Charge Symmetry Breaking in dd → ^{4}He π^0 with WASA-at-COSY

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Motivation

Charge Symmetry

- **subset** of isospin symmetry:
  - rotation in isospin space, 180º around I_2-axis
  - interchange of u↔d quarks
- ☺ pion mass difference does not contribute to CS breaking
  → handle on quark mass differences
- 😐 signal is still small

„Null experiments“: minimizing CS conserving contributions

- $np \rightarrow d\pi^0$ forward-backward assymmetry
  $A_{fb} = (17.2 \pm 8.0 \pm 5.4) \cdot 10^{-4}$ (A.Opper et al., PRL 91 (2003) 212302)
- **$dd \rightarrow {}^4He\ \pi^0$**
  first observation at IUCF: σ = 12 (15) pb at Q = 1.4 (3) MeV
  (E.Stephenson et al., PRL 91 (2003) 142302)

Experimental task

Goal: determination of *p*-wave contributions in dd $\rightarrow {}^4\mathrm{He}\pi^0$ at Q ≈ 60 MeV

→ theoretical calculations based on existing data under way

→ parameter free prediction of p-waves expected

Cross section estimate

- σ (1.4/3 MeV) ≈ 12/15 pb $\xrightarrow{s\text{-wave ph.sp.}}$ σ (60 MeV) ≈ 75 pb
- open channels: dd → dd, pnd, pnpn, tp, $n^3\mathrm{He}$
  dd → (dd, pnd, pnpn, tp, $n^3\mathrm{He}$) + π^0 no data available!
- ⇨ high luminosity, selective trigger, high background suppression
  ⇨ exclusive measurement: detecting **^{4}He** and **π^0** in WASA

Polarised beam necessary

- identical particles in initial state: symmetric angular distributions
- no *sp*-interfereces allowed in any unpolarised measurement
- *p*-waves and *sd*-interferences have same signature

Status

1 week in November 2007

- focus on CS conserving reaction: dd → ^{3}He N π
  - *feasibility*
  - *input for theoretical calculations:*
    - *total and differential cross sections*
    - *dd ISI, 4N final state*

P.Podkopał (talk), W.Węglorz (poster)

2 weeks in June 2008

- first, unpolarized run
  - *observation of a signal on dd → ^{4}He π^0*
  - *total cross section*
- expected number of events ≈ 300 - 400

this talk

Helium reconstruction

very low kinectic energy

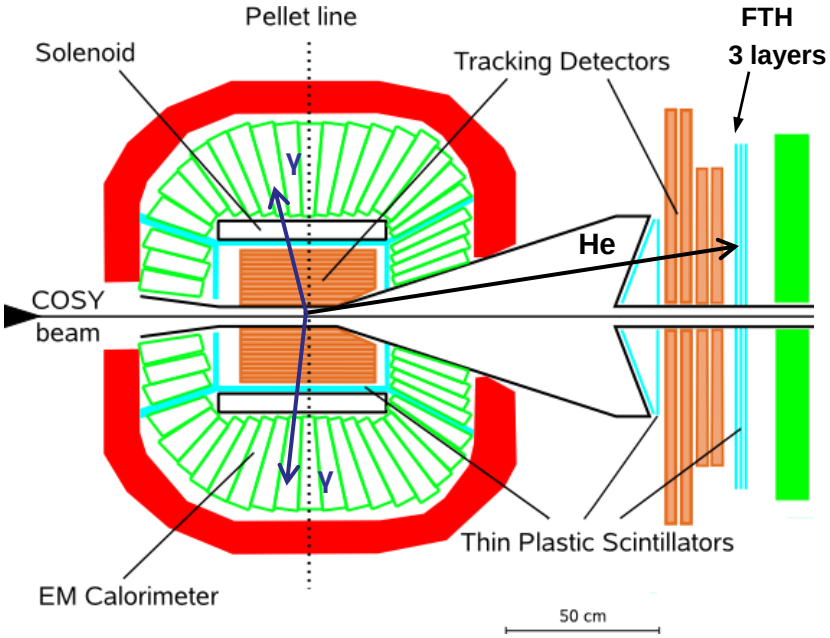
- stopped in FTH1 (FTH2)
- sensitive to variations in material thicknesses
- quenching

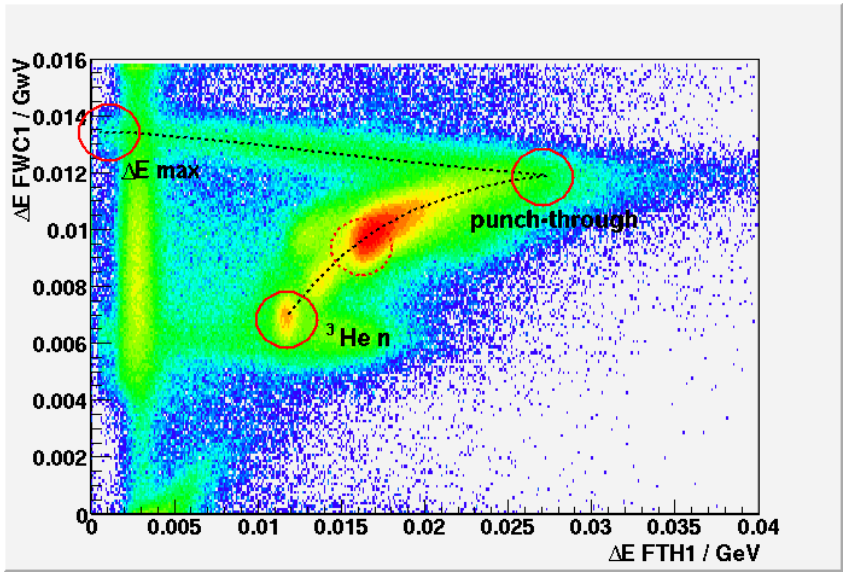
energy calibration:

- element-wise (48) on ^{3}He band
- fine-tuning:
  time dependence, dE bands
  ^{3}He n π^0 kinematics
- apply same calibration for ^{4}He

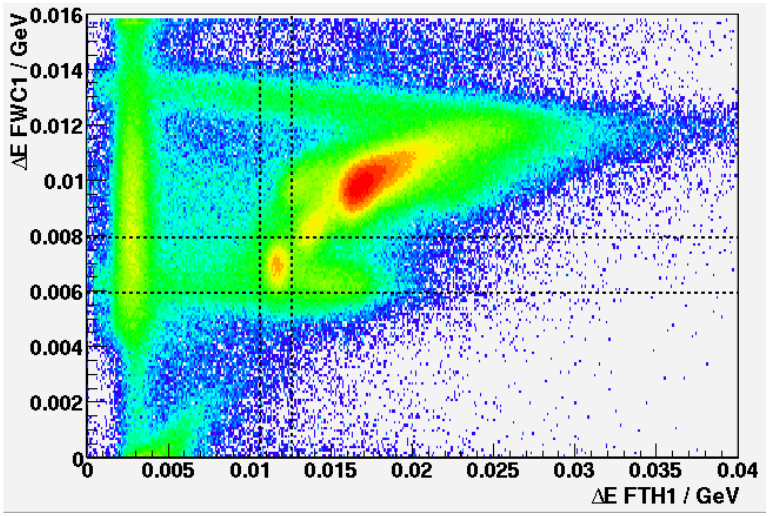
kinetic energy reconstrucion

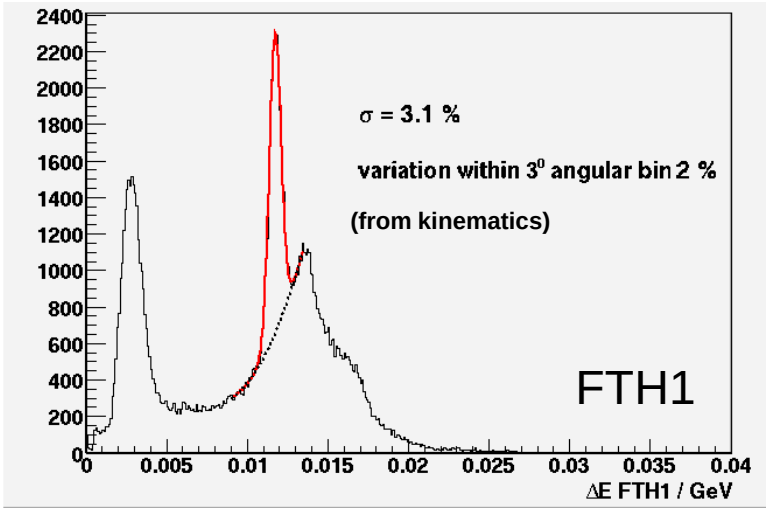
- fit Ekin(dE_i,MC) to data

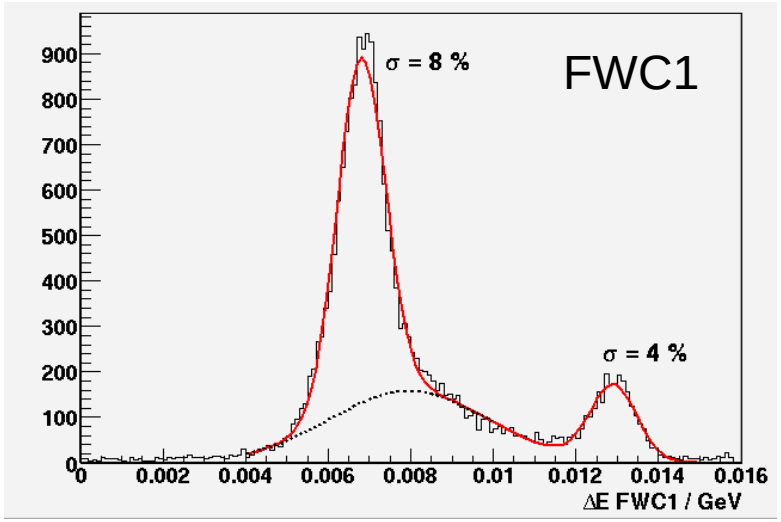




^{3}He energy resolution







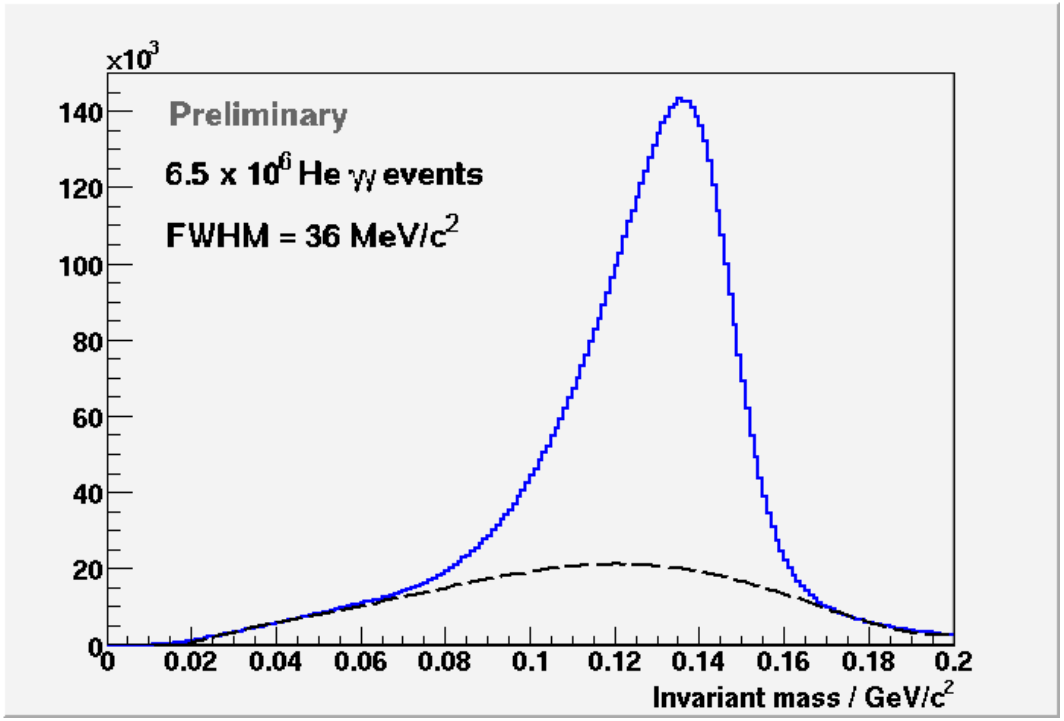
angular bin: $6 < \theta < 9$

variation of energy loss due to 2-body kinematics: 2-3%

resolution matches expectations

Photon detection

Condition: He candidate in forward detector



total statistics:
$(5 - 6)\times10^6$ ^{3}He π^0 coinc.

expectation:

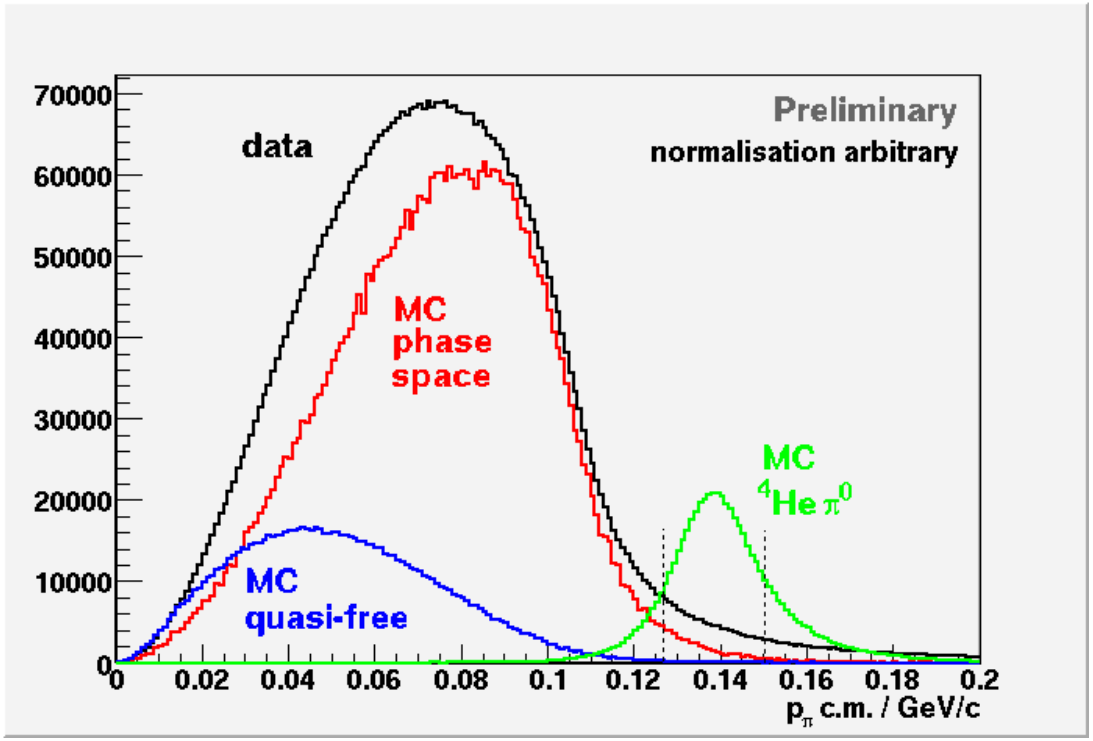
$$\frac{\sigma(^4He\pi^0)}{\sigma(^3He n\pi^0)} \approx 10^{-4}$$

^{4}He π^0 cuts: 2-body vs. 3-body

pion momentum in overall c.m. system

- 2-body:
  fixed momentum
  p = 0.138 GeV/c

- 3-body:
  smooth distribution
  with p < $p_{2\text{-body}}$

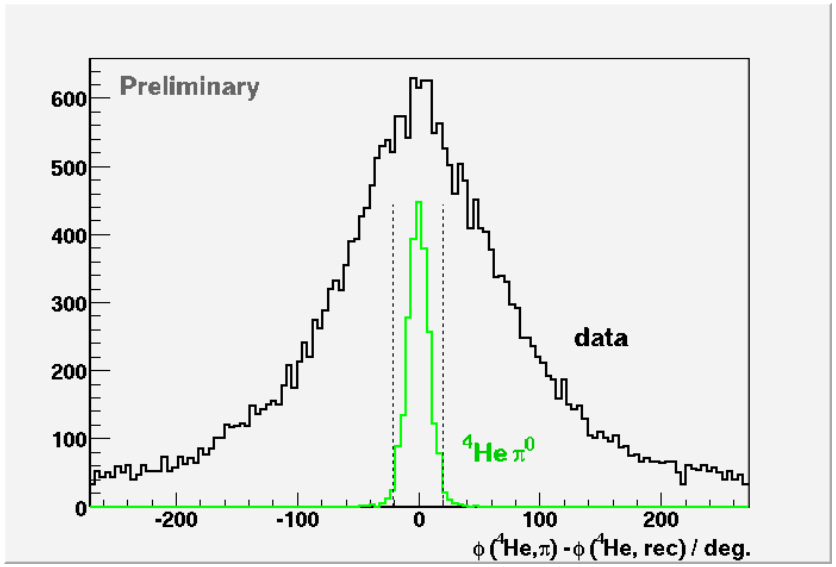


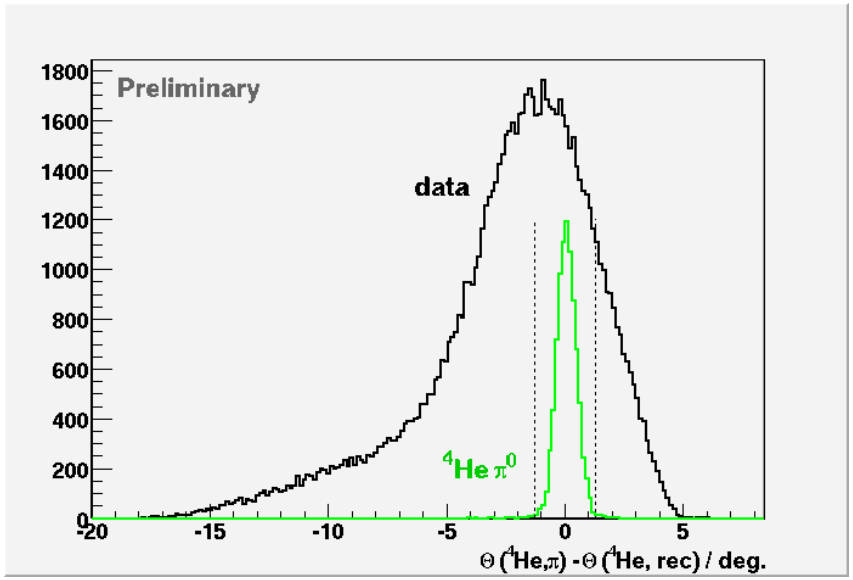
^{4}He π^0 cuts: angular matching

Check direction of ^{4}He rather than energy:

4-vector π^0 → missing 4-vector ^{4}He

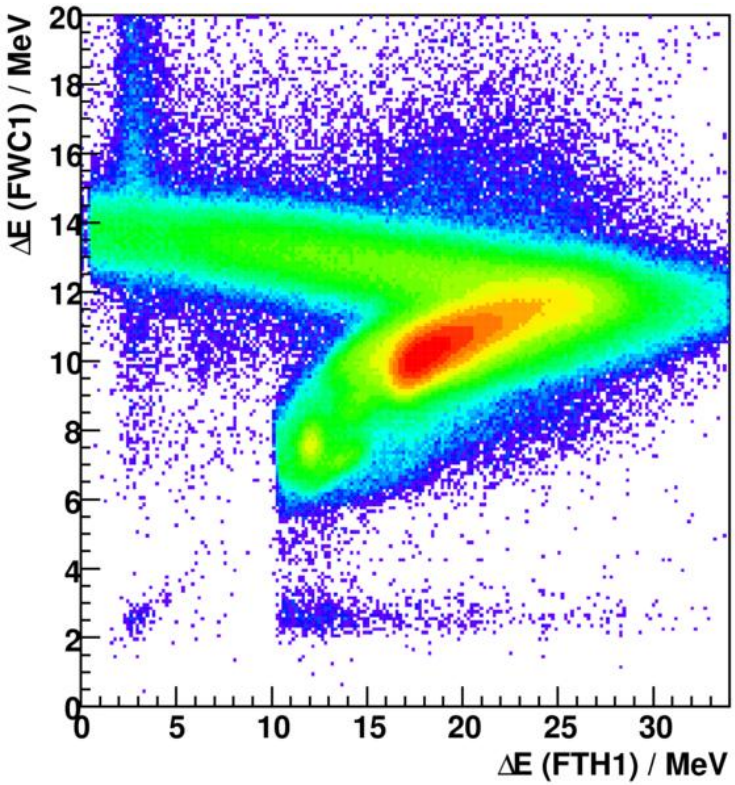
→ compare with measured directions



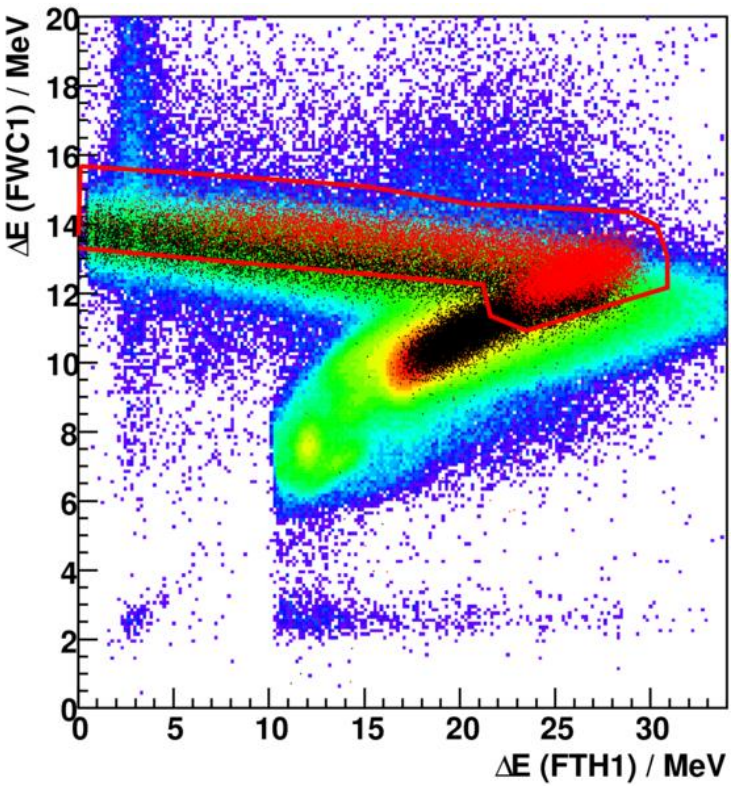


^{4}He π^0 cuts: weak ΔE cut

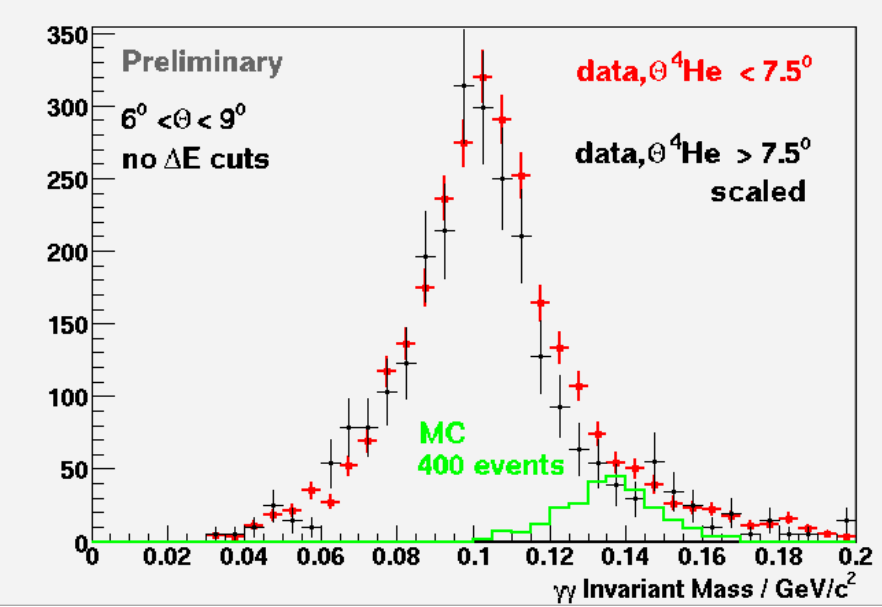
exp. data

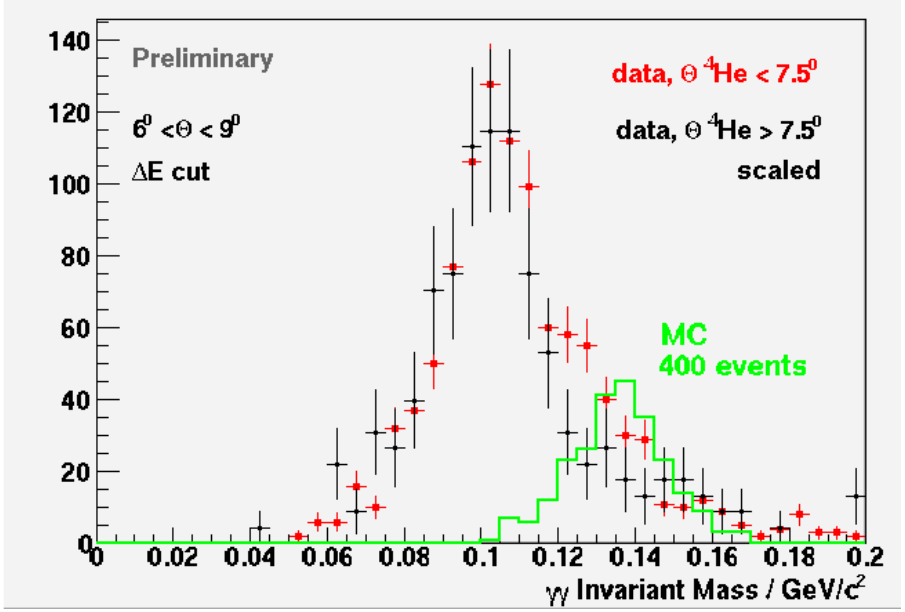


exp. data + MC ^{3}He ^{4}He



π^0 invariant mass



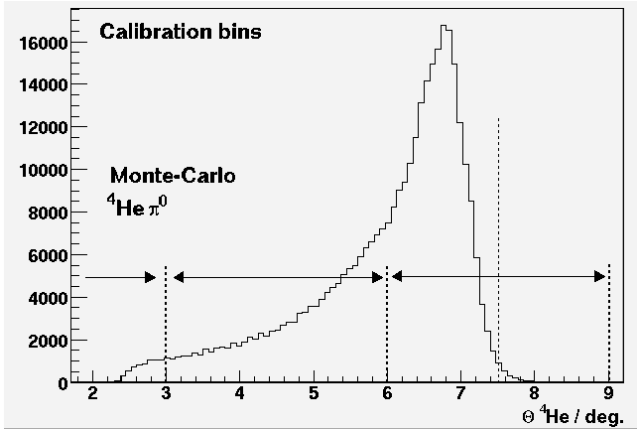


after all momentum and angle cut:

compare bins $6 < \theta < 7.5$

and $7.5 < \theta < 9$

expected signal: 300 – 500 events



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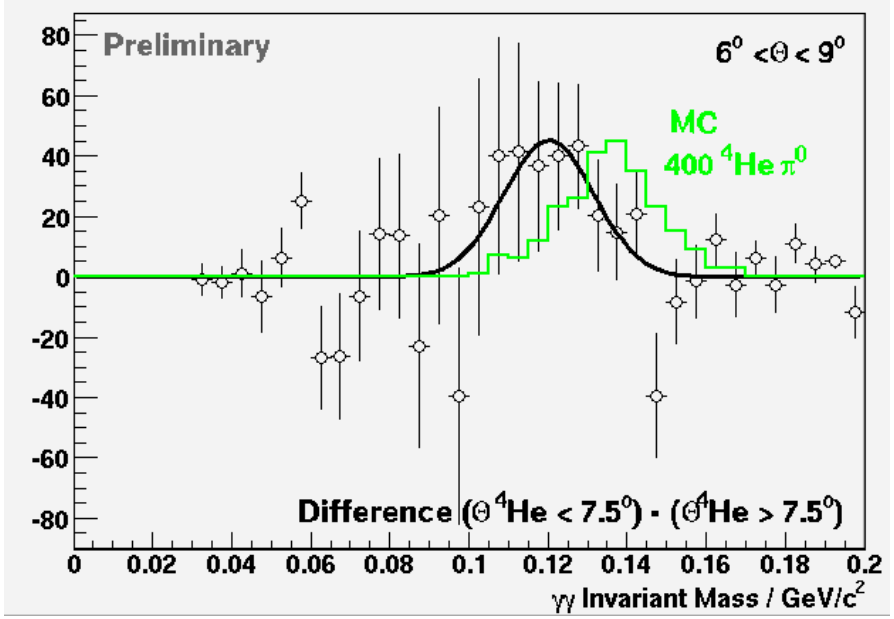

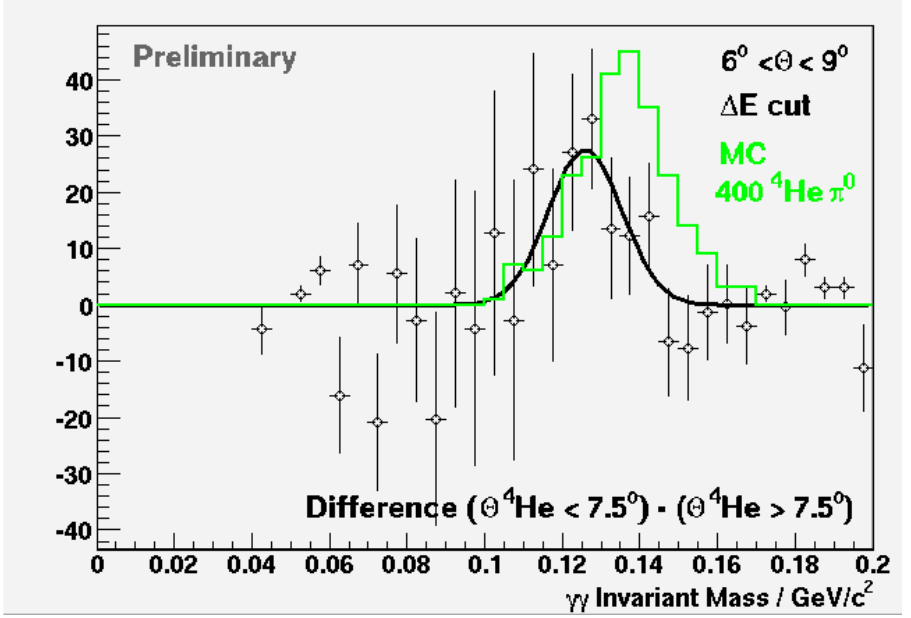

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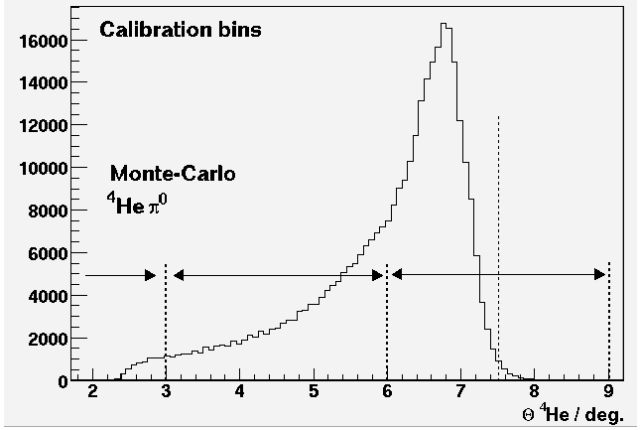
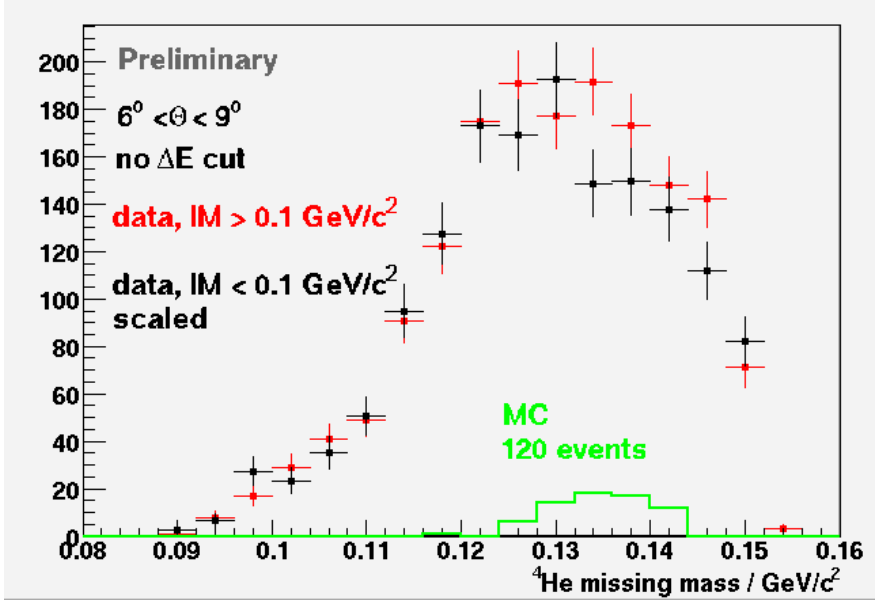
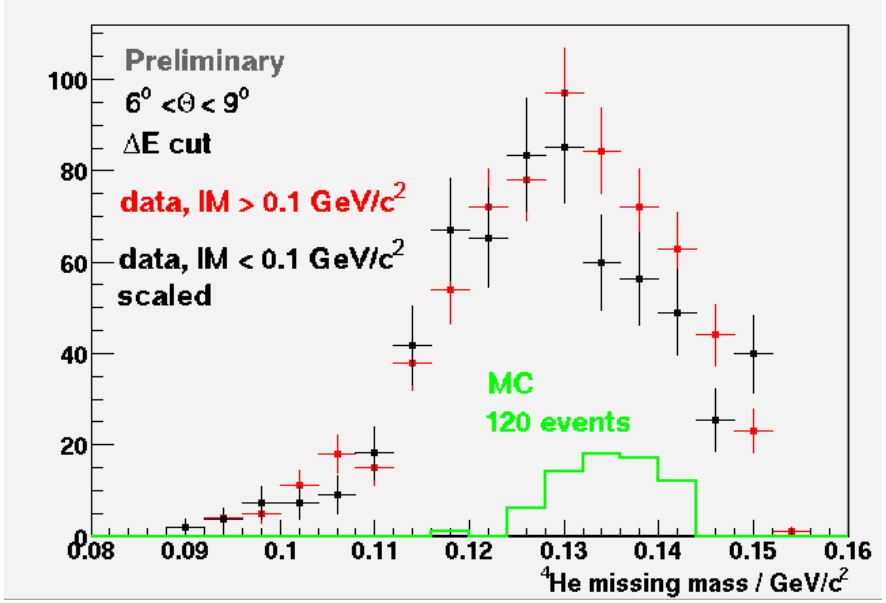


^{4}He missing mass



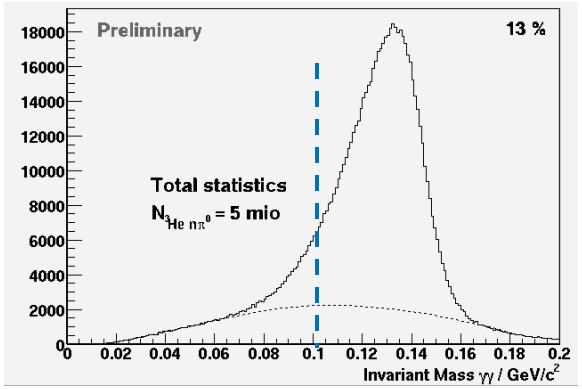


after all momentum and angle cut:

compare bins $m_{\gamma\gamma} < 0.1$ GeV/c^2

and $m_{\gamma\gamma} > 0.1$ GeV/c^2

smaller signal remains



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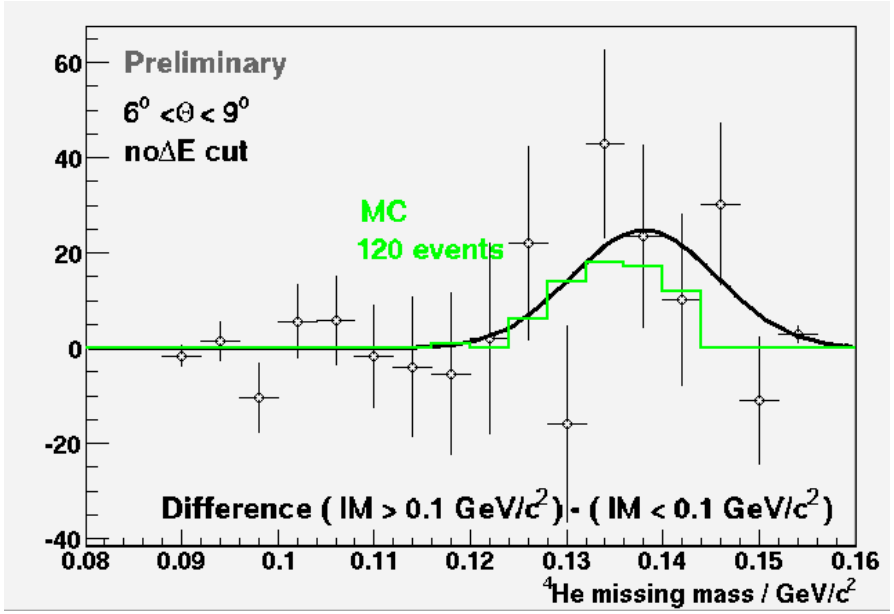

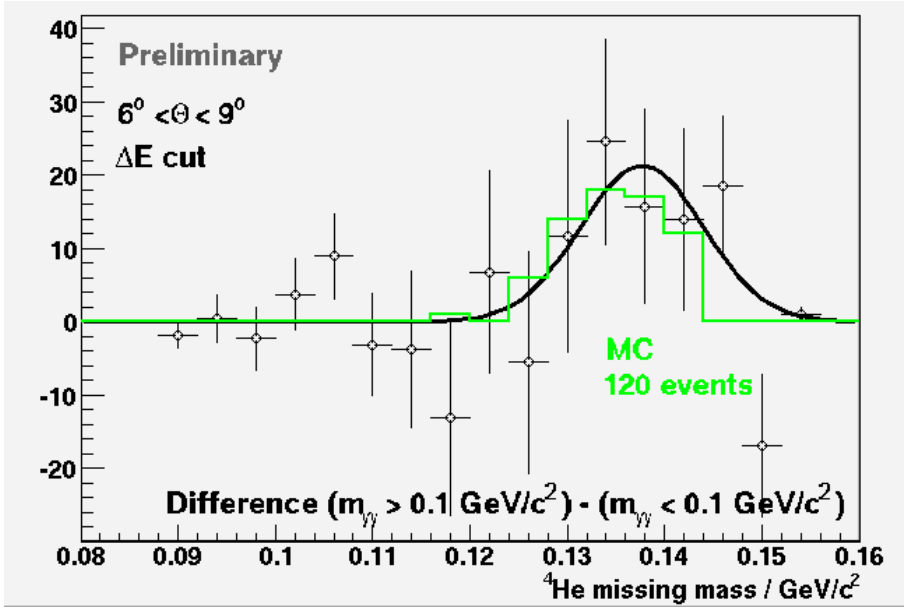

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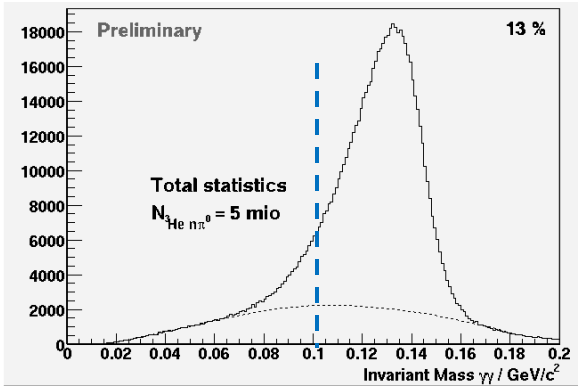

Summary and Outlook

- Charge Symmetry Breaking
  - tool to study quark mass effects
  - precision experiments on np $\rightarrow$ dπ^0 and dd $\rightarrow$ ^{4}He π^0 triggered theory collaboration
  - task: verify predictions on p-wave contributions
- experimental status
  - 2 weeks run on dd $\rightarrow$ ^{4}He π^0 at Q = 60 MeV
  - exclusive measurement
  - data consistent with expected signal
  - improvements on ^{4}He identification / background subtraction in progress: comparison with MC, kinematic fit, …
- final polarized run depends on the results of the on-going analysis