



Double-Pionic Fusion to He nuclei

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Meeting on two pion production in the HADES
and WASA experiments

4/04/2013 Orsay



Overview

- ABC effect in He nuclei
- $pd \rightarrow {}^3\text{He} \pi^0 \pi^0$
 - Measurements
 - Brief look into analysis
 - Preliminary results
- $dd \rightarrow {}^4\text{He} \pi^0 \pi^0$
 - Measurements
 - Results
- Summary

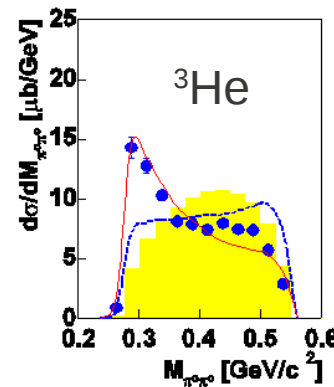


ABC effect in He nuclei

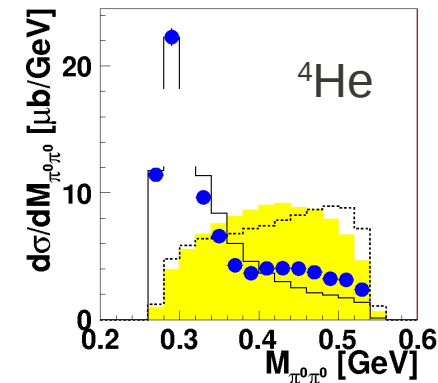
- First observation of ABC: Double-Pionic fusion to ^3He
 - inclusive measurements $pd \rightarrow ^3\text{He} X$
 - **Low mass enhancement in M_x**
 - Alexander **A**bashian, Norman E. **B**ooth Kenneth M. **C**rowe, Phys. Rev. Lett. 5, 258 (**1960**)
- Exclusive measurements with high statistics carried out at WASA/CELSIUS and WASA-at-COSY

- WASA/CELSIUS:

- $pd \rightarrow ^3\text{He} \pi^0\pi^0$
- $T_{\text{beam}} = 0.895 \text{ GeV}$ ($\sqrt{s} = 3.357 \text{ GeV}$)



PL B 637 (2006) 223



PR. C 86 (2012) Rapid Comm. 032201

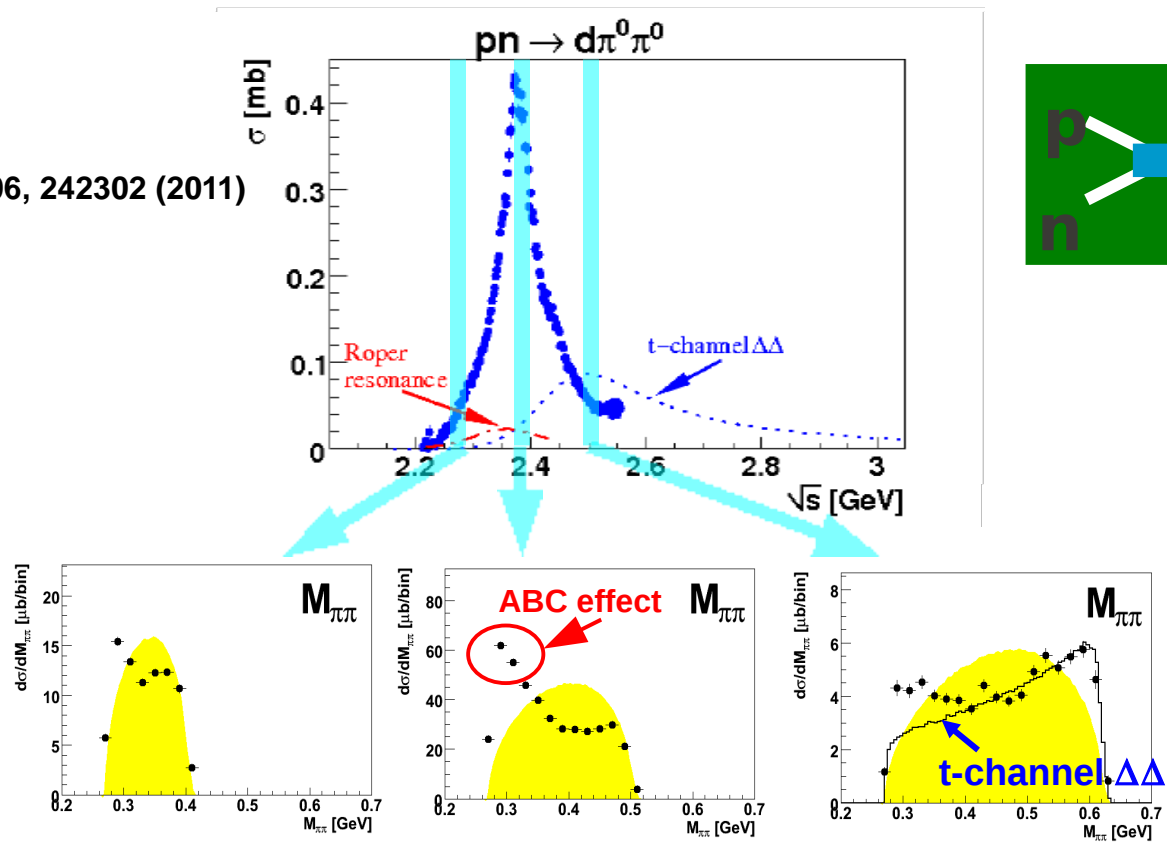
- WASA-at-COSY

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

ABC effect in He nuclei

- $pn \rightarrow d\pi^0\pi^0$: ABC connected to d^* resonance

Phys.Rev.Lett.106, 242302 (2011)

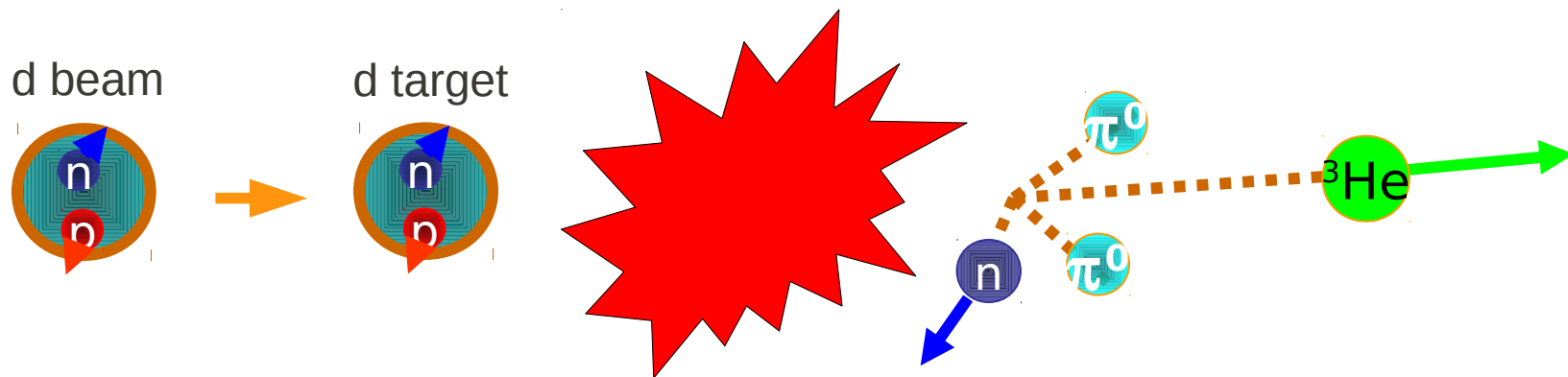


- New measurements with WASA-at-COSY of $pd \rightarrow {}^3\text{He} \pi^0\pi^0$



Double-Pionic Fusion to ^3He

- 2 ways of measuring the reaction
 - pd collisions $pd \rightarrow ^3\text{He} \pi^0\pi^0$ $T_p=1.0 \text{ GeV}$ ($\sqrt{s}=3.416 \text{ GeV}$)
 - Quasifree measurements in dd collisions
 - $dd \rightarrow ^3\text{He} \pi^0\pi^0 (n)$ $T_d=1.4 \text{ GeV}, 1.7 \text{ GeV}$

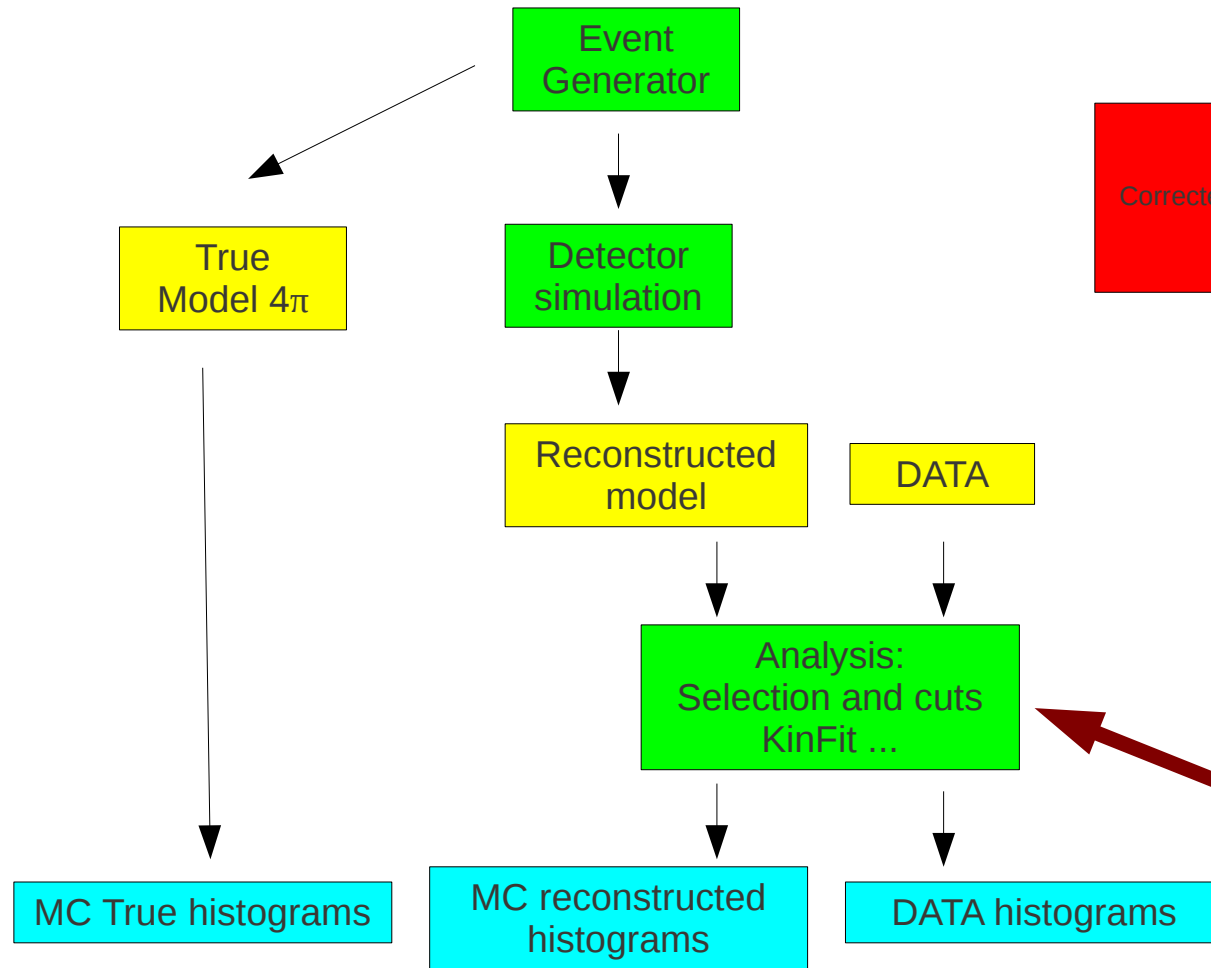


End state two possibilities:

- Neutron is active part of the reaction: coherent production
- Neutron as spectator: quasi-free production providing a range of collision energies due to Fermi motion



Double-Pionic Fusion to ^3He

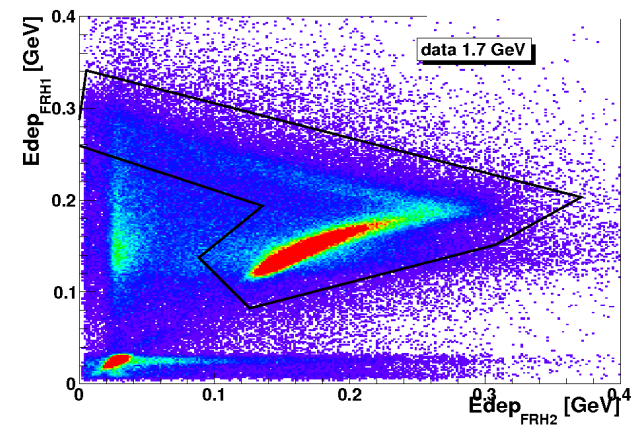
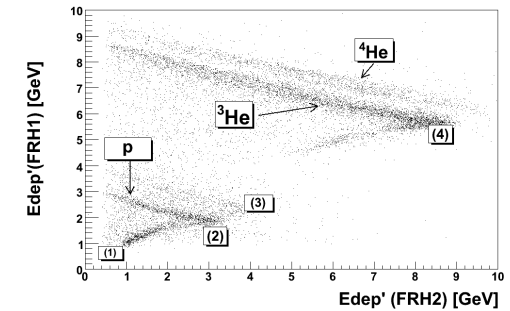
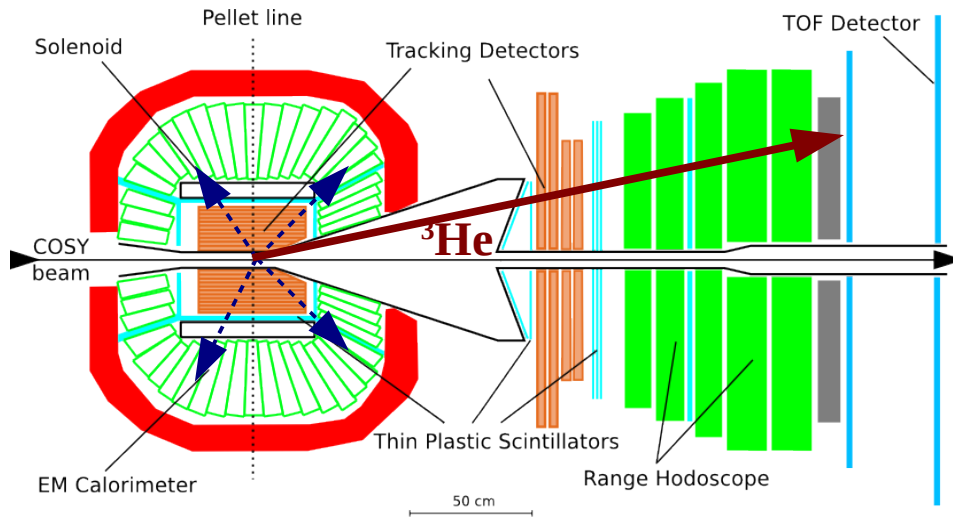


$$\text{Corrected DATA} = \text{histogram DATA} \times \frac{\text{MC True histogram}}{\text{MC reconstructed histogram}}$$

* If there is a hole in the acceptance then the corrected data will be model dependent

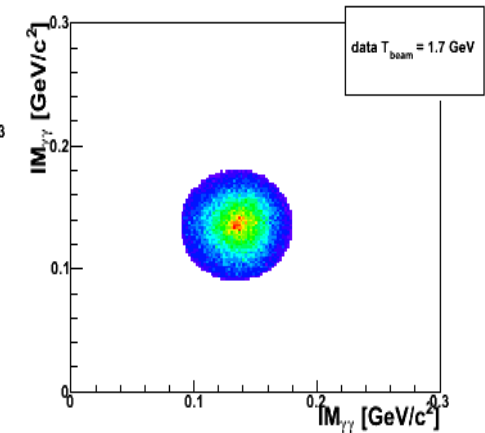
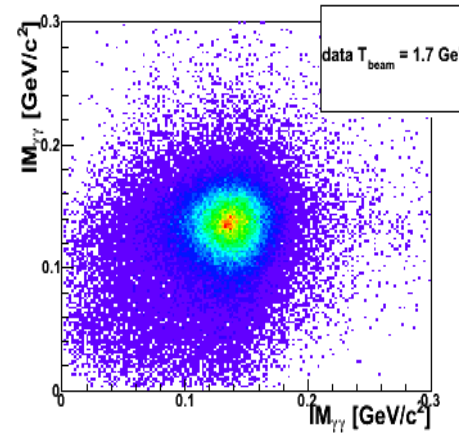
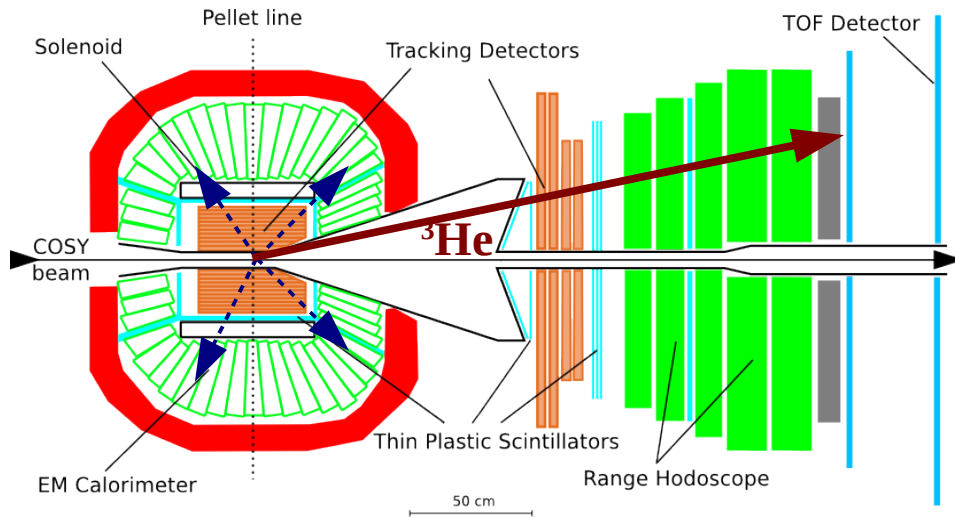
Not only selection cuts but also those in need to describe the experiment → MC needs to reproduce all experimental conditions too

Double-Pionic Fusion to ^3He

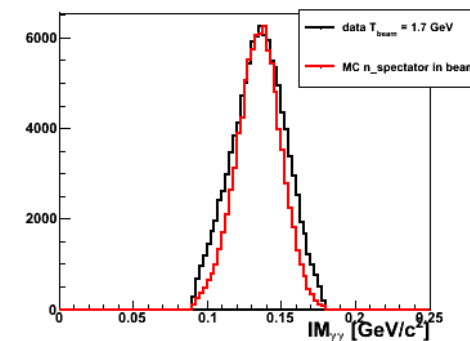


- **Forward Detector**
 - Energy losses in thick plastic scintillator → Particle Identification
 - charged tracks as ^3He
- CD → calorimeter:
 - Identification of the $2\pi^0$

Double-Pionic Fusion to ^3He



- Forward Detector
 - Energy losses in thick plastic scintillator \rightarrow Particle Identification
 - charged tracks as ^3He
- CD \rightarrow calorimeter:
 - Identification of the $2\pi^0$
 - Recombination of all gamma pairs
 - χ^2 to chose the best combination



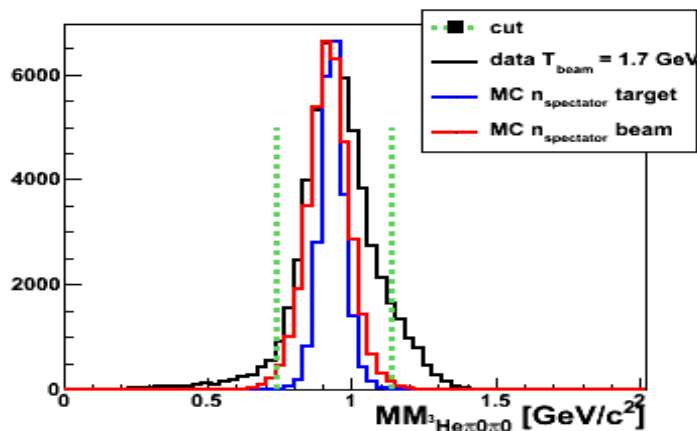


Double-Pionic Fusion to ^3He

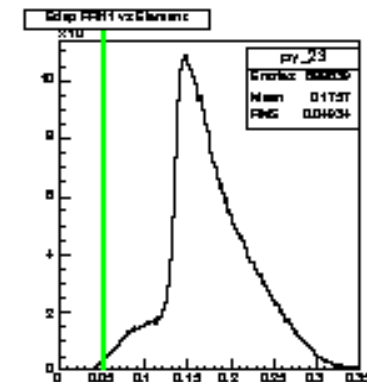
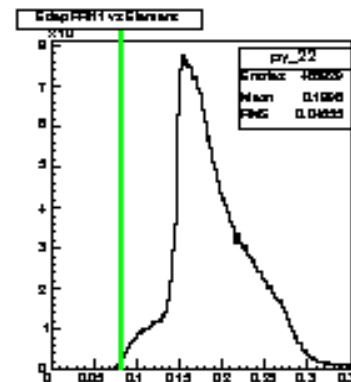
- **General cuts for the reaction**
 - $MM_{3\text{He}\pi^0\pi^0}$ around Mass of neutron
- **Special cuts:**
 - Threshold “simulation”
 - Elements with misbehavior / low efficiency
- **Additional calculations**
 - Magnetic Field correction for charged tracks

Get rid of background,
simulate detector response for MC,
etc...

Kinematic Fit



Data $T_{\text{beam}} = 1.7 \text{ GeV}$

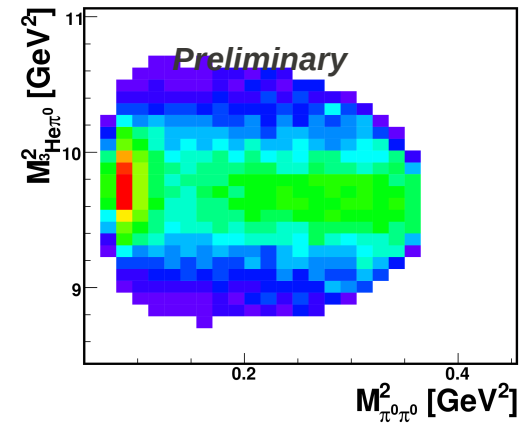
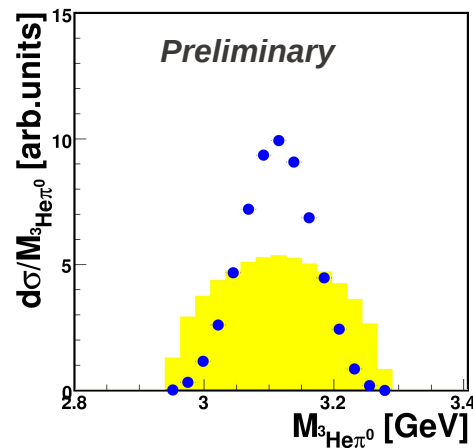


$Edep_{\text{FRH1}} [\text{GeV}]$

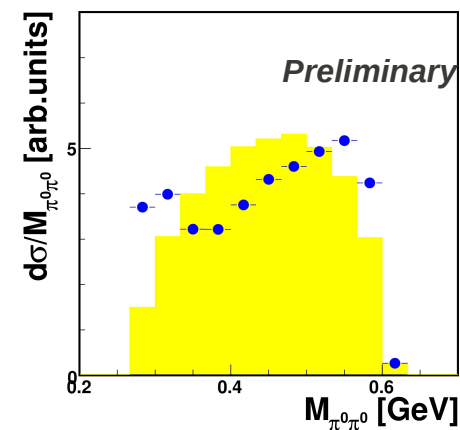


Double-Pionic Fusion to ${}^3\text{He}$ Preliminary Results

- $pd \rightarrow {}^3\text{He}\pi^0\pi^0$
 - $T_{\text{beam}} = 1.0 \text{ GeV}$ ($\sqrt{s} = 3.416 \text{ GeV}$)



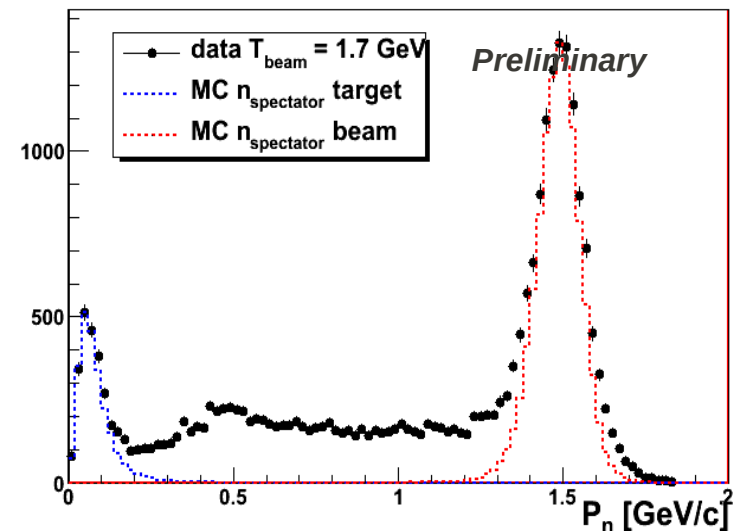
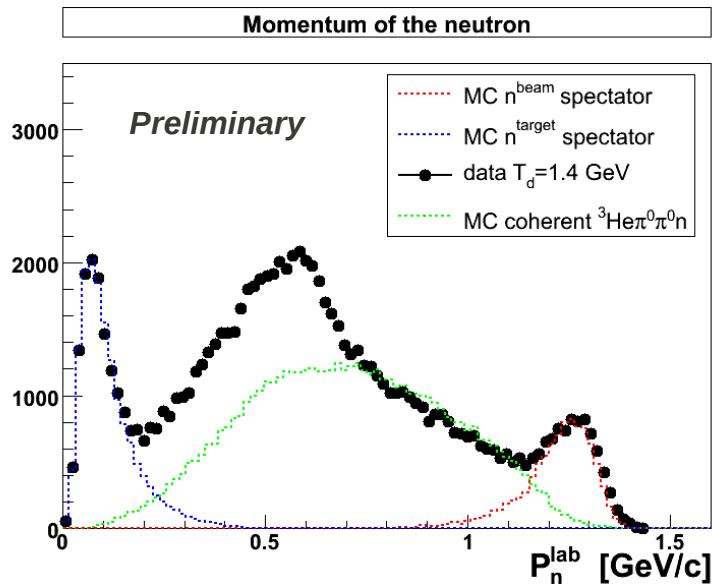
- Well above maximum
- ABC effect fading away
- Visible Δ contribution





Double-Pionic Fusion to ^3He

- dd collisions
 - Reconstruction of the neutron based on energy-momentum conservation
 - $P_n = P_{\text{initial}} - P_{^3\text{He}} - P_{2\pi^0}$
 - Well separated regions depending on process
 - Cut on momentum of neutron to select
 - Beam spectator: forward angle cut

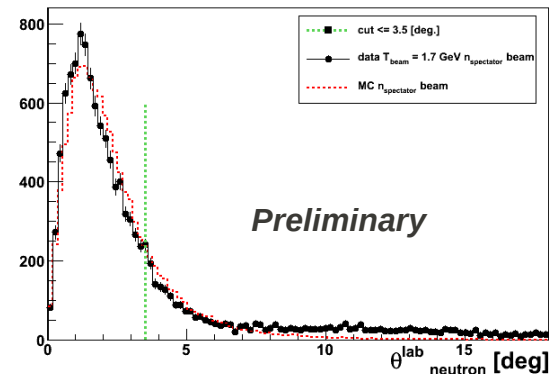
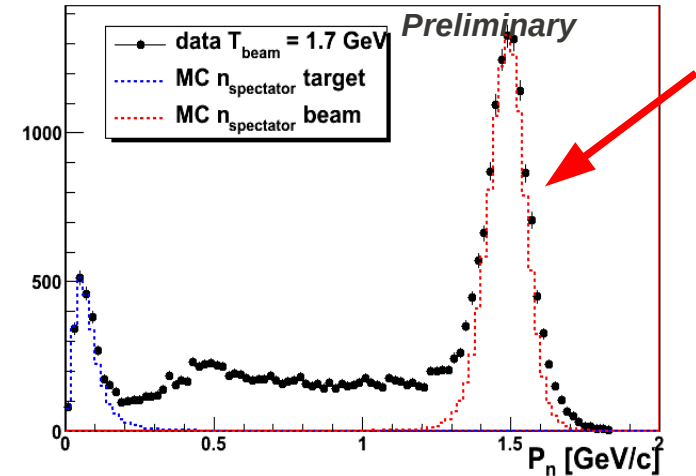




Double-Pionic Fusion to ^3He Preliminary Results

- $dd \rightarrow ^3\text{He}\pi^0\pi^0(n)$
- $T_{\text{beam}} = 1.7 \text{ GeV}$

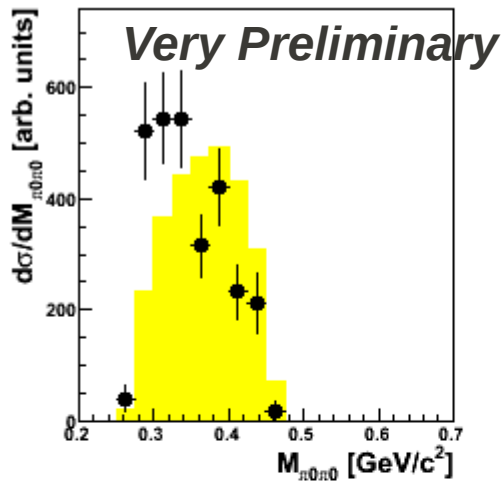
- Analysis ongoing
- Neutron spectator from target cut out by thresholds
- Preliminary results for neutron spectator from beam
 - $\text{IM}_{\pi^0\pi^0}$ corrected data



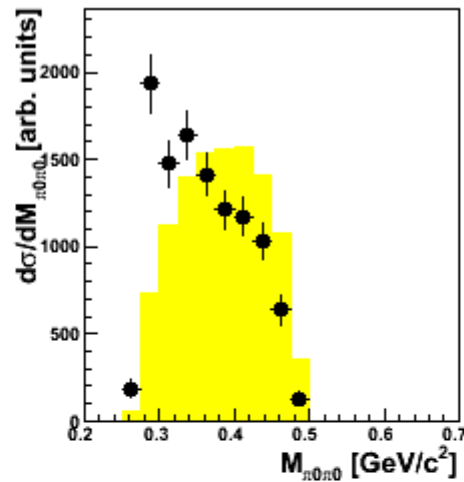


Double-Pionic Fusion to ^3He Preliminary Results

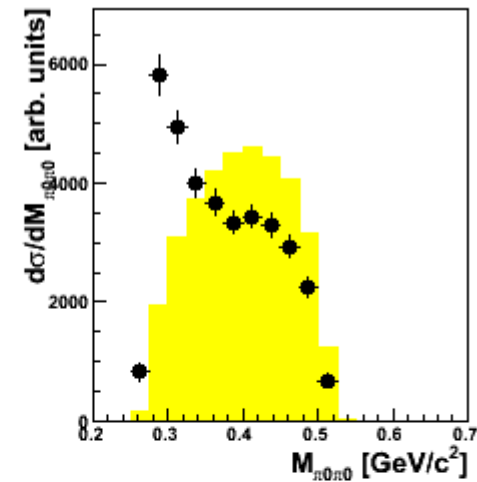
$3.25 \text{ GeV} \leq \sqrt{s} \leq 3.28 \text{ GeV}$



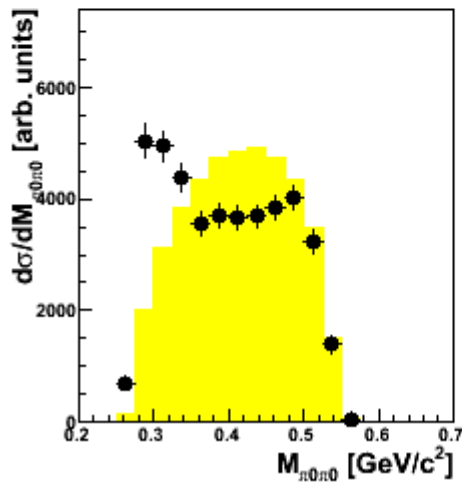
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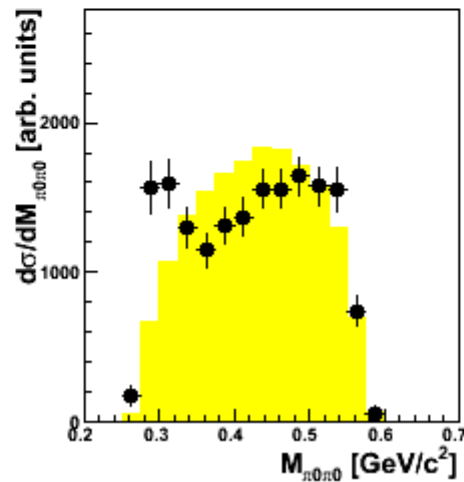
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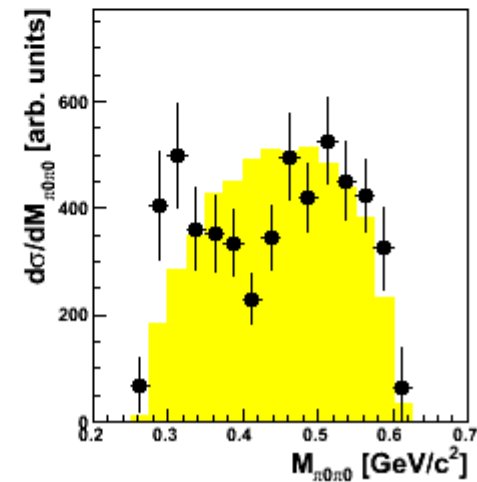
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$3.37 \text{ GeV} \leq \sqrt{s} \leq 3.40 \text{ GeV}$



$3.40 \text{ GeV} \leq \sqrt{s} \leq 3.43 \text{ GeV}$





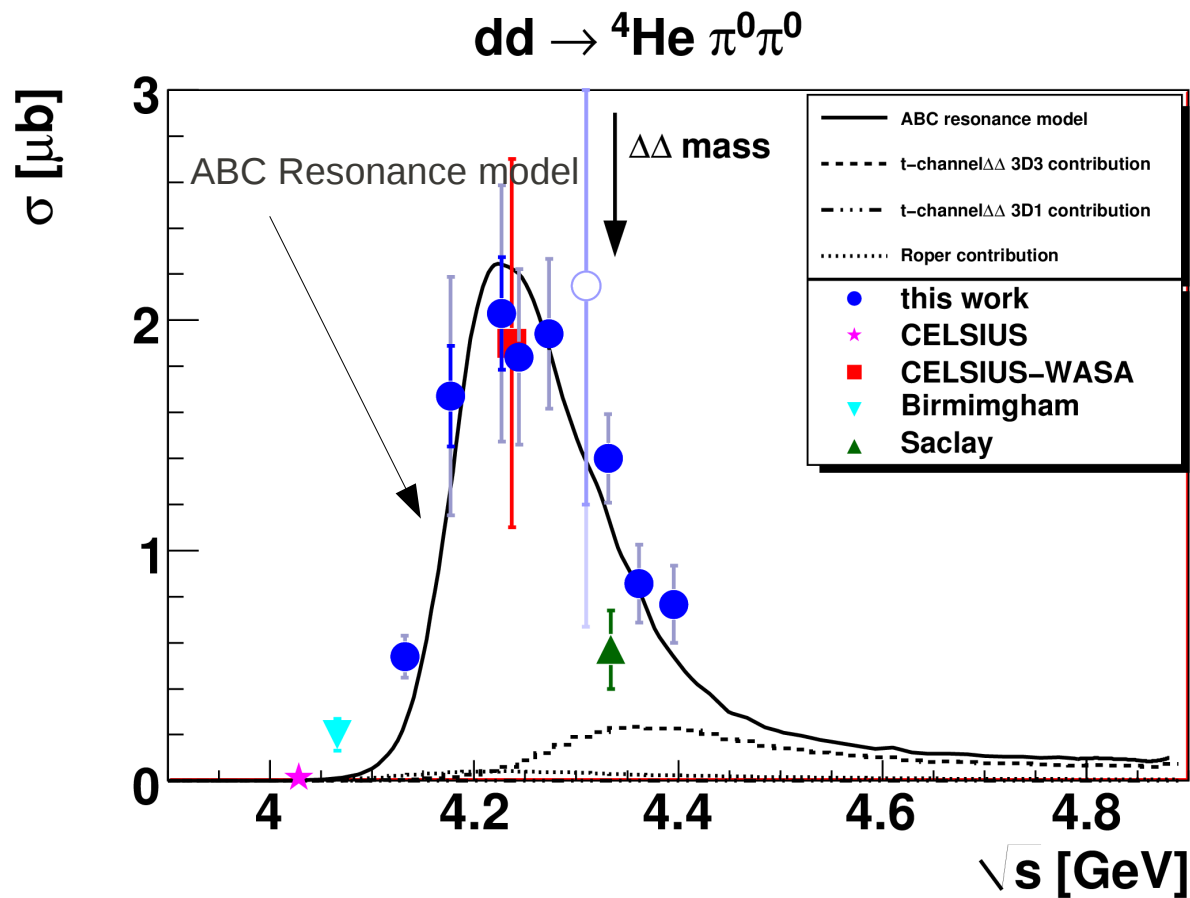
Double-Pionic Fusion to ${}^4\text{He}$

- Measured with WASA-at-COSY
 - Nine different energies over the region where ABC effect is expected
 - T_{beam} : 0.8 GeV, 0.9 GeV, 1.0 GeV, 1.05 GeV, 1.117 GeV, 1.2 GeV, 1.25 GeV, 1.32 GeV, 1.4 GeV
 - Absolute normalization to ${}^3\text{He}$ n
 - Total cross section energy dependence
 - Differential distributions



Double-Pionic Fusion to ${}^4\text{He}$

- Total cross section energy dependence



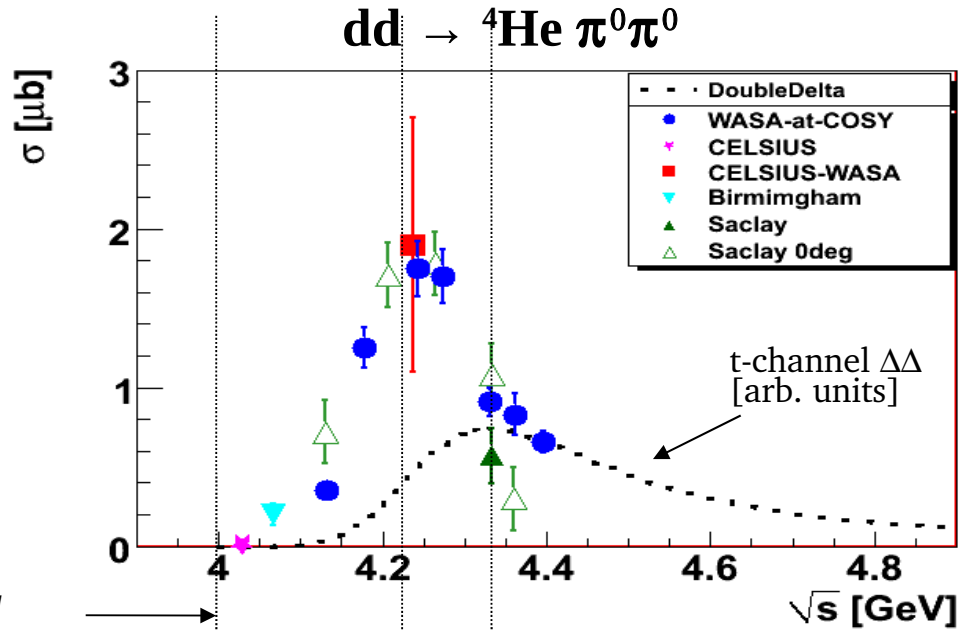
Phys.Rev. C86 (2012) Rapid Comm. 032201



Double-Pionic Fusion to ${}^4\text{He}$

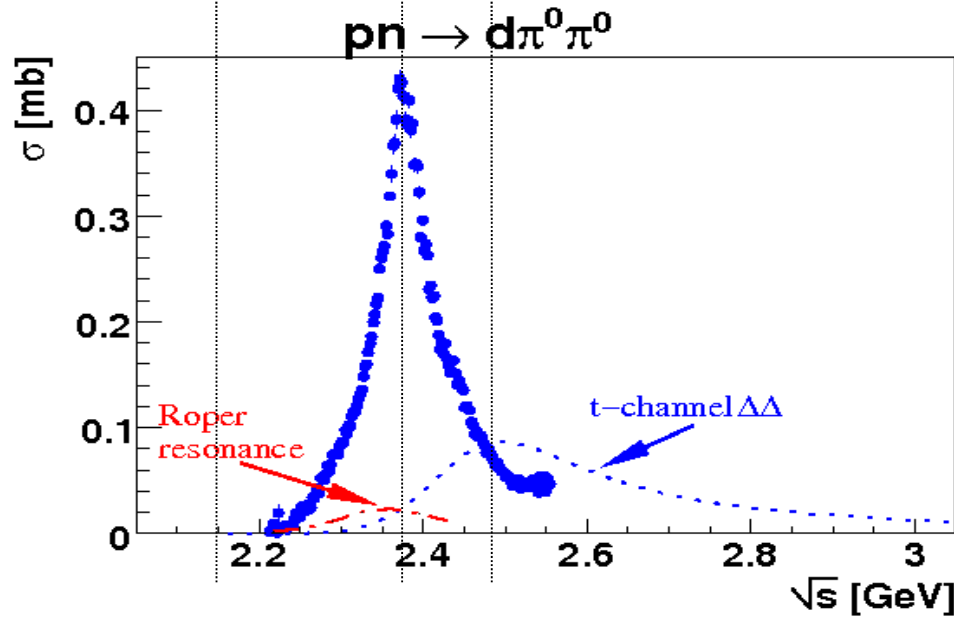
${}^4\text{He}$

$\pi\pi$ threshold



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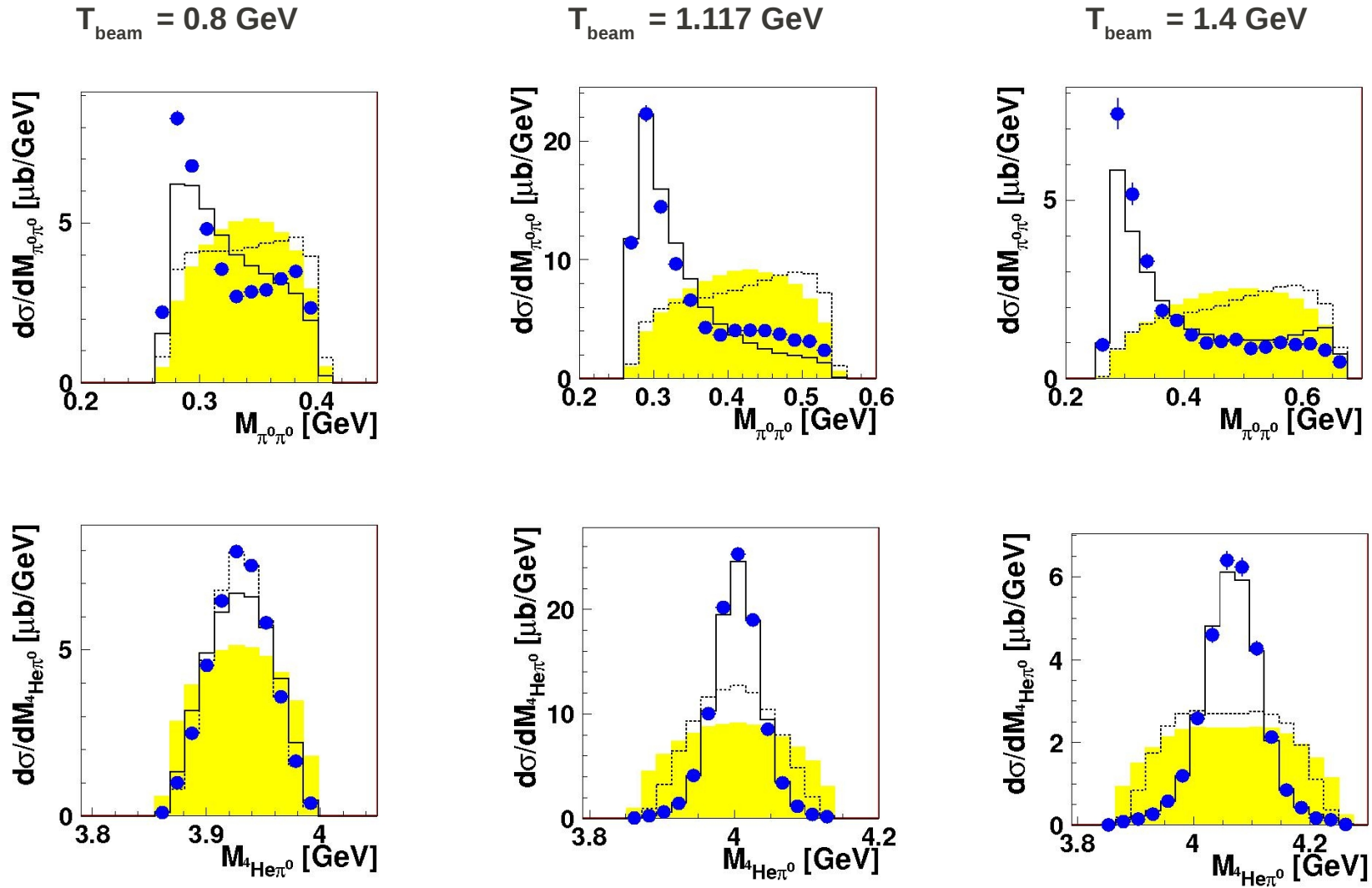
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PRL 106 (2011) 202302

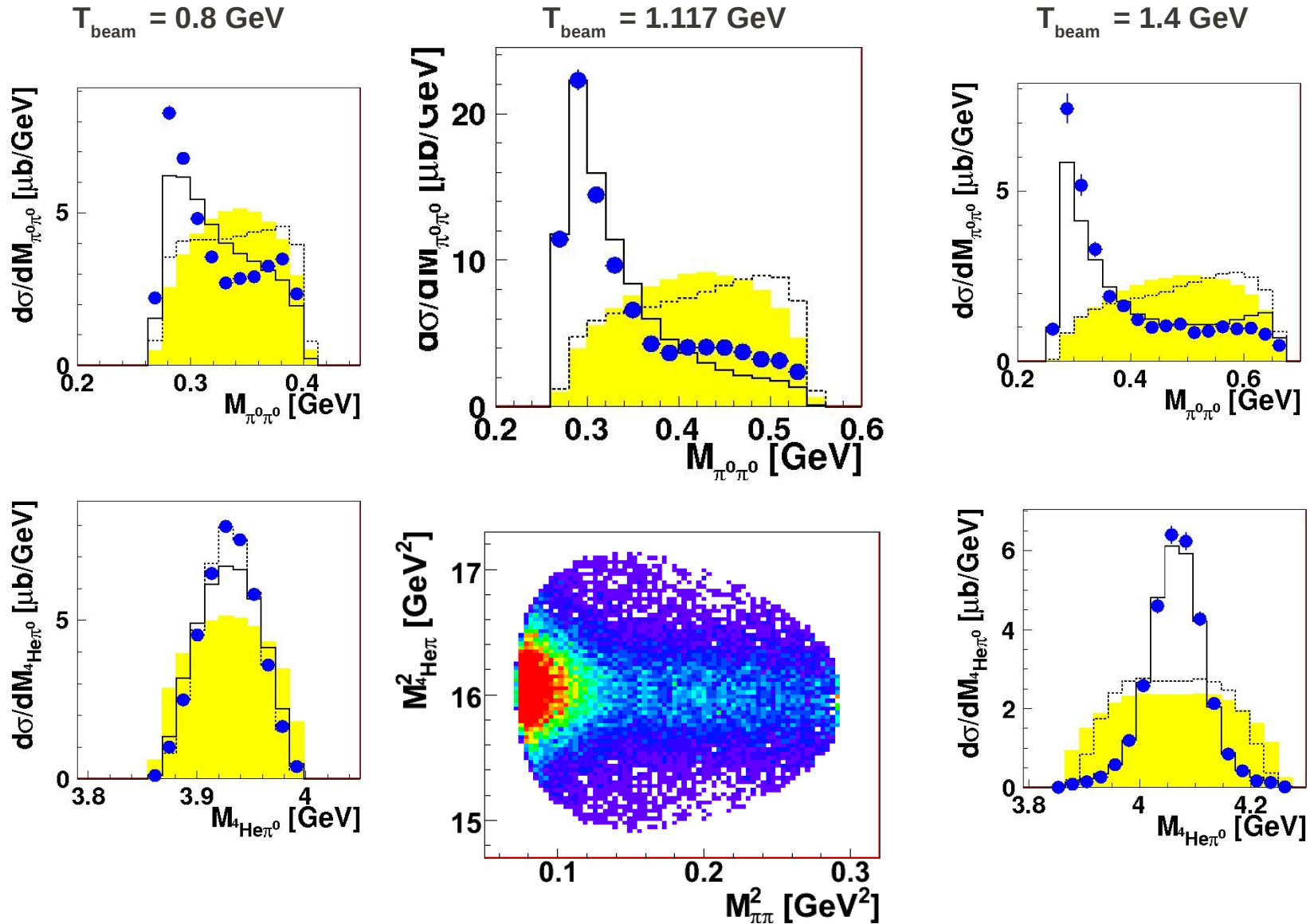


Double-Pionic Fusion to ^4He





Double-Pionic Fusion to ^4He





Summary

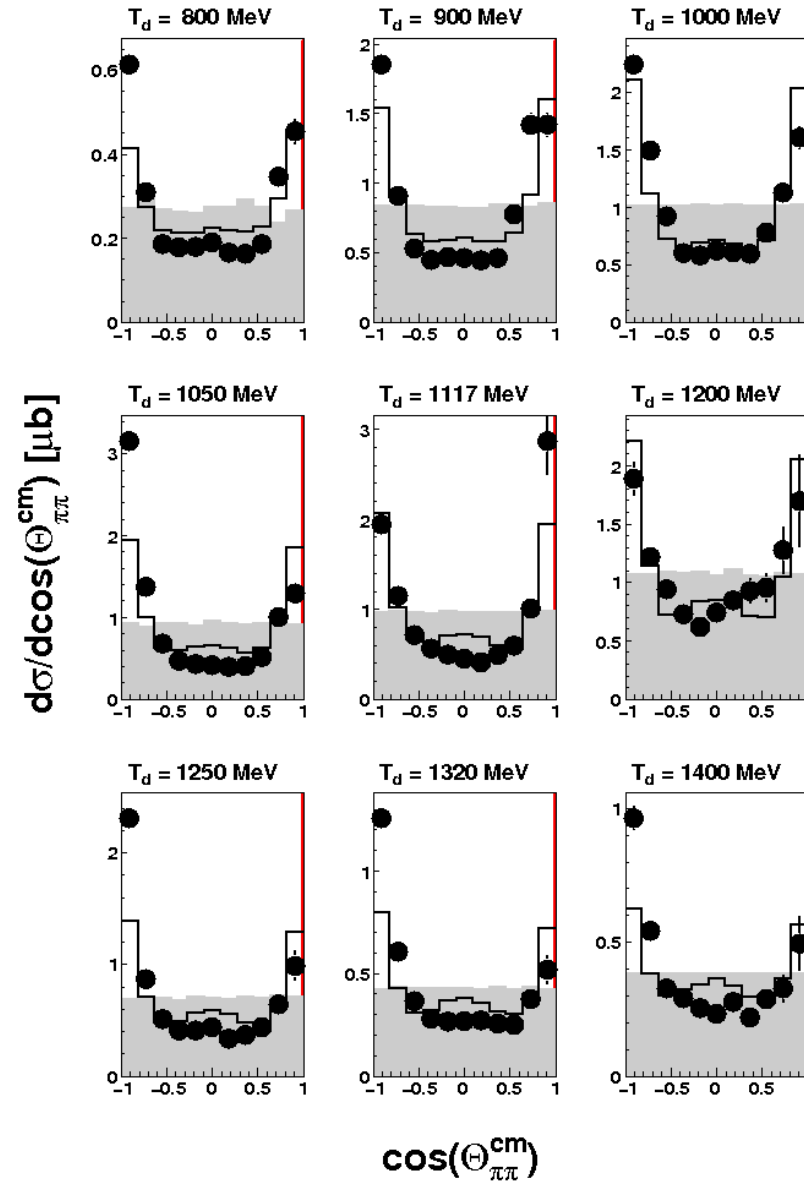
- Double-Pionic Fusion to ${}^3\text{He}$
 - $dd \rightarrow {}^3\text{He}\pi^0\pi^0(n)$ and $pd \rightarrow {}^3\text{He}\pi^0\pi^0$
 - Preliminary results
 - ABC effect
- Double-Pionic Fusion to ${}^4\text{He}$
 - $dd \rightarrow {}^4\text{He}\pi^0\pi^0$ measured at 9 energies over the full ABC region
 - Kinematically complete measurements over the entire region of the ABC effect
 - d^* Resonance
 - Fermi motion of the nucleons broadens the Resonance respect to the Double-Pionic fusion to deuteron.



Thank you for your attention

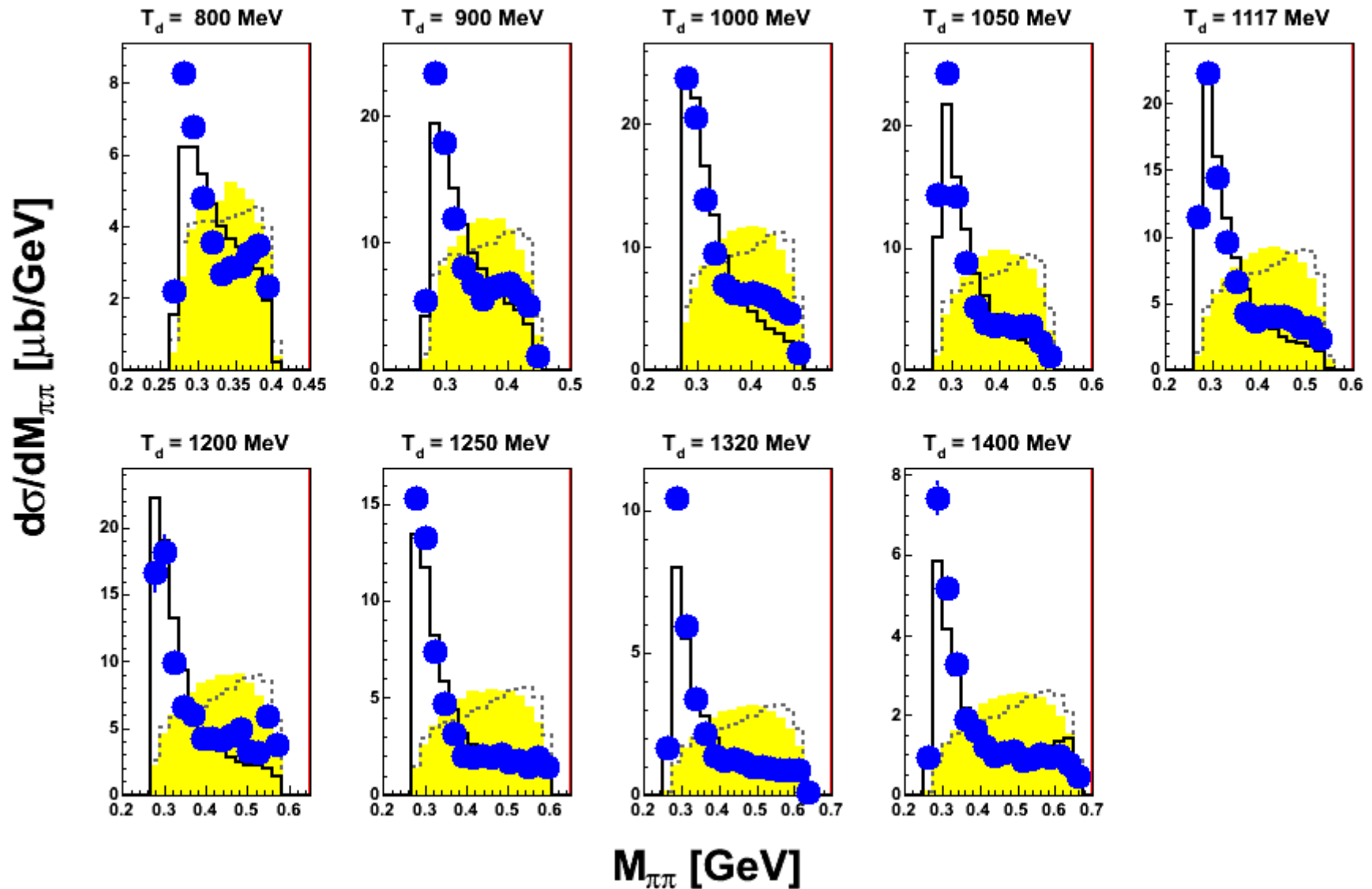


Double-Pionic Fusion to ^4He



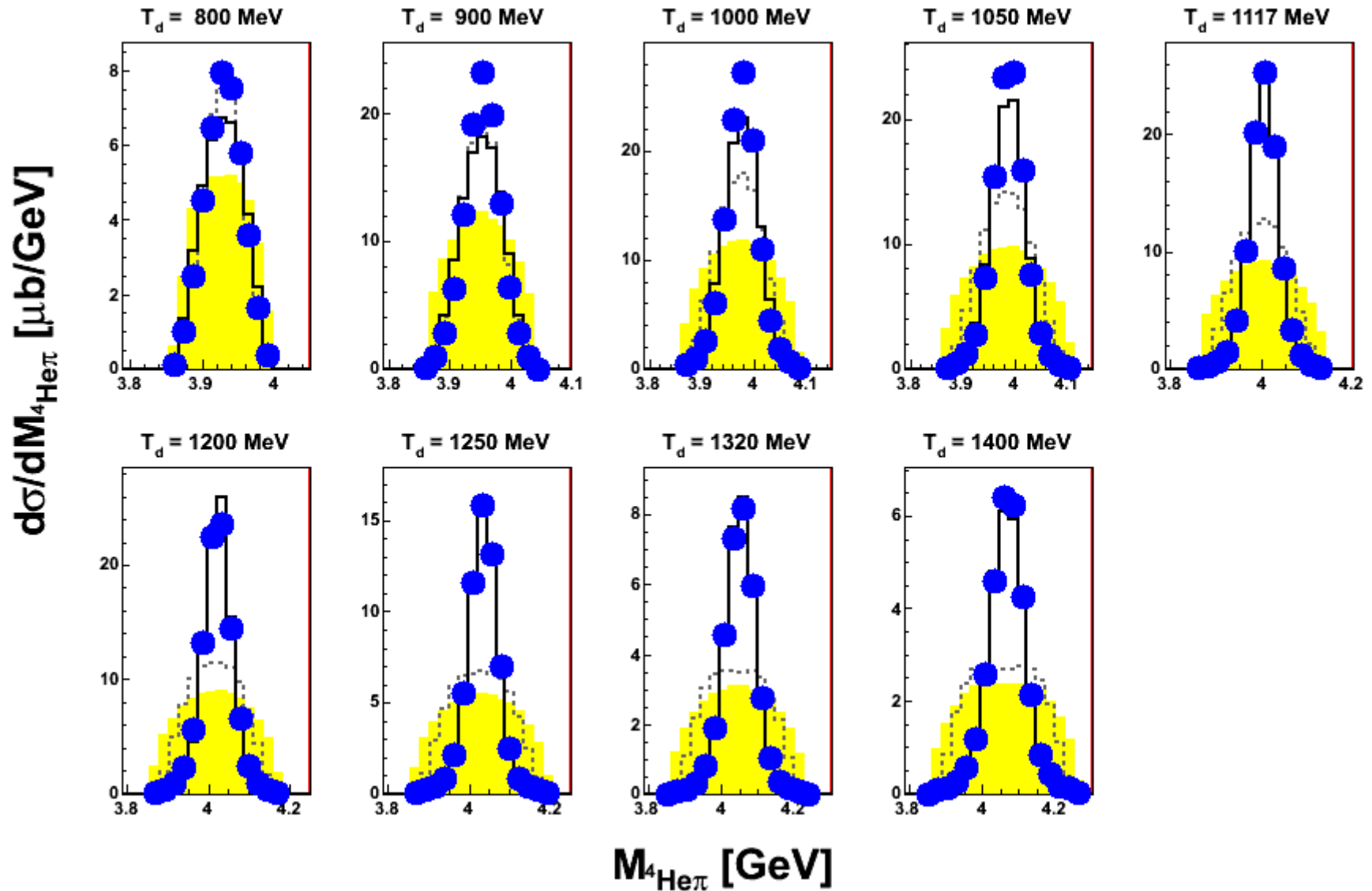


Double-Pionic Fusion to ^4He



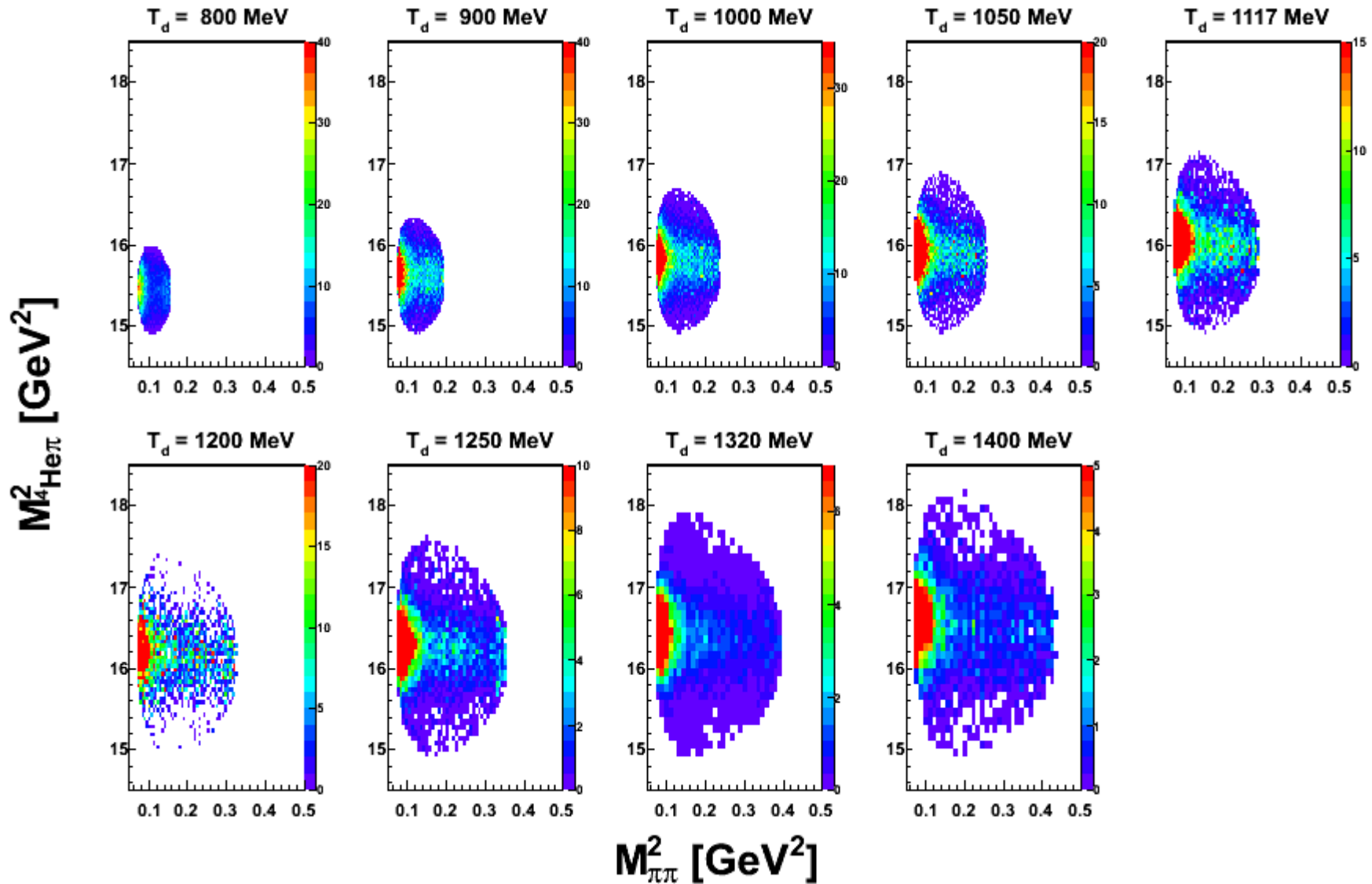


Double-Pionic Fusion to ^4He





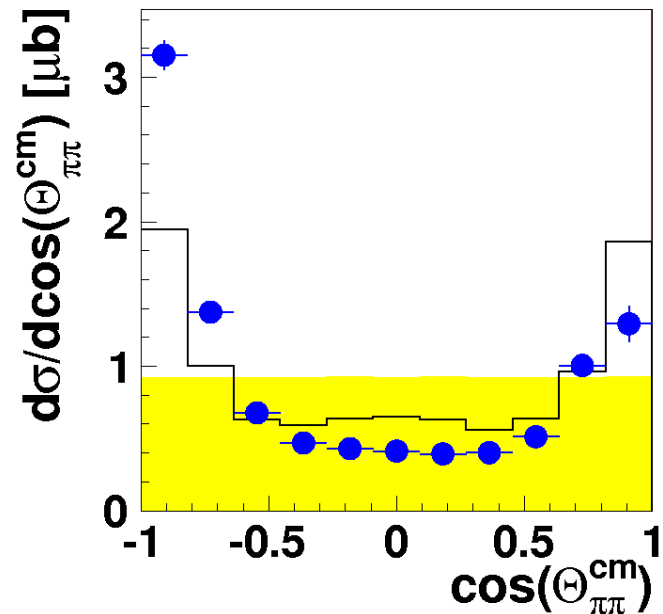
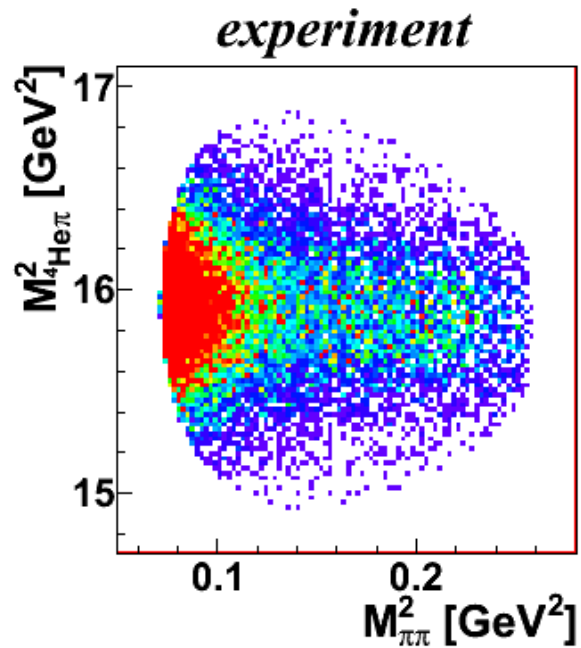
Double-Piononic Fusion to ^4He





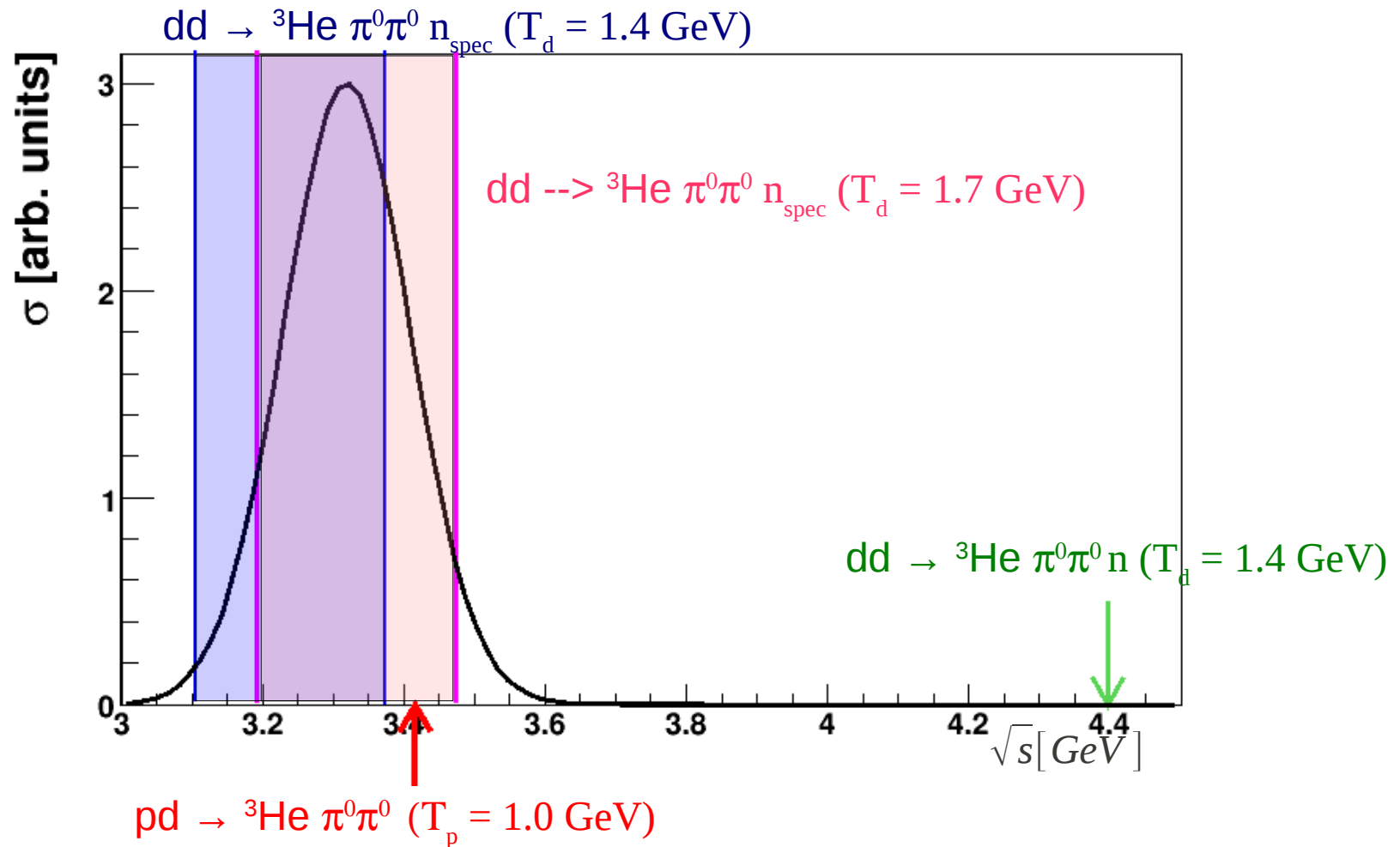
Double-Pionic Fusion to ^4He

- $T_{\text{beam}} = 1.05$ GeV about maximum of the Resonance





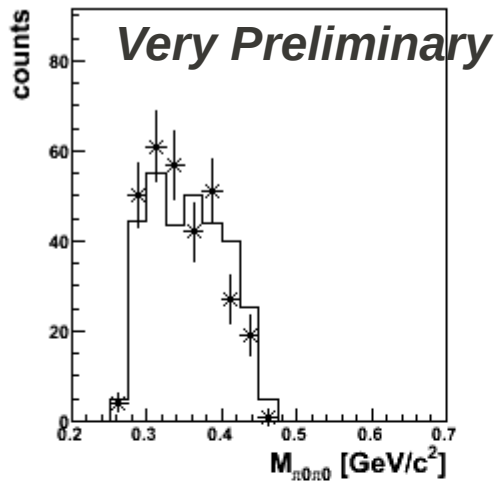
Double-Pionic Fusion to ${}^3\text{He}$



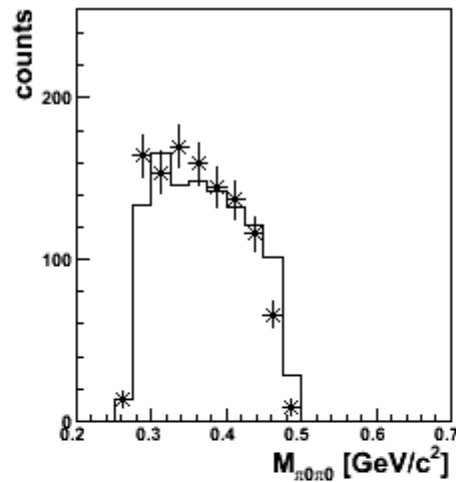


Double-Pionic Fusion to ^3He Preliminary Results

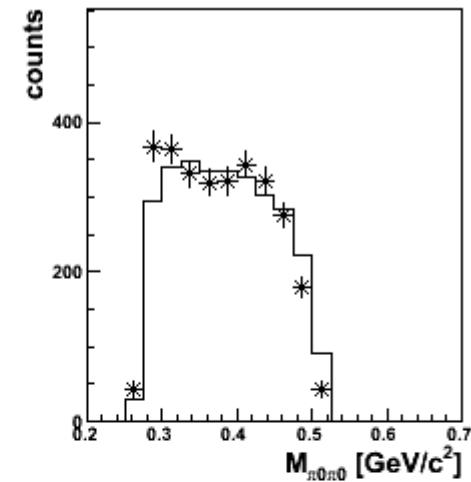
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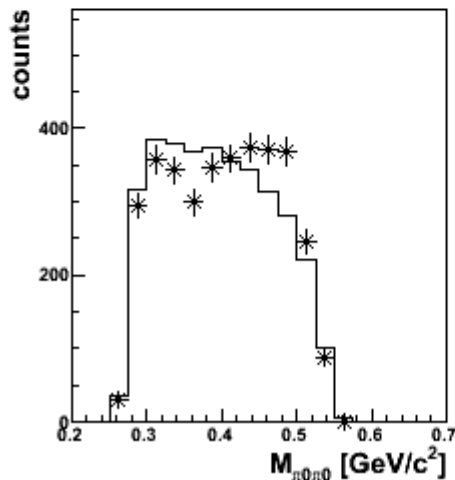
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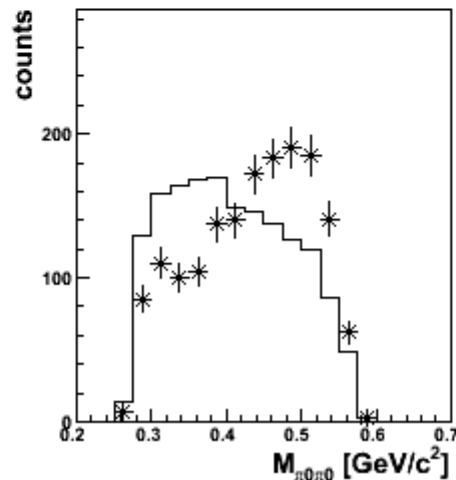
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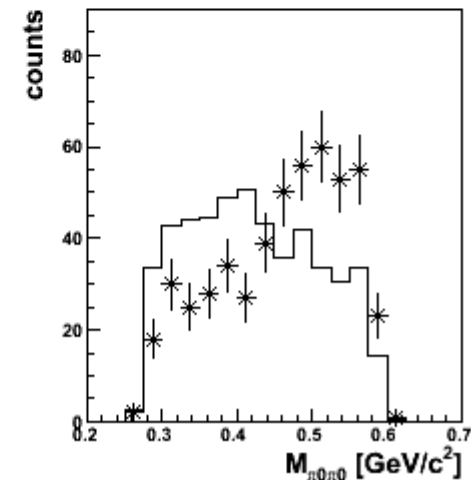
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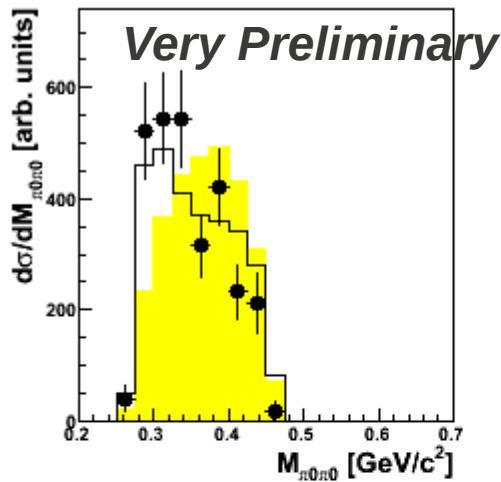
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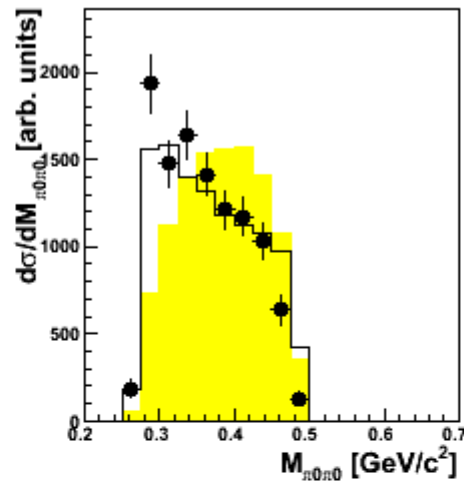


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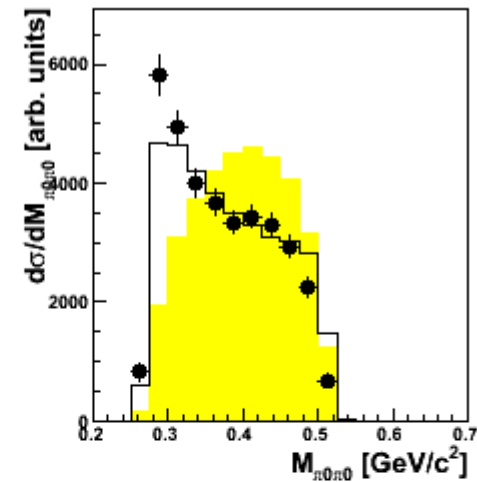
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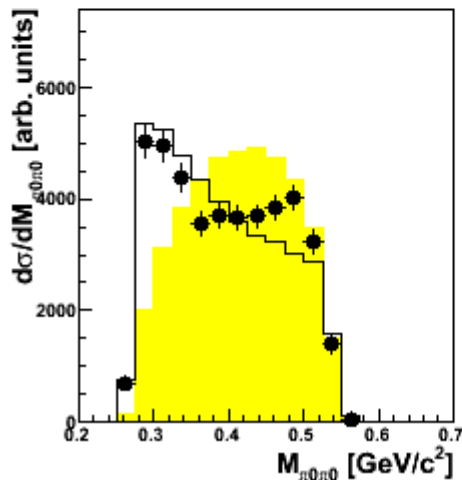
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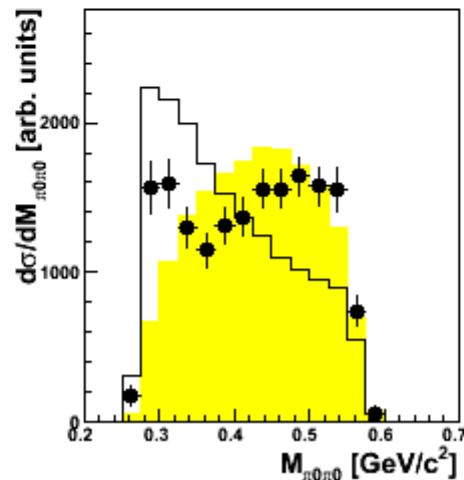
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