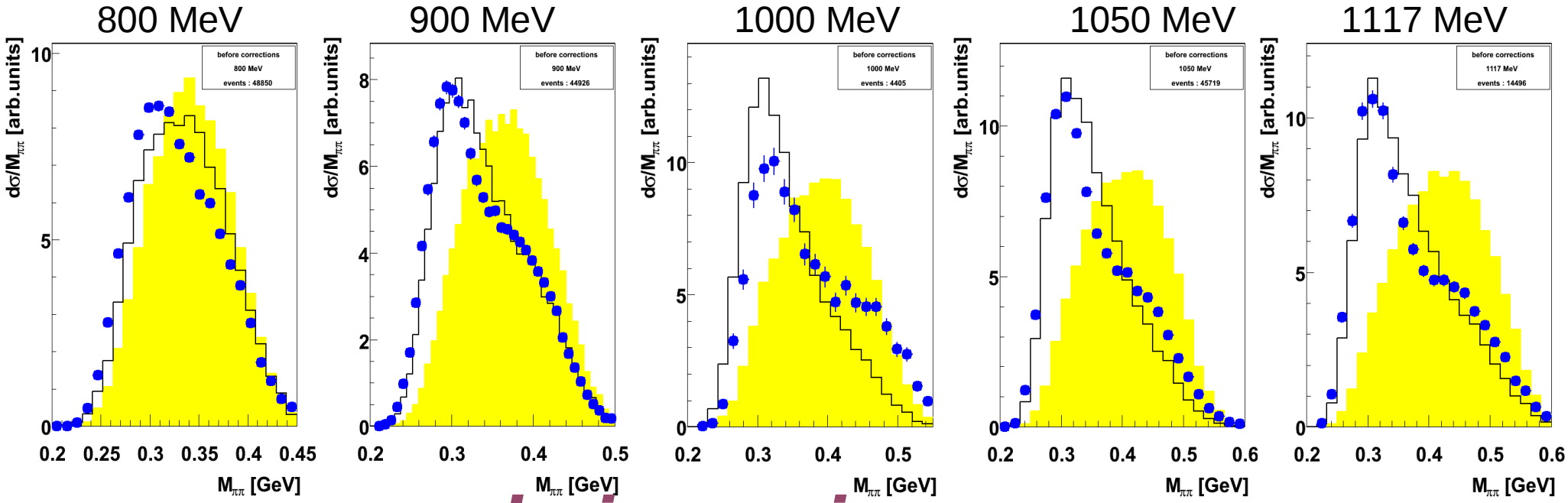
usual He selection



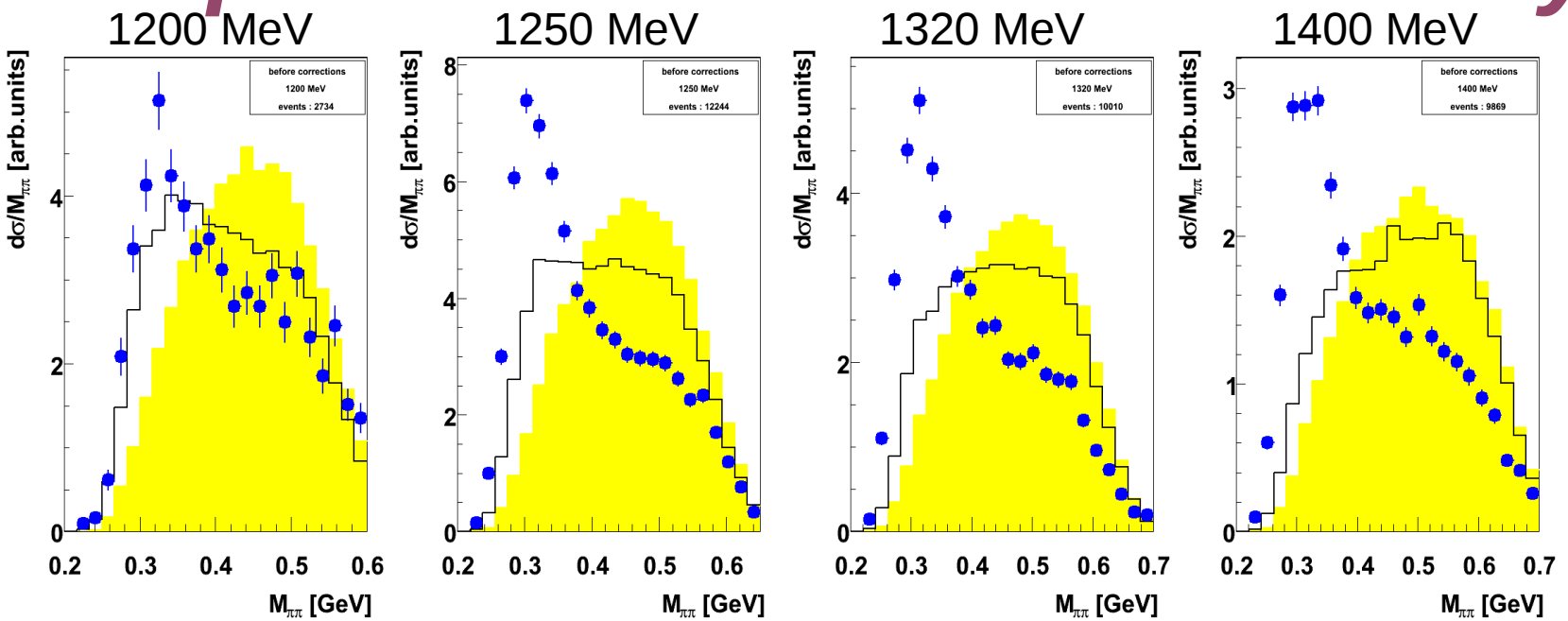


^{4}He selection for some elements

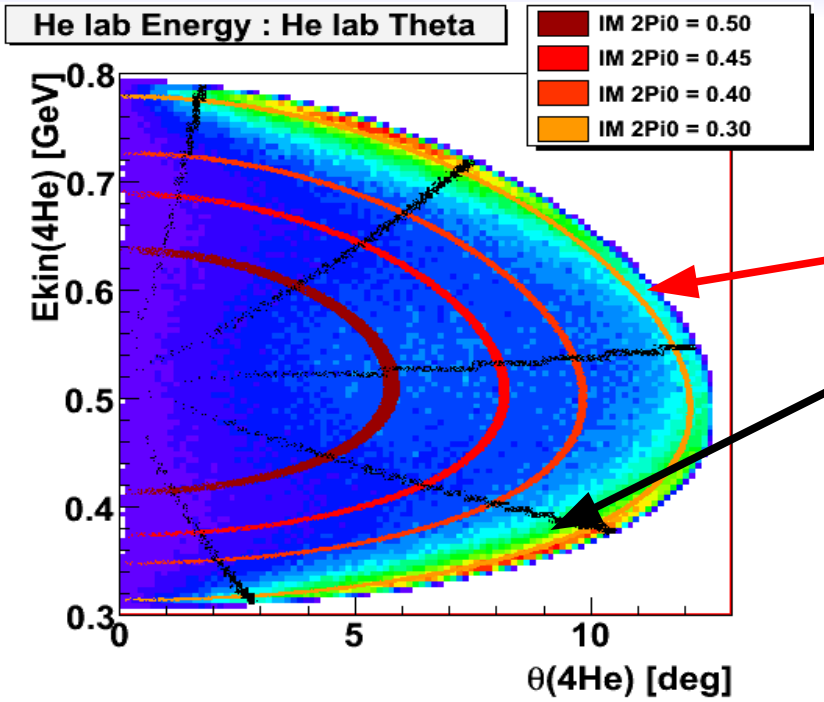
Not corrected before kinfit $M_{\pi^0\pi^0}$



p r e l i m i n a r y

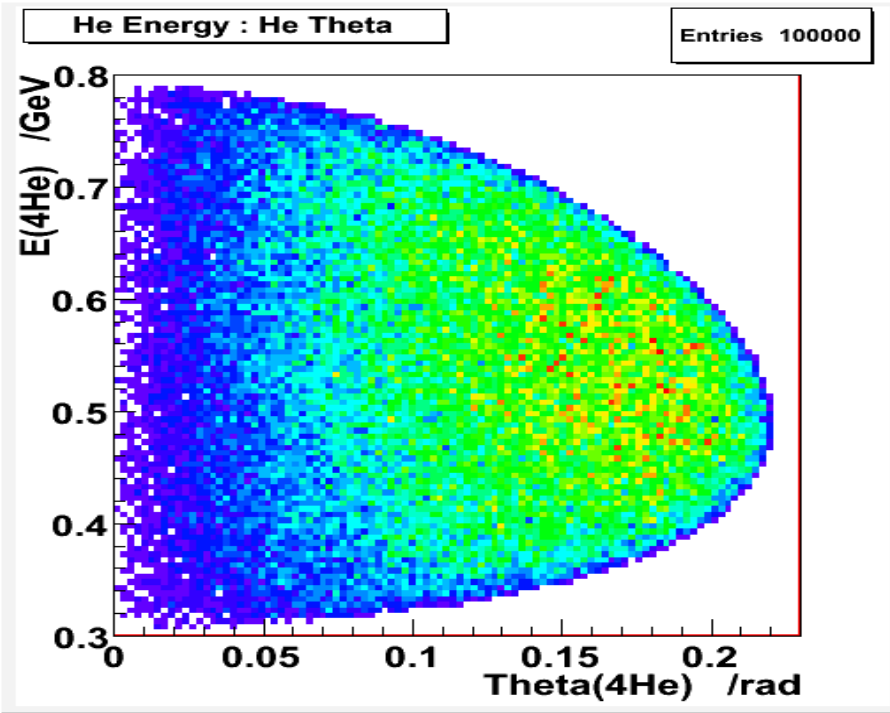


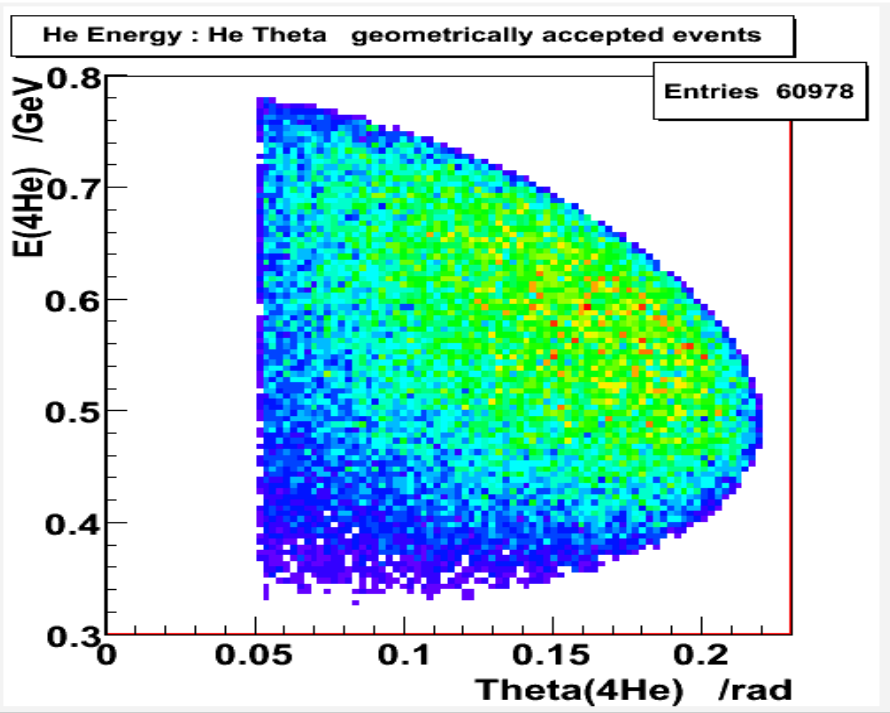
Acceptance for 1117 MeV



same IM 2Pi0

same Theta cm 2Pi0





total cross section

Absolute normalization with dd→ ^{3}He n

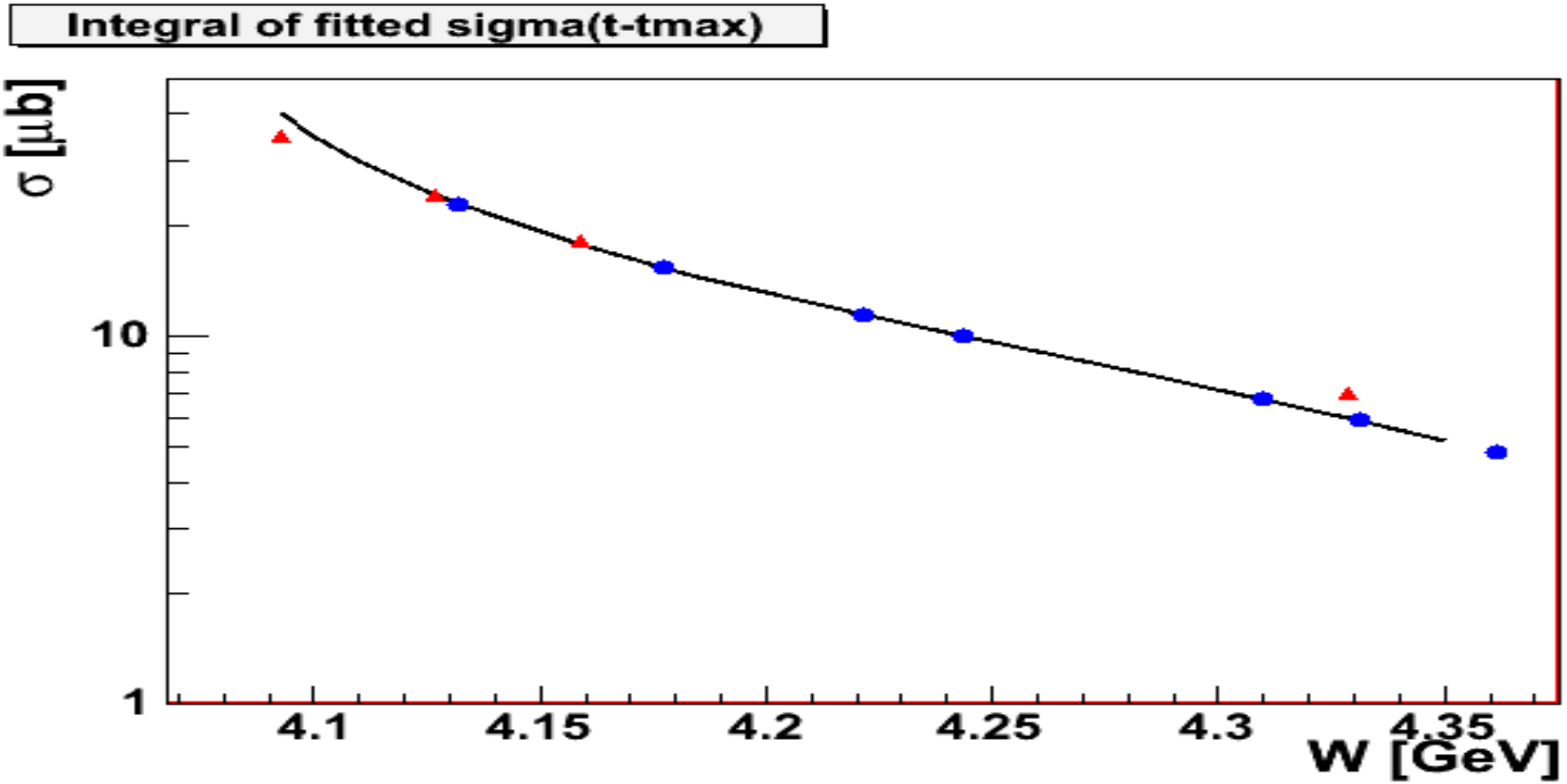
Easy to separate

Same trigger

Saclay data available **at 4 different energies**

Fit differential spectra with f = p1*exp(p2) + p3*exp(p4) + p5*exp(p6)

Fit the parameters to get the energy dependance



total cross section

- we had thresholds on FRH1 ...
  - ^{3}He deposites much less energy: cut in some elements
  - might also cut in ^{4}He for some elements

  → ***identify such elements, not used for cross section determination***

- **1320 and 1400 MeV**: FRH4, FRH5 not calibrated

  → ***do ^{3}Hen selection for single elements***

  → ***θ is ok, and that gives Ekin (binary reaction)***

- **1200 MeV**: low statistics, hard to identify the bad elements in ^{4}He

- **900 and 1050**:

  Trigger including a Veto on FRH3, while all ^{3}Hen come to FRH3 …

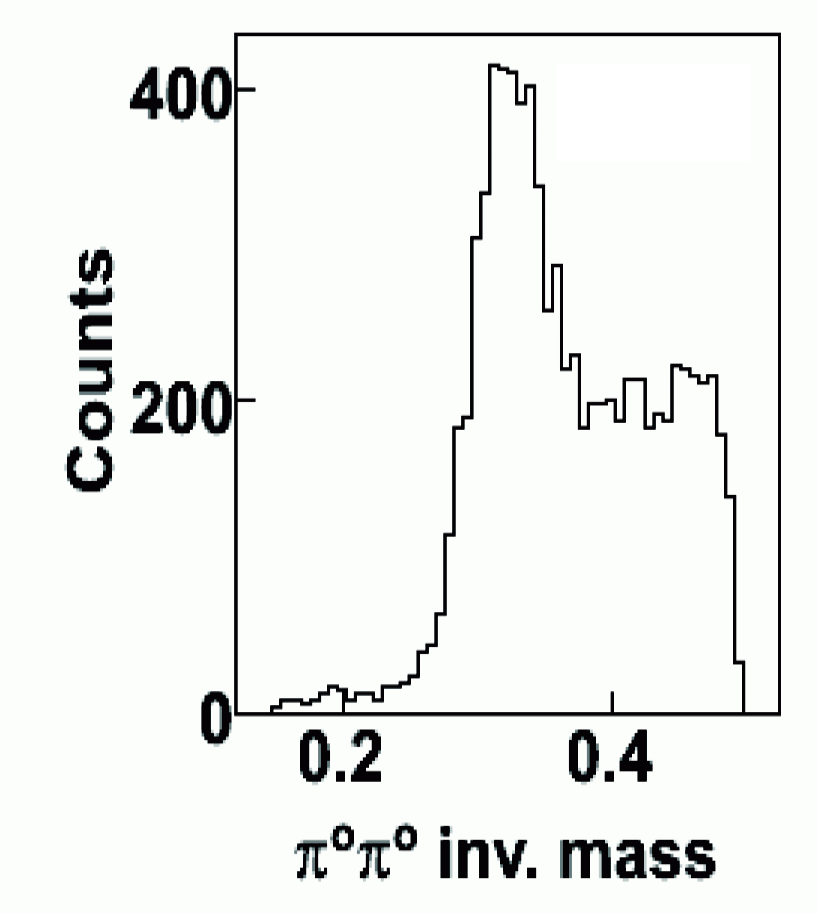
  → ***900 MeV 1 run without veto***

  → ***1050 MeV second trigger without Veto***

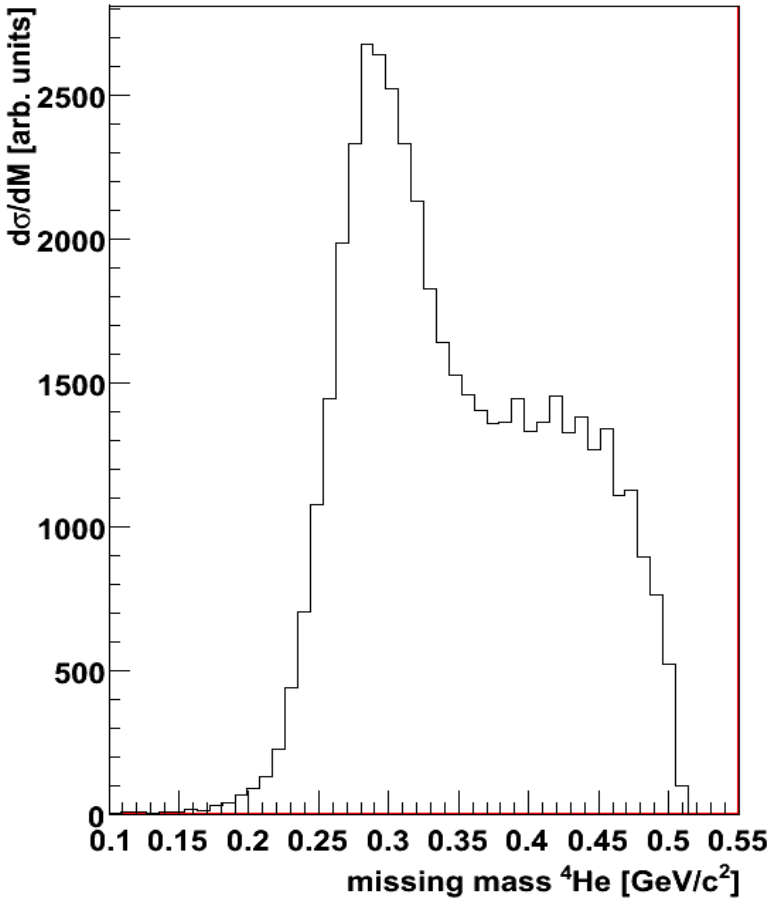
Comparison to Celsius-Wasa data at 1.029 GeV

before acceptance and efficiency correction

1.029 GeV



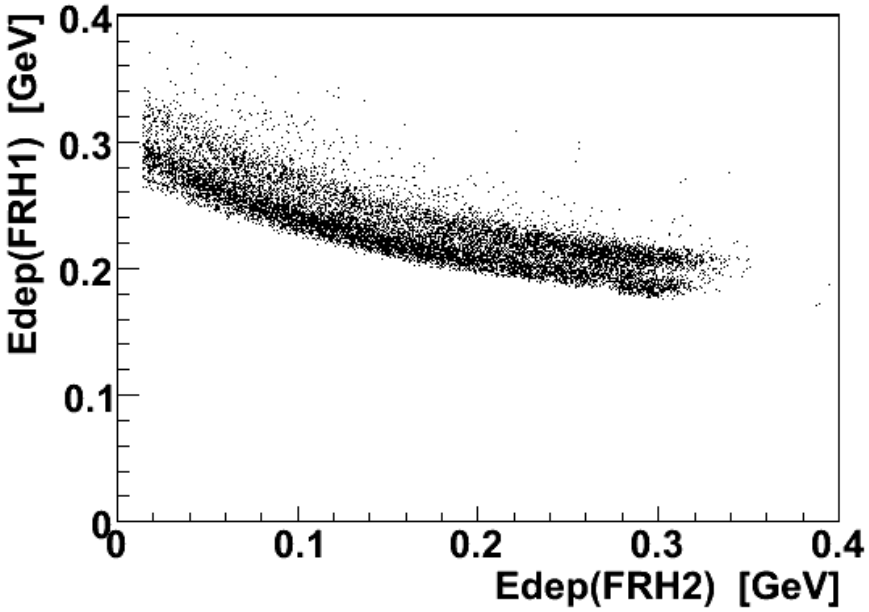
1.05 GeV

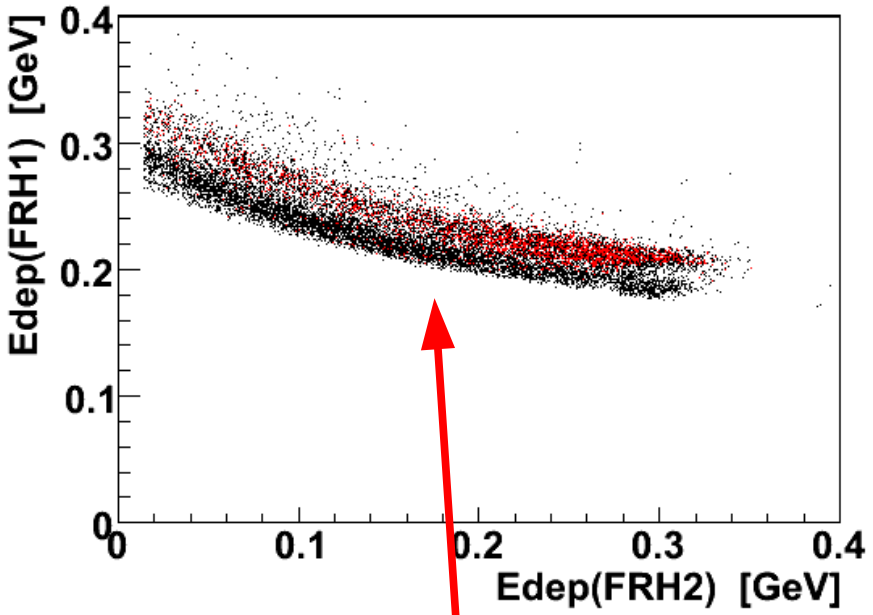


S.Keleta PhD Thesis

^3He / ^4He Separation with Kinematic Fit

all He which have $2\pi^0$





kinematic fit
assuming the He to be ^4He