Simulation Results for a Resonance Scan of the X(3872) at $\overline{\text{P}}$ANDA *

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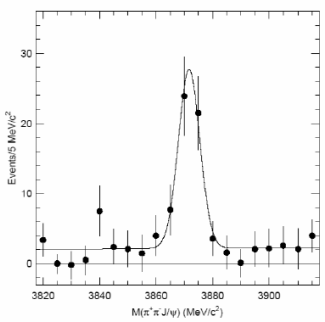
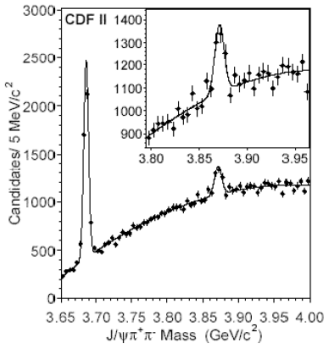
Motivation: Measure Width of $X(3872)$

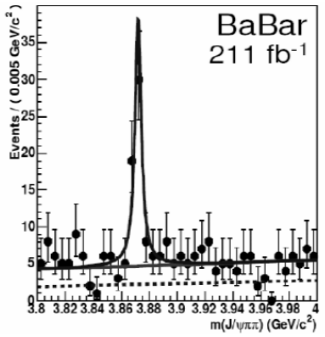
- Discovered by Belle in X(3872) $\rightarrow J/\psi\ \pi^+\pi^-$
- Confirmed by numerous experiments in the same decay channel
- Observed in several additional decay channels such as
  - X(3872) $\rightarrow J/\psi\ \gamma$
  - X(3872) $\rightarrow D^0\bar{D}^{*0}$
  - X(3872) $\rightarrow J/\psi\ \omega$
- Structure of $X(3872)$ is still unclear
- To date only an upper limit for its width is known
  - Recent publication: $\Gamma_{X(3872)} \leq 1.2$ MeV at 90% C.L.*

Belle, Phys. Rev. Lett.91(2003) 262001

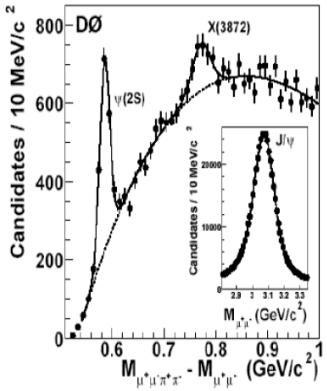


CDF-II, Phys. Rev. Lett.93(2004) 072001

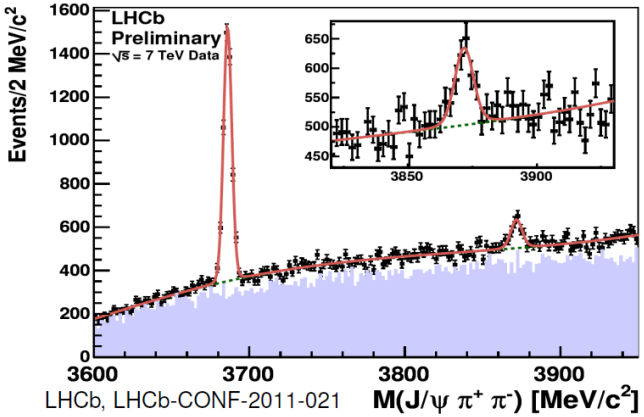




BaBar, Phys. Rev. D71(2005) 071103



D0, Phys. Rev. Lett.93(2004) 162002



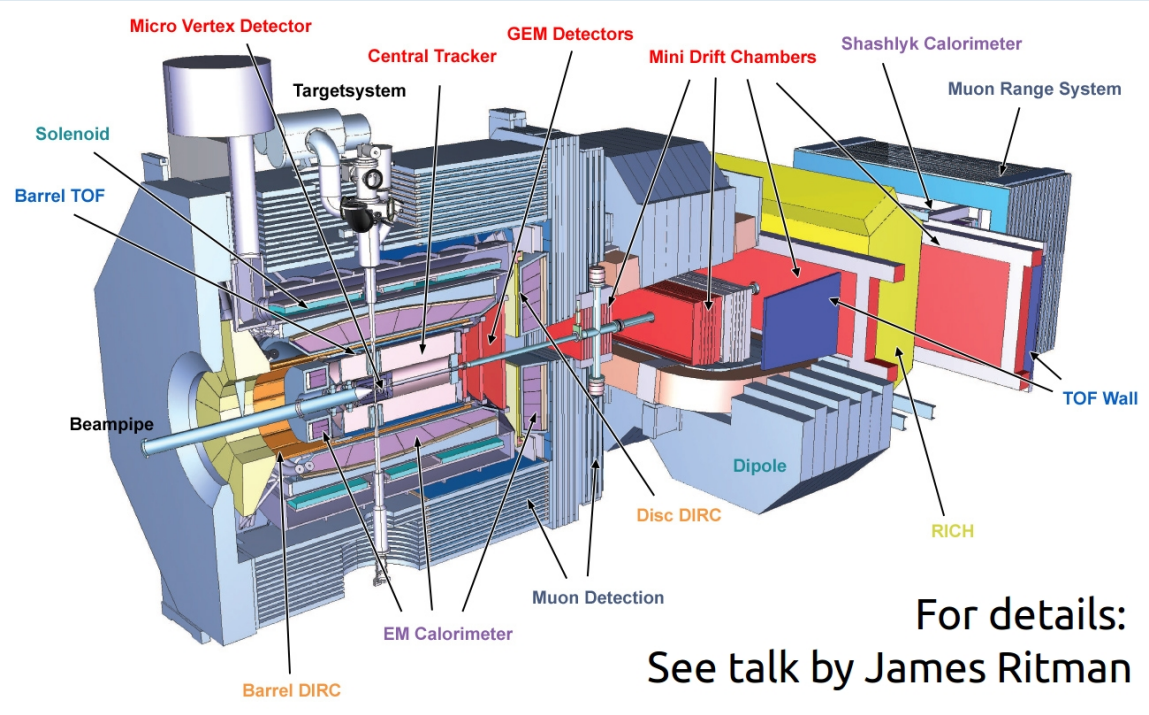
LHCb, LHCb-CONF-2011-021

* Belle Collaboration, arXiv:1107.0163 [hep-ex] (submitted to Phys. Rev. D)

Prospects for $\overline{\text{P}}$ANDA

- $J^{PC} = 1^{++}$ favored, $J^{PC} = 2^{-+}$ possible for X(3872). $\Rightarrow C = +1$
- $p\bar{p} \to X(3872)$ ✓ $\quad$ ~~$e^+e^- \to X(3872)$~~
- Resolution in $p\bar{p}$ resonance scan only limited by knowledge of $\sqrt{s}$, <u>not</u> limited by detector resolution.
- $\overline{\text{P}}$ANDA will combine excellent PID capabilities with cooled antiproton beams ($\Delta\sqrt{s} \simeq 33.6$ keV for $\sqrt{s} \simeq 3.872$ GeV).

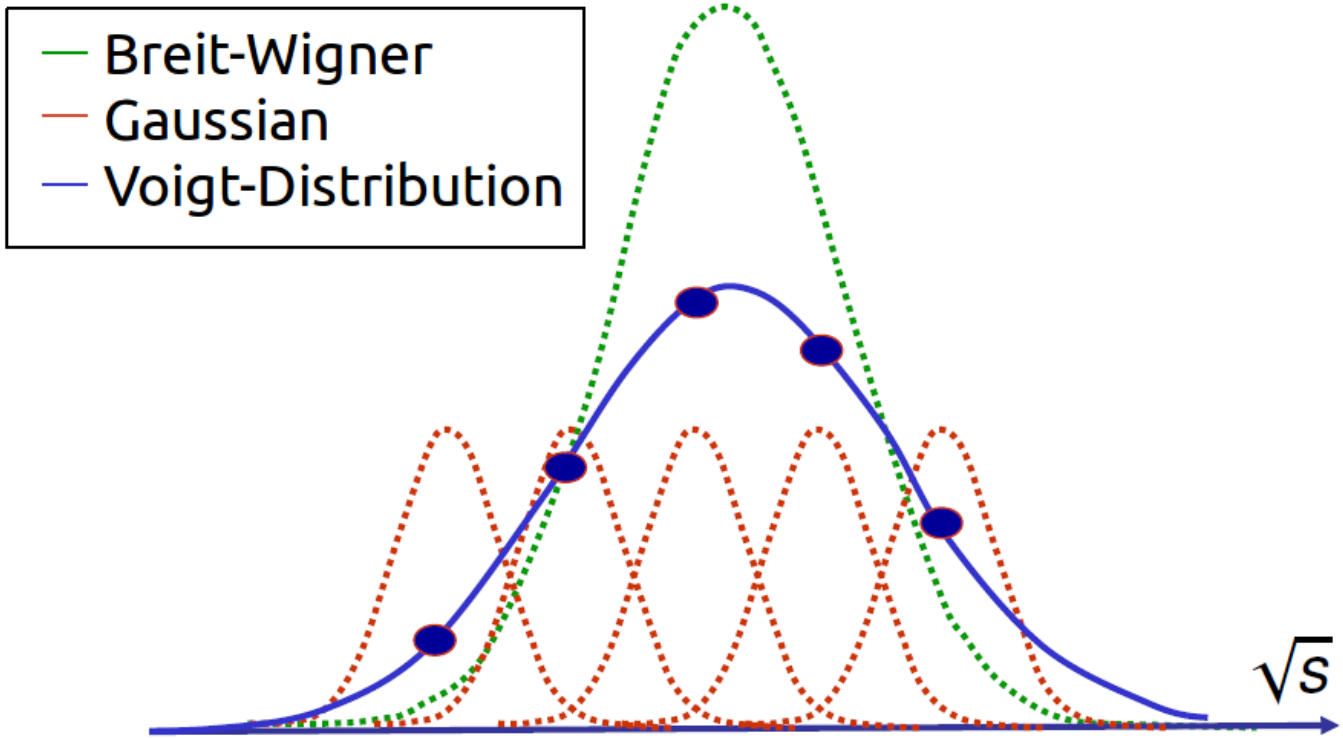
The $\overline{\text{P}}$ANDA Experiment



Resonance Scan

Goal of this Work

Detailed simulation of a resonance scan of X(3872) within the PandaRoot framework.



Probability density function:
Voigt-distribution (convolution of Gaussian and Breit-Wigner).

Input Parameters for Simulation of X(3872) Resonance Scan at $\overline{\text{P}}$ANDA

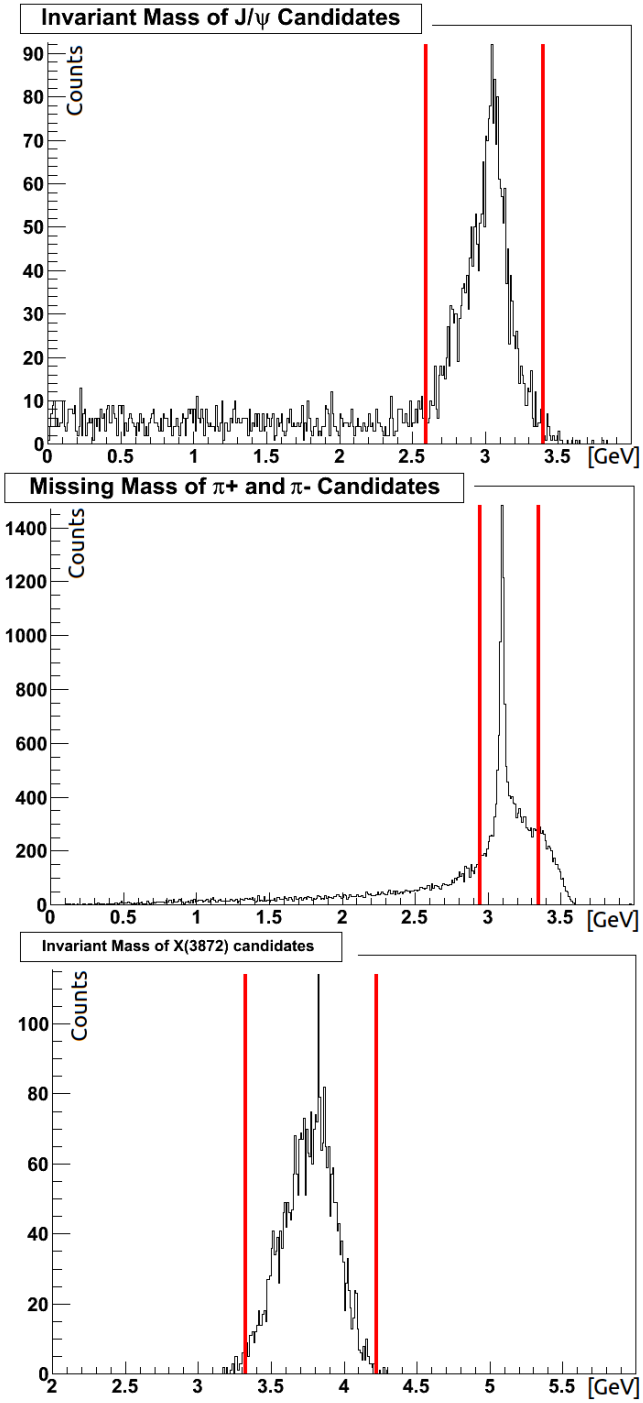
Mass $m_{X(3872)}$	3.872 GeV
Width $\Gamma_{X(3872)}$	100 keV
Production	$p\bar{p} \to X(3872)$ ($\sigma_{BW} = 50$ nb)*
Decay	$X(3872) \to J/\psi\, \pi^+\pi^-$ (BR $= 0.1$)
Subsequent Decay	$J/\psi \to e^+e^-$ (BR $= 0.06$)†
Time Requirement	$20 \cdot 2$ days
Accelerator duty factor	50%
Luminosity	0.864 pb^{-1}/day
HESR	High resolution mode
p_{beam} distribution	Gaussian, rms $\simeq 2 \cdot 10^{-5} \cdot p_{beam}$
$\sqrt{s}$ distribution	Gaussian, rms $\simeq$ 33.6 keV

*Corresponds to: BR($X(3872) \to p\bar{p}$) $\simeq 3.9 \cdot 10^{-5}$

†K. Nakamura et al. (PDG) J. Phys. G37, 075021 (2010)

Reconstruction Procedure

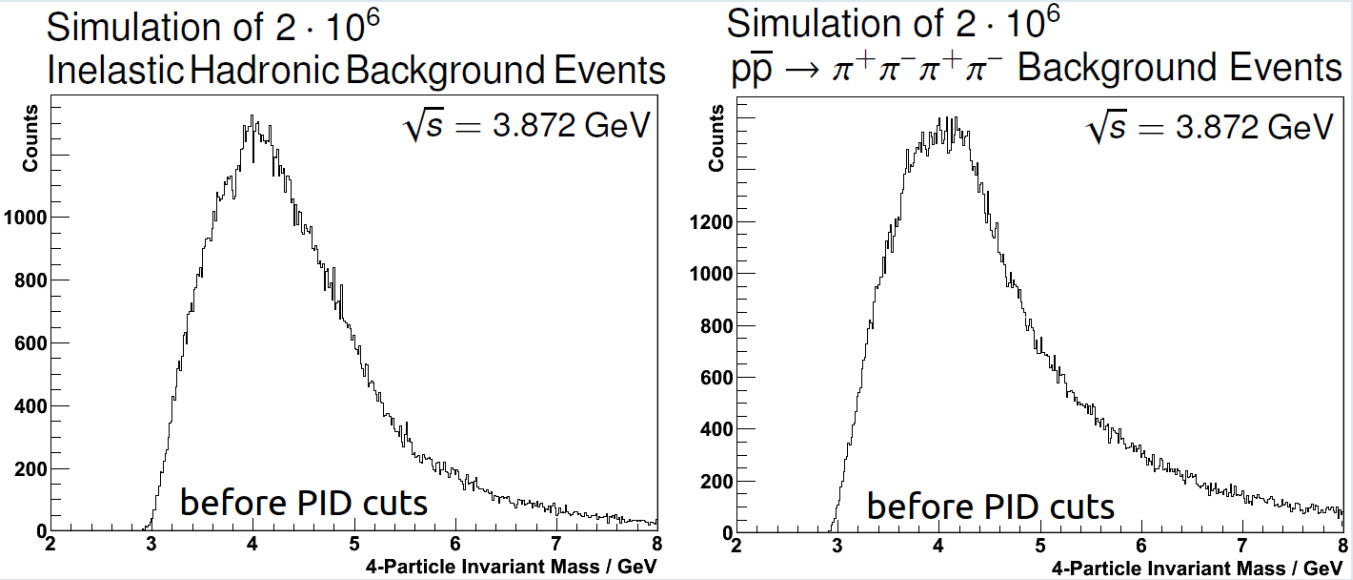
1. Apply PID cuts.
2. Cut on invariant mass of all e^+e^- candidates.
   $\rightarrow J/\psi$ candidates.
3. Cut on missing mass of all $\pi^+\pi^-$ candidates.
4. Cut on invariant mass of $e^+e^-\pi^+\pi^-$ candidates.
   $\rightarrow$ X(3872) candidates.
   $\rightarrow$ Signal counts for scan point.



Plots are shown for simulation of $p\bar{p} \rightarrow$ X(3872) signal events at $\sqrt{s} = 3.872$ GeV with subsequent X(3872) $\rightarrow J/\psi\, \pi^+\pi^-$ and $J/\psi \rightarrow e^+e^-$ decays.

Study of Background Processes

- Direct process $\sigma(p\bar{p} \to J/\psi\, \pi^+\pi^-) = 1.2$ nb* for $\sqrt{s} \simeq m_{X(3872)}$.
- All other processes assumed to be suppressible with PID
  - $\sigma_{\text{inelastic}} \simeq 45$ mb†
  - $\sigma(p\bar{p} \to \pi^+\pi^-\pi^+\pi^-) \simeq 50\ \mu$b‡
  - Study of events produced with dual parton model based generator⊥



- After PID cuts: No fake signals observed.
- Investigation of larger sample sizes will follow.

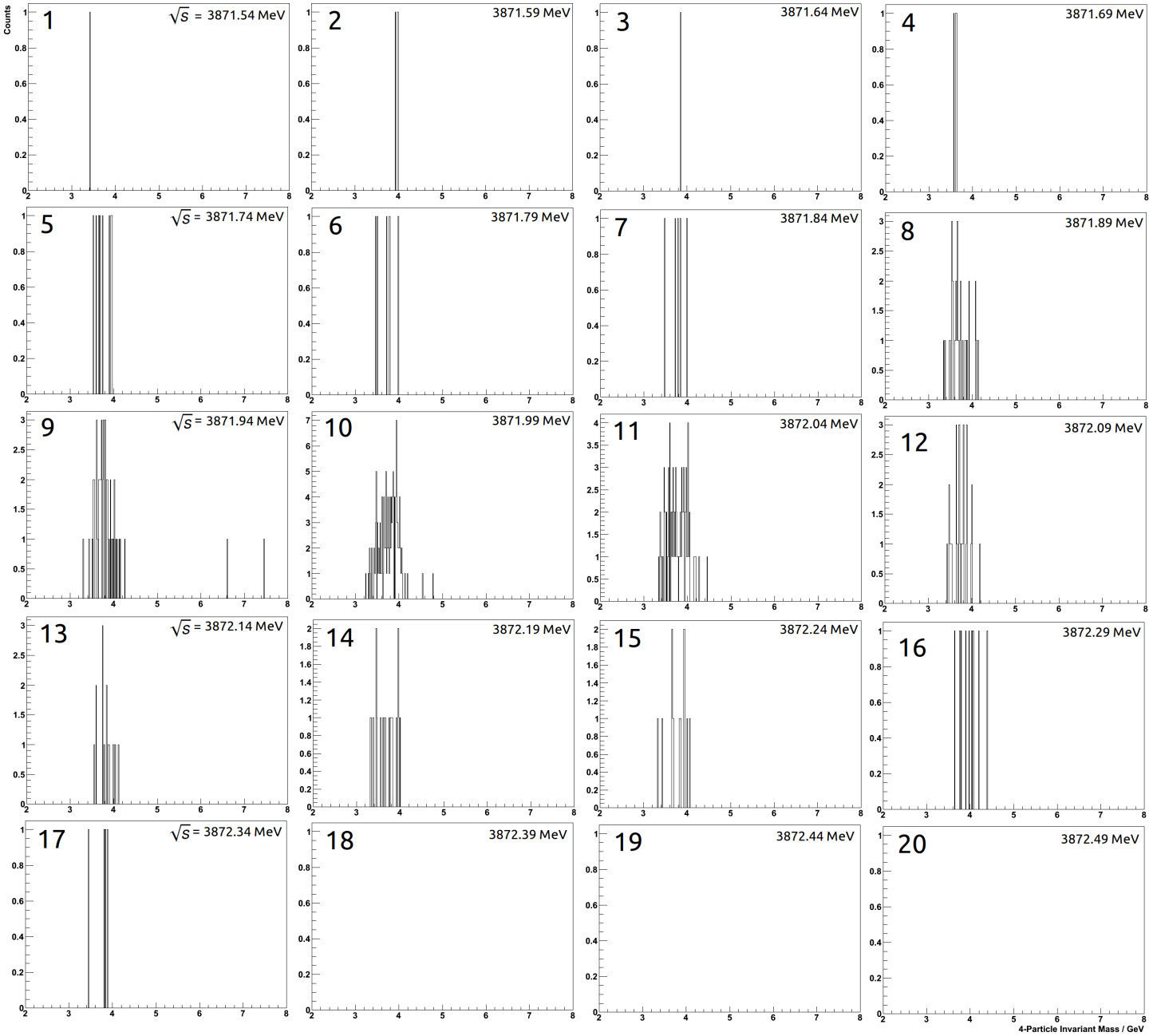
* G. Y. Chen, J. P. Ma, Phys. Rev. D77(2008)097501

† K. Nakamura et al. (PDG) J. Phys. G37, 075021 (2010)

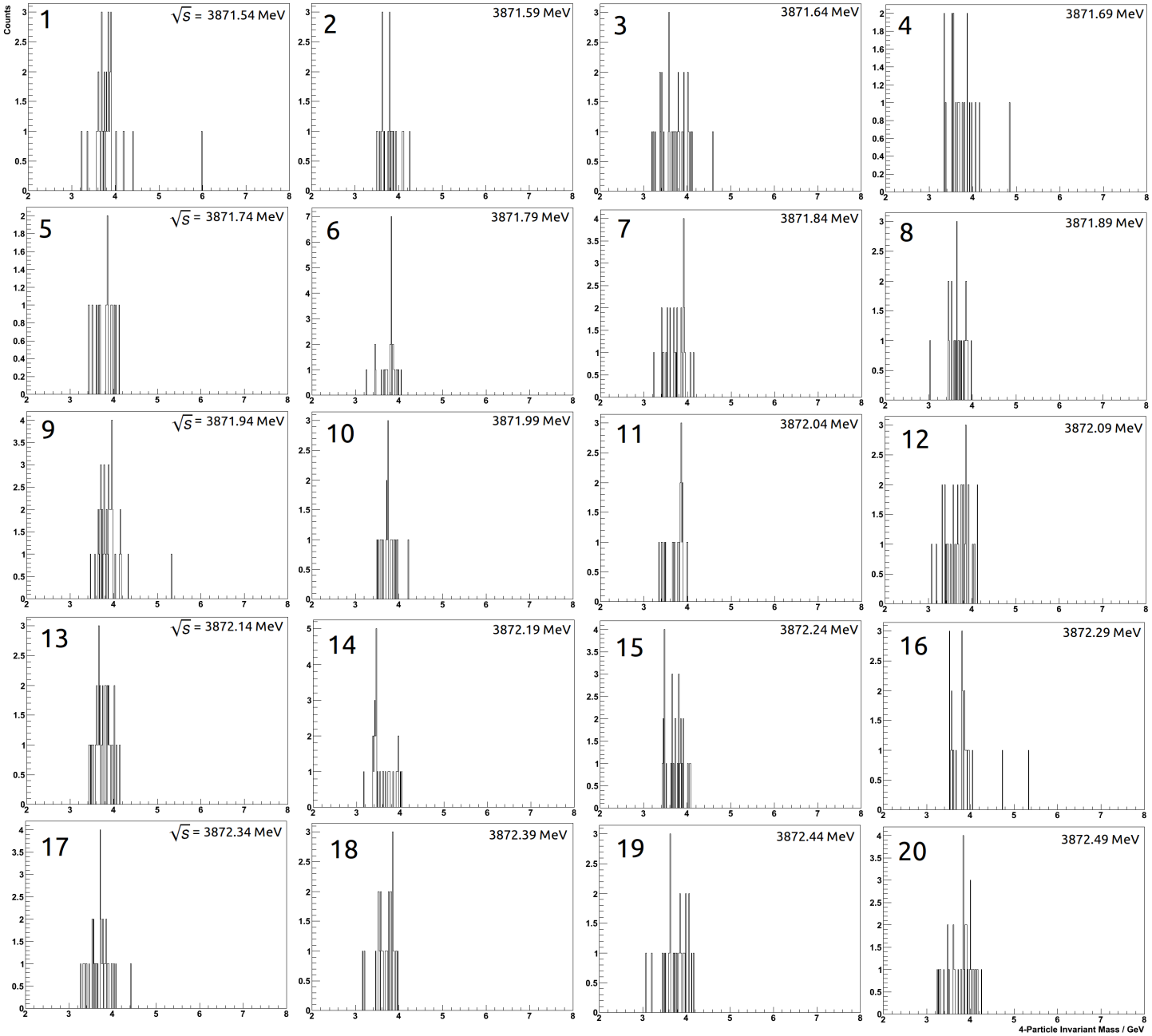
‡ V. Flaminio et al. (Compilation of Cross-Sections) CERN-HERA-79-03 (1979)

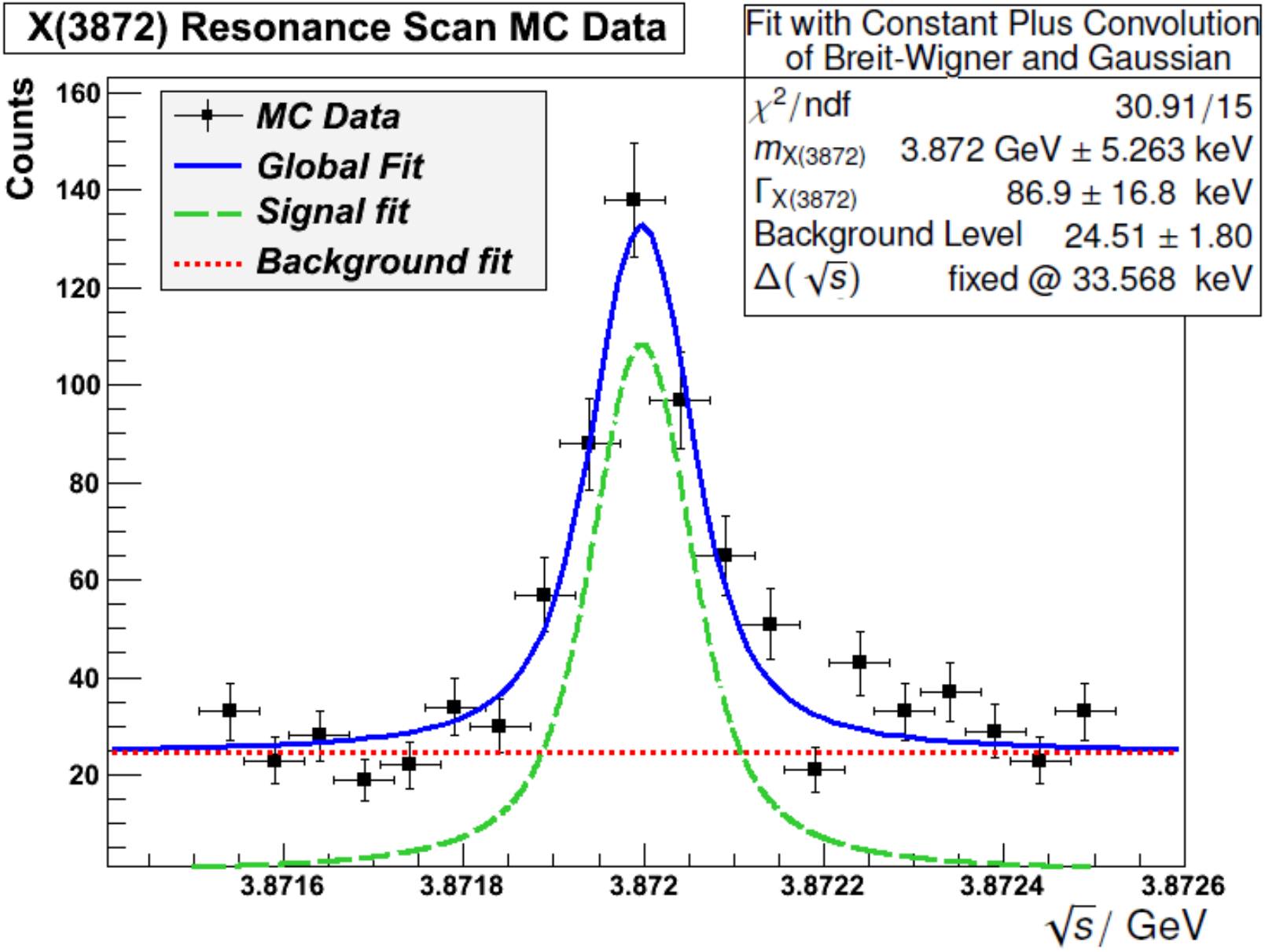
⊥ V. Uzhinsky, A. Galoyan, hep-ph/0212369

Signal Simulation for X(3872) Resonance Scan



Background Simulation for X(3872) Resonance Scan





Reconstructed width $\Gamma_{X(3872)}$ is consistent with input width of 100 keV.*

*Results are preliminary. Only statistical errors are shown.

Conclusions and Outlook

Conclusions

- $\overline{\text{P}}$ANDA is well suited for resonance scan investigations of narrow resonances which can be directly formed in $\text{p}\overline{\text{p}}$.
- $\overline{\text{P}}$ANDA will be able to either measure $\Gamma_{X(3872)}$ or at least significantly improve the current upper limit of $\Gamma_{X(3872)} \leq 1.2$ MeV at 90% C.L.*.

Outlook

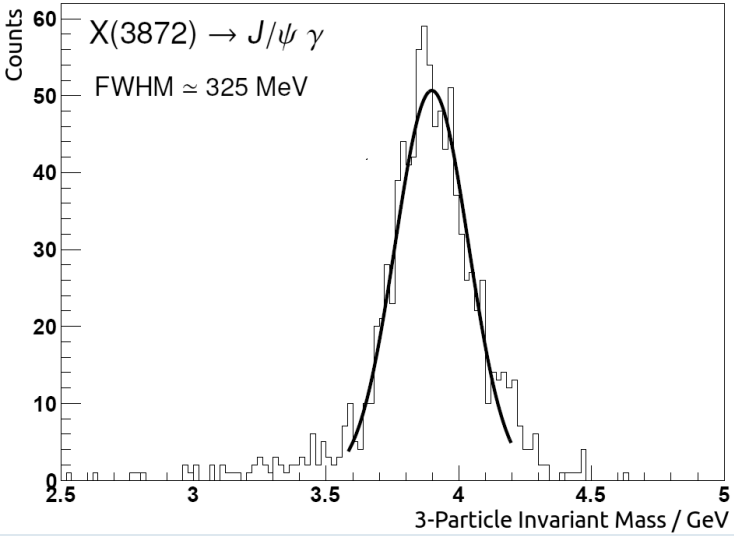
- Investigation of larger background samples.
- Reconstruction of J/ψ via $\mu^+\mu^-$ decay.
- Simulation of resonance scan for additional decay channels. **(See next slide.)**

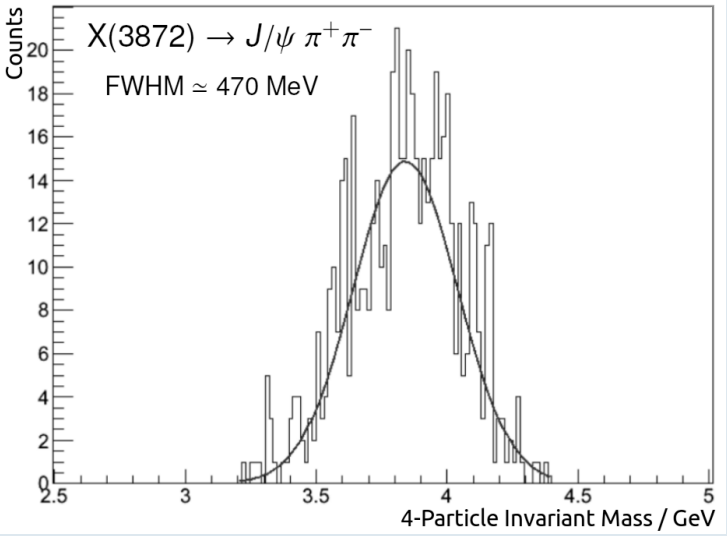
* Belle Collaboration, arXiv:1107.0163 [hep-ex]

Work in Progress: Investigation of X(3872) $\rightarrow J/\psi\,\gamma$

Comparison of X(3872) $\rightarrow J/\psi\,\gamma$ and X(3872) $\rightarrow J/\psi\,\pi^+\pi^-$

- $9 \cdot \mathrm{BR}(\mathrm{X}(3872) \rightarrow J/\psi\,\gamma) \simeq \mathrm{BR}(\mathrm{X}(3872) \rightarrow J/\psi\,\pi^+\pi^-)^*$
- Efficiency before PID: $\varepsilon(J/\psi\,\gamma) \simeq \varepsilon^2_{\mathrm{track}} \cdot \varepsilon_\gamma \leftrightarrow \varepsilon(J/\psi\,\pi^+\pi^-) \simeq \varepsilon^4_{\mathrm{track}}$
- Mass resolution: 325 MeV $\leftrightarrow$ 470 MeV





- Main background: $\mathrm{p\overline{p}} \rightarrow \pi^+\pi^-\pi^0$ ($\sigma \simeq 70\ \mu\mathrm{b}^\dagger$) with misidentified $\pi^\pm$ and one γ from $\pi^0 \rightarrow \gamma\gamma$ lost in beampipe.
- Background analysis will show whether X(3872) $\rightarrow J/\psi\,\gamma$ might be favorable for $\overline{\mathrm{P}}$ANDA.

* Derived from product branching fractions of B-decays.

† V. Flaminio et al. (Compilation of Cross-Sections) CERN-HERA-79-03 (1979)

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Thank you very much for your attention!

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