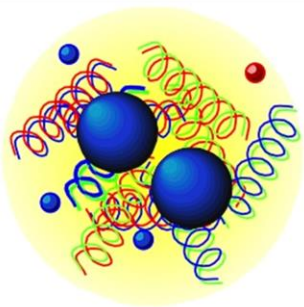
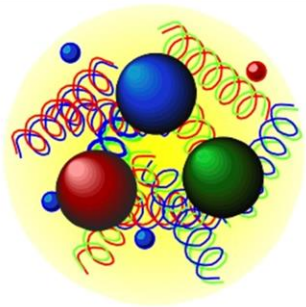
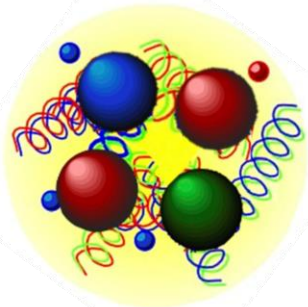
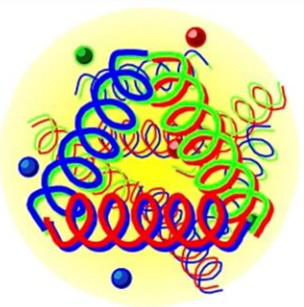
Glueball searches with BESIII

› Rosa Kappert

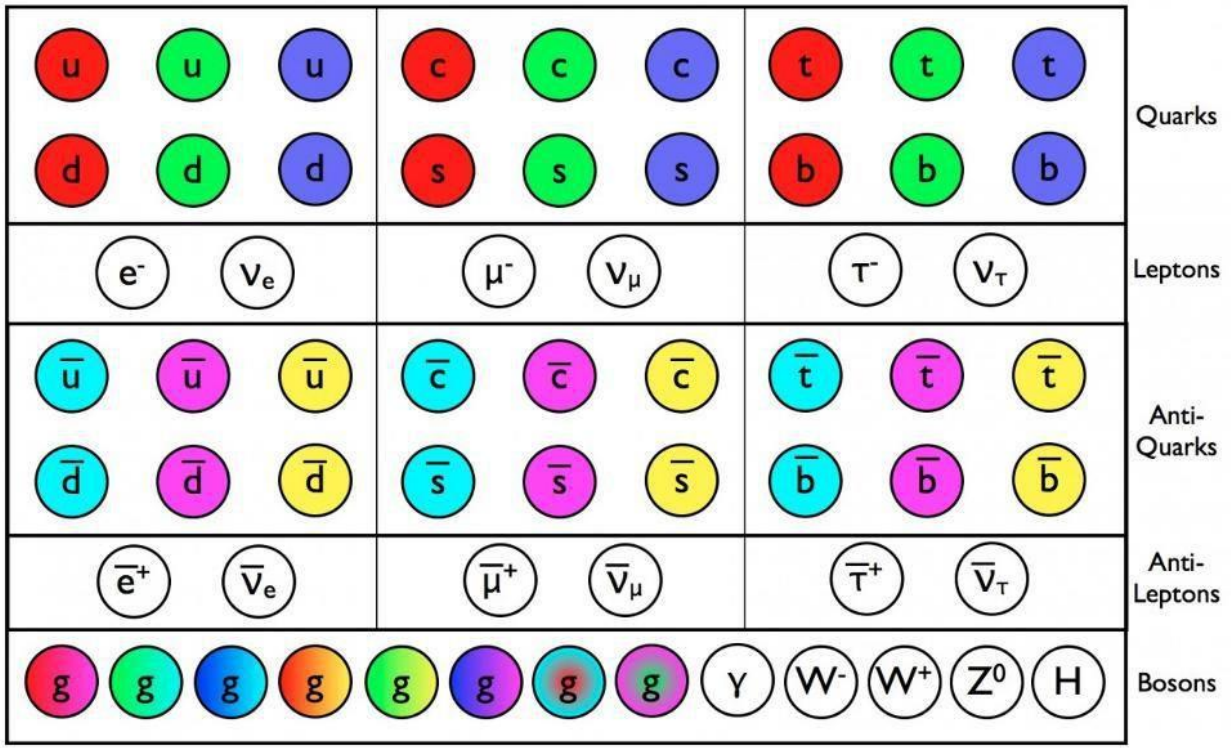

meson

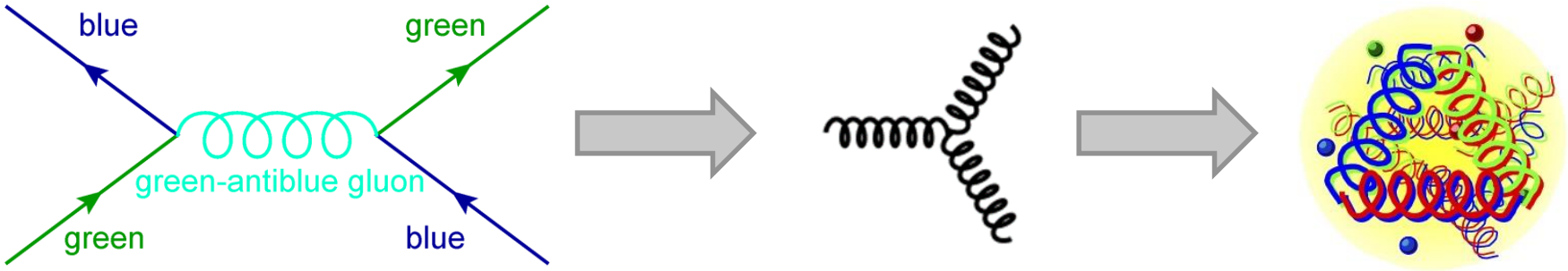

baryon


tetraquark

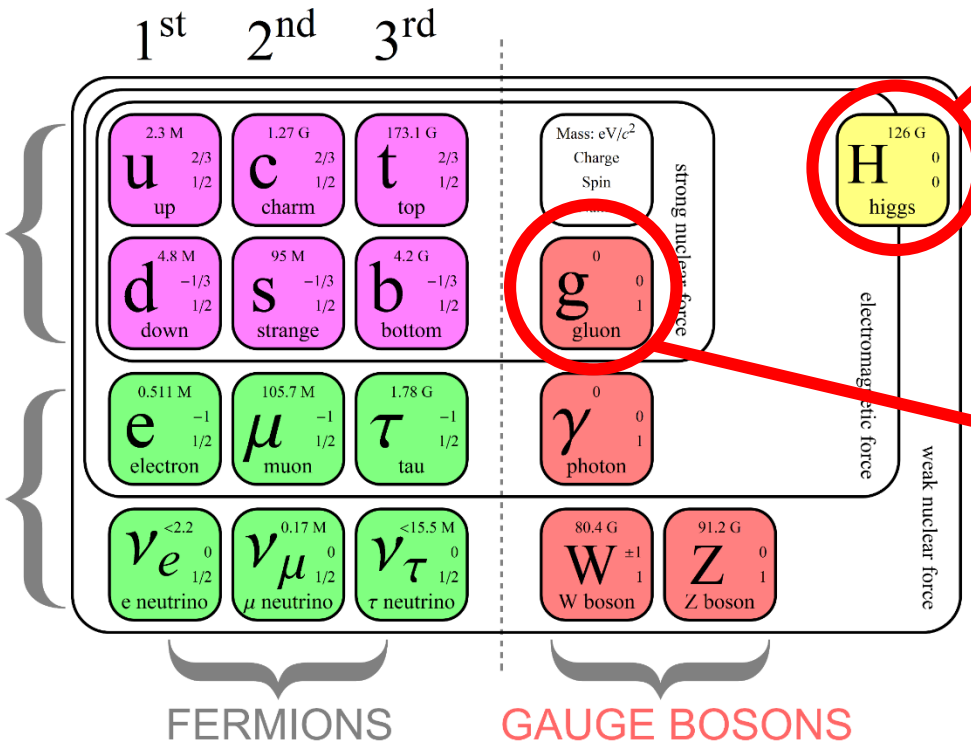

glueball?

What is a glueball?





Why search for it?

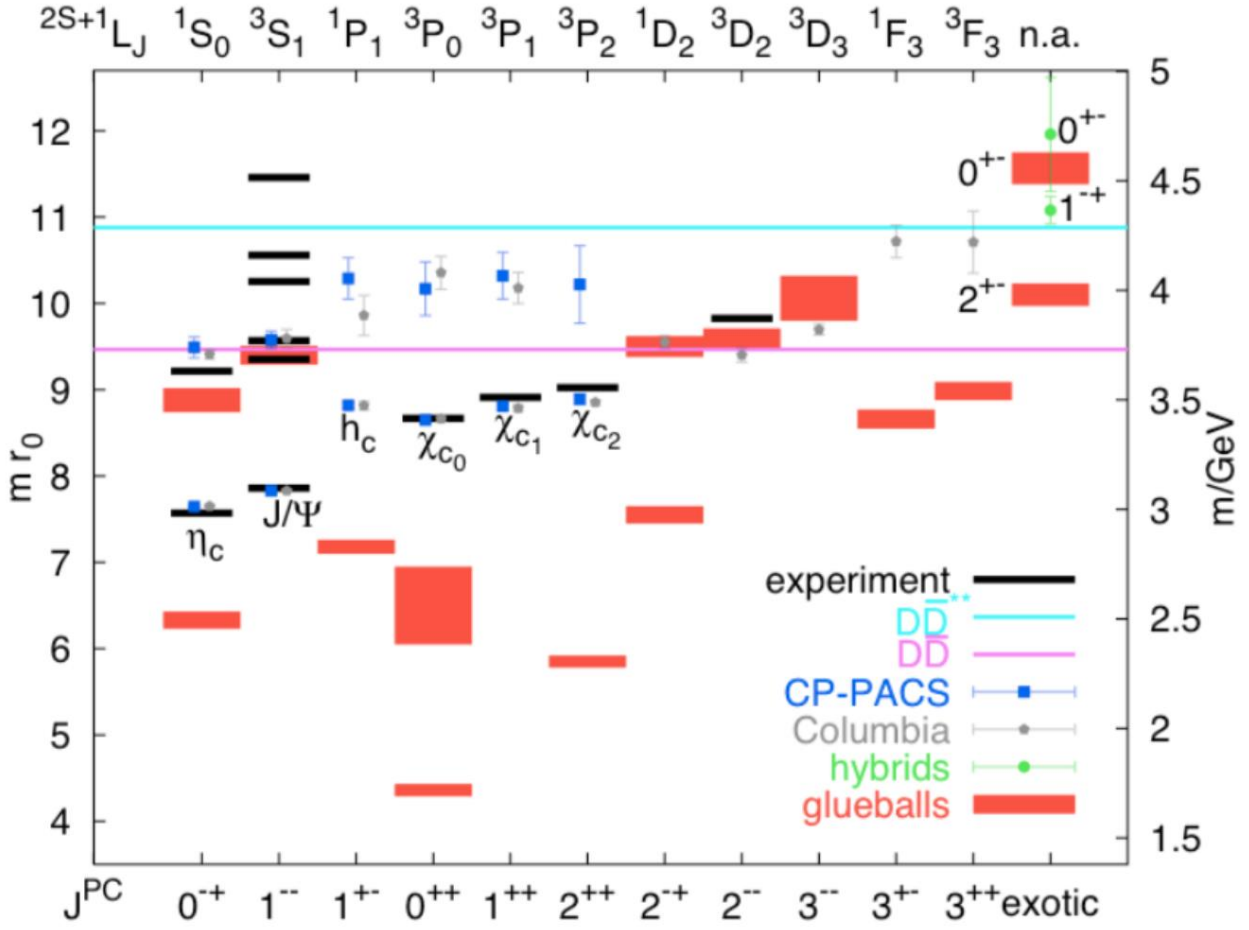


Only 1% of baryon mass!

QCD: **99%** from gluon self-interactions.

→ Glueballs predicted by QCD but never unambiguously detected

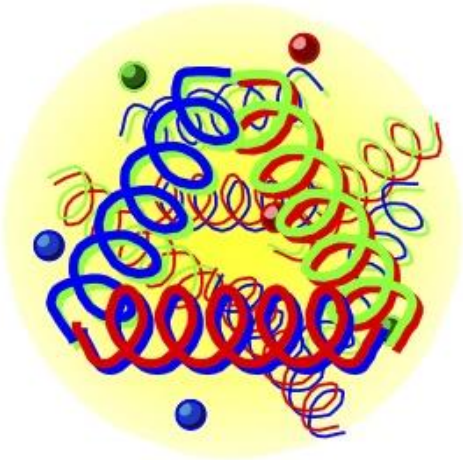
Candidates calculated with Lattice QCD.



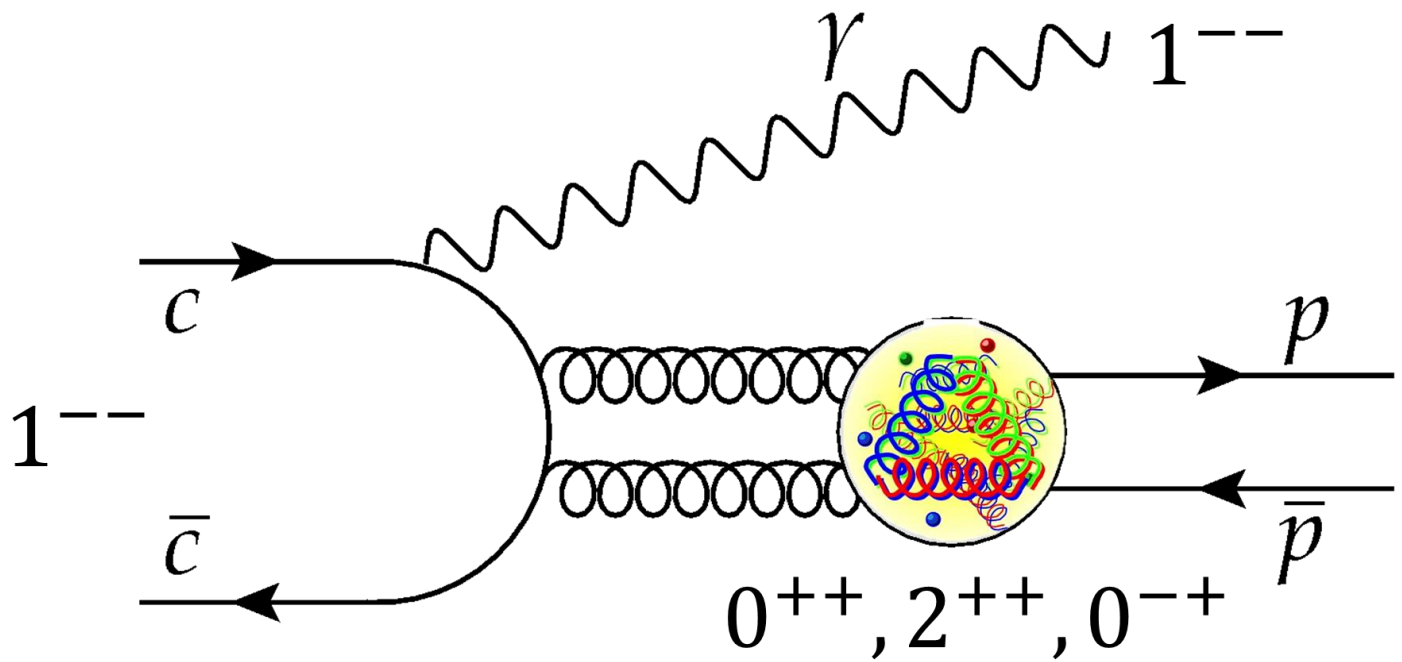
International Journal of Modern Physics A21,5610(2006)

How to find it?

- Sensitive detection channel
- Good detector: full phase space coverage
- Clean data: excellent signal-to-background ratio
- High statistics
- Model-independent analysis technique

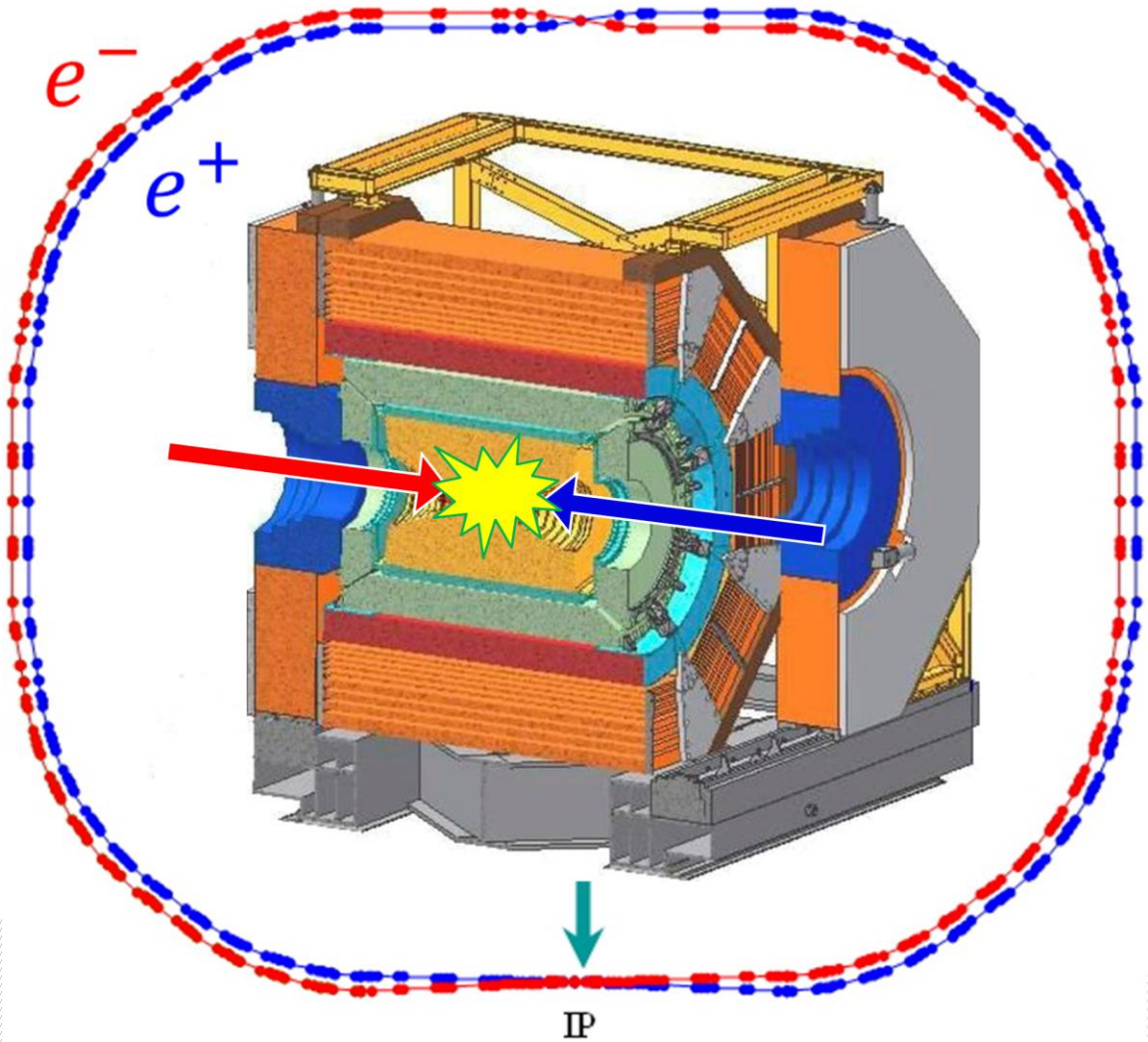


Sensitive channel: $J/\psi \rightarrow \gamma X$



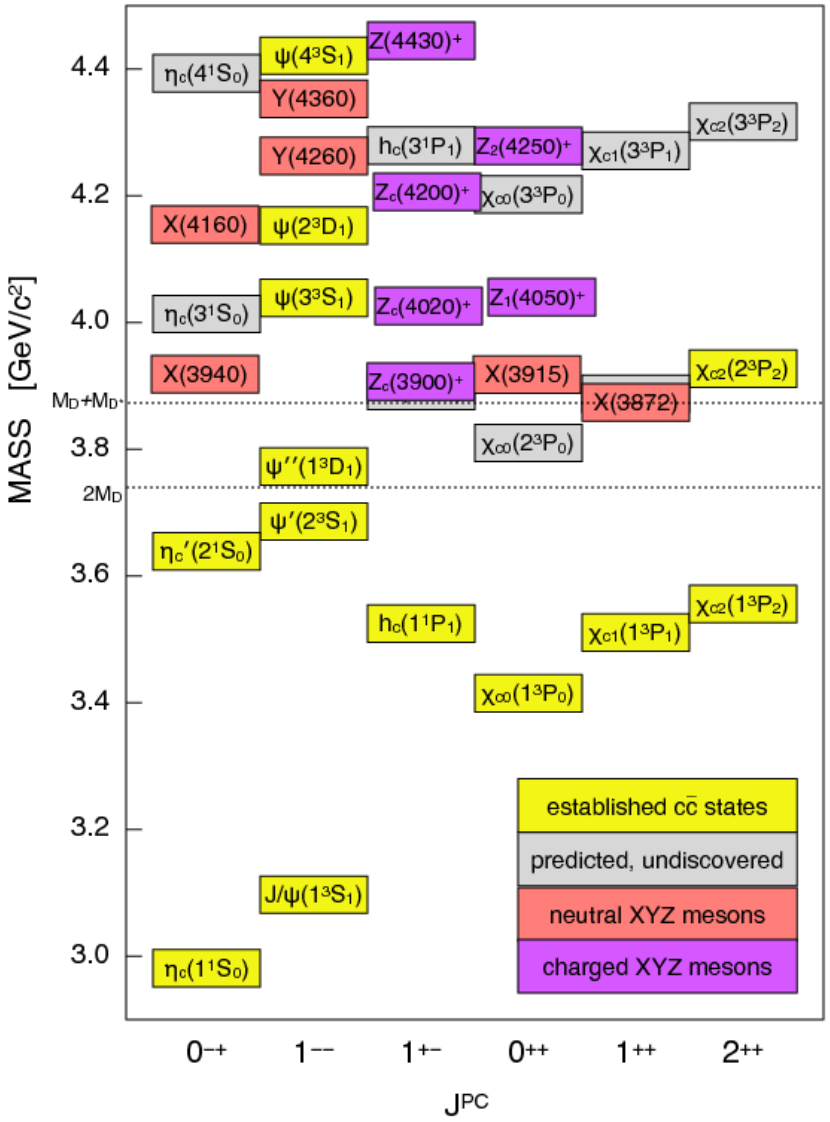
Beijing Spectrometer (BES) III

The Beijing Electron Positron Collider (BEPC) II



BESIII best option

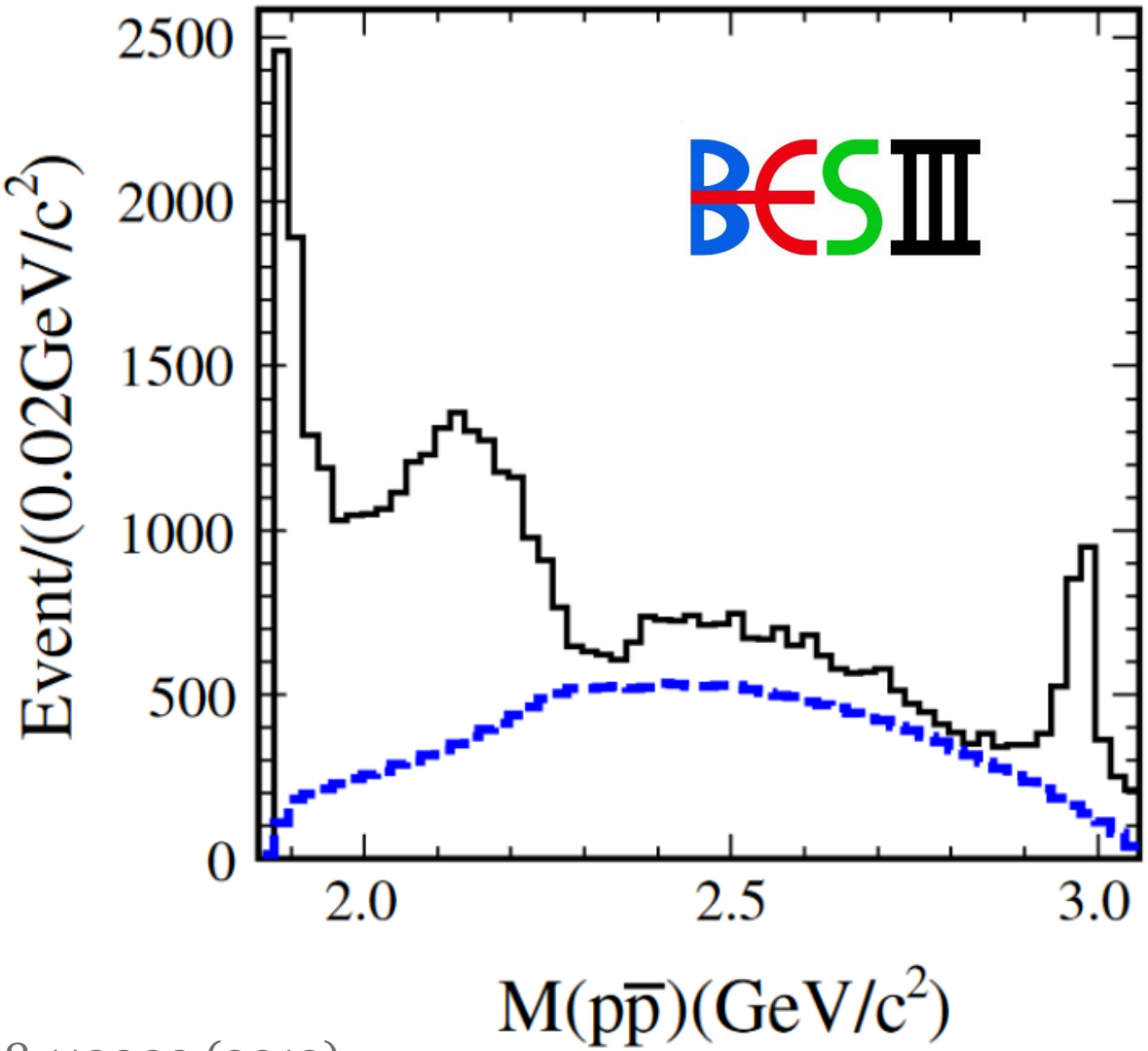
- World's record: 10^{10} J/ψ
- Energy range of glueballs
- Proven potential to observe exotics



Zc(3900): PRL110, 252001 (2013)
Zc(4040): PRL112, 132001 (2014)
Zc(3885): PRL112, 022001 (2014)
X(3872): PRL112, 092001 (2014)
Zc(4020)⁰: PRL113, 212002 (2014)

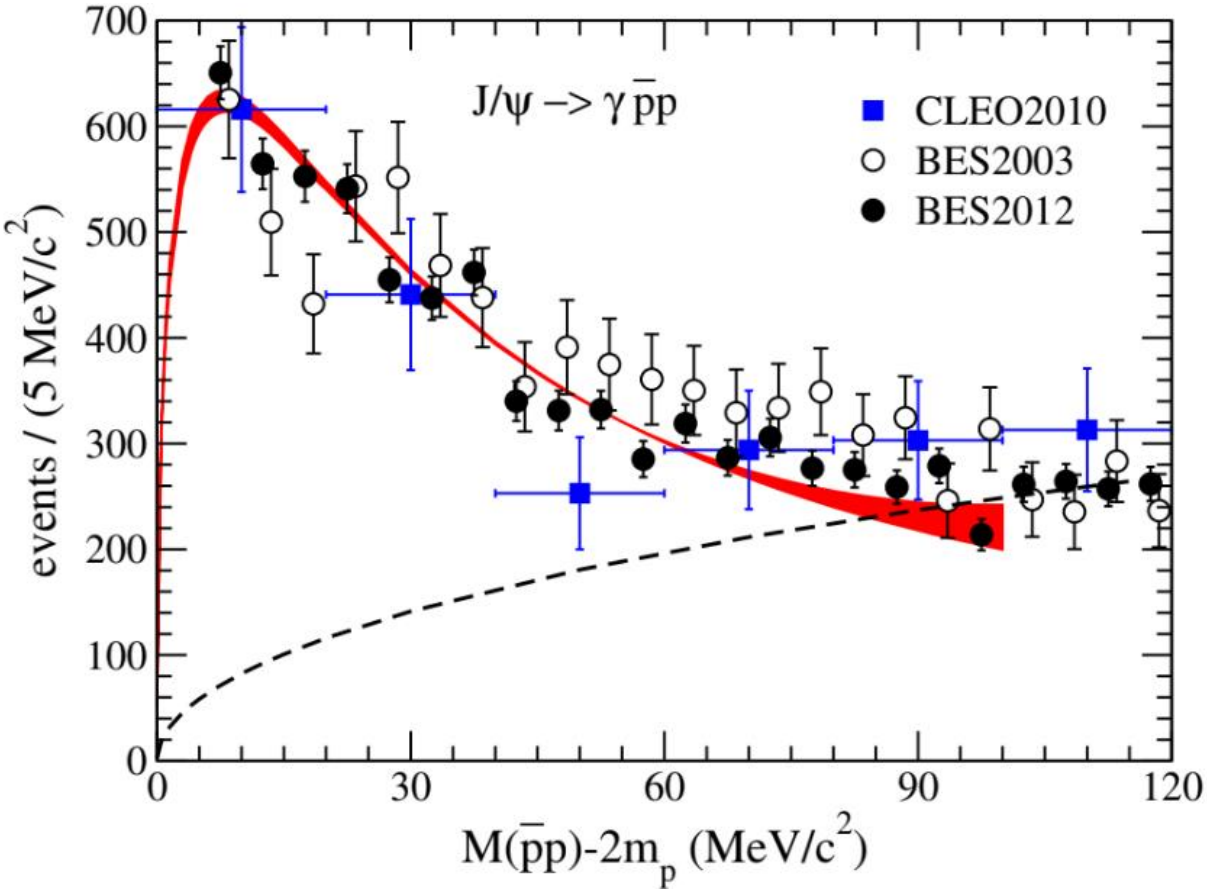
X(3823): PRL115, 011803 (2015)
Zc(3900)⁰: PRL115, 112003 (2015)
Zc(4025)⁰: PRL115, 182002 (2015)
Zc(3885)⁰: PRL115, 222002 (2015)

$J/\psi \to \gamma p\bar{p}$



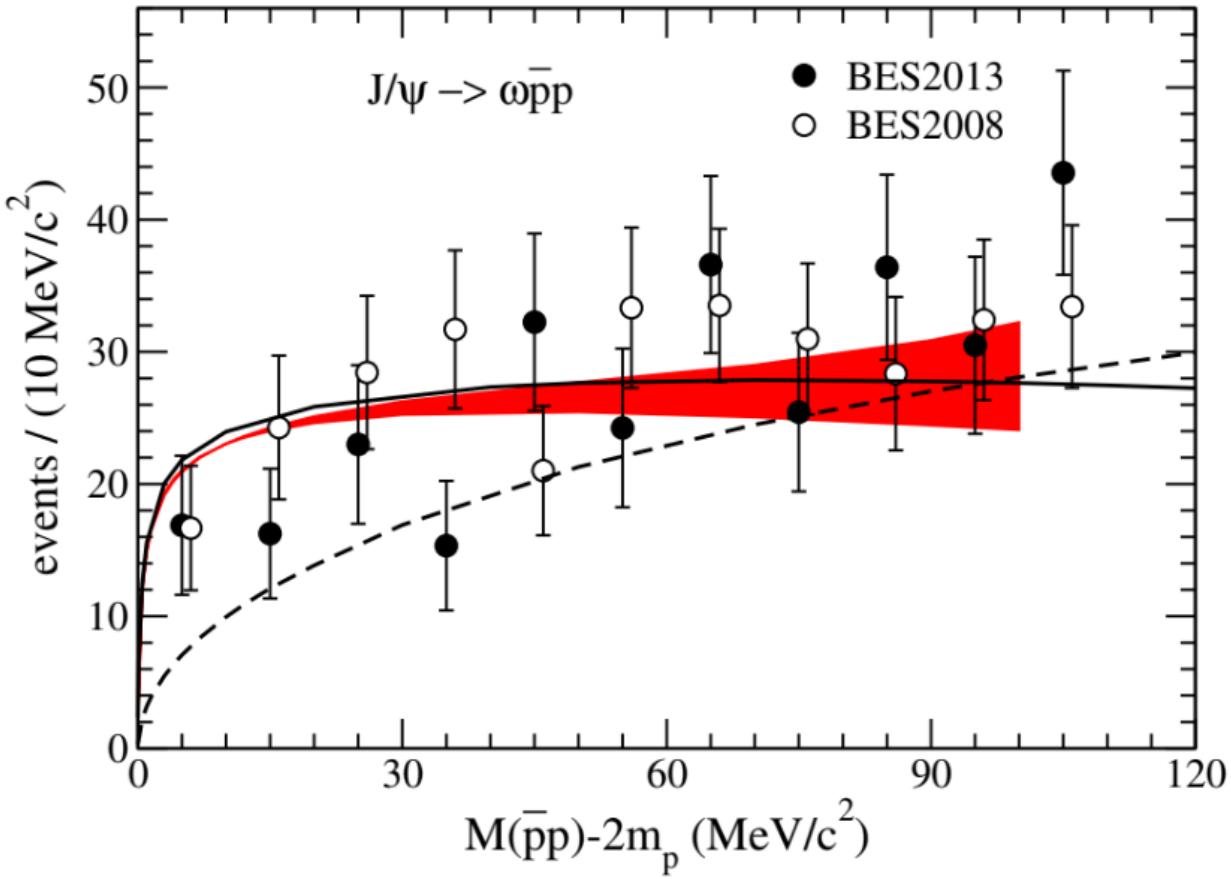
PRL108,112003 (2012)

Near $p\bar{p}$ threshold



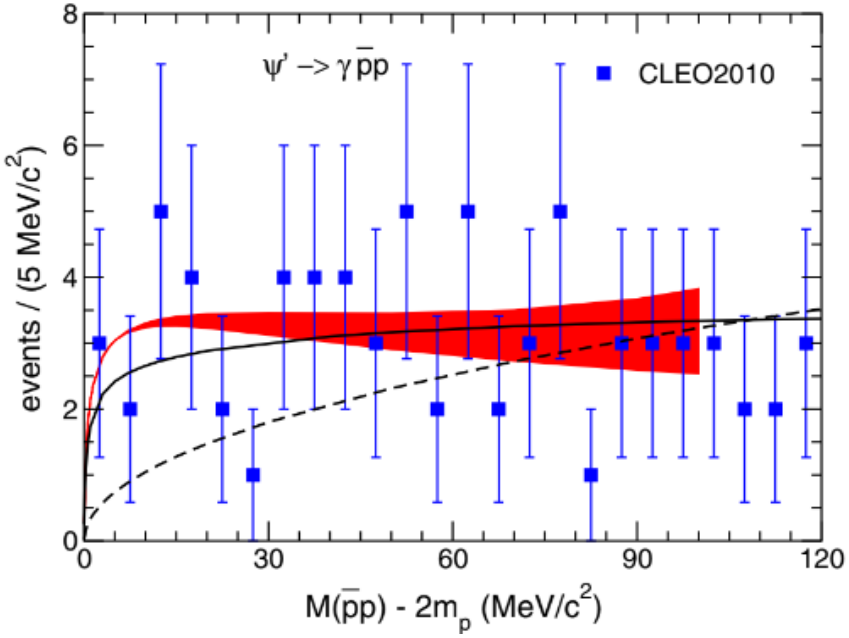
PhysRevD91, 074003 (2015), PRL91, 022001 (2003), PRL106, 072002 (2011), PRL108, 112003 (2012).

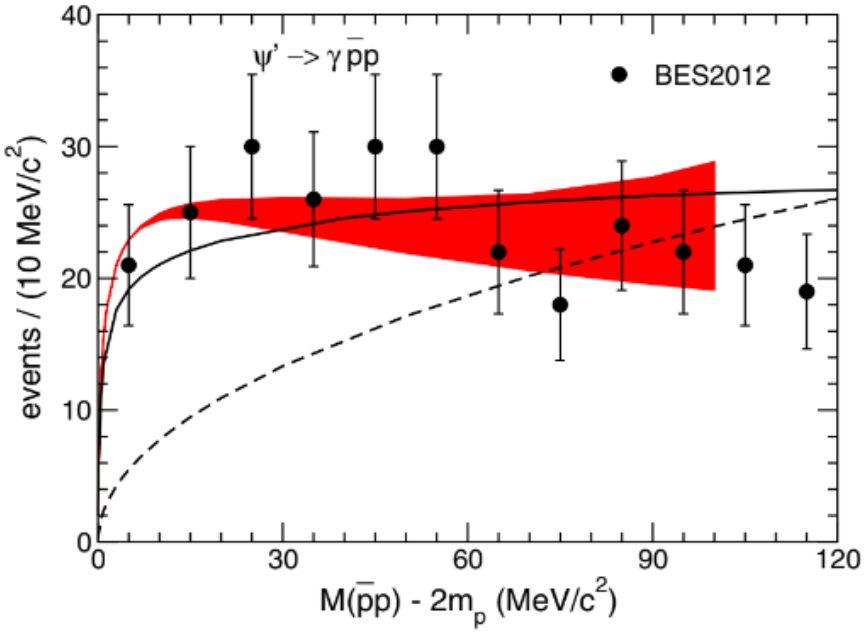
Near $p\bar{p}$ threshold



PhysRevD91, 074003 (2015), Eur.Phys.J.C53, 15 (2008).
PhysRevD87, 112004 (2013).

Near $p\bar{p}$ threshold



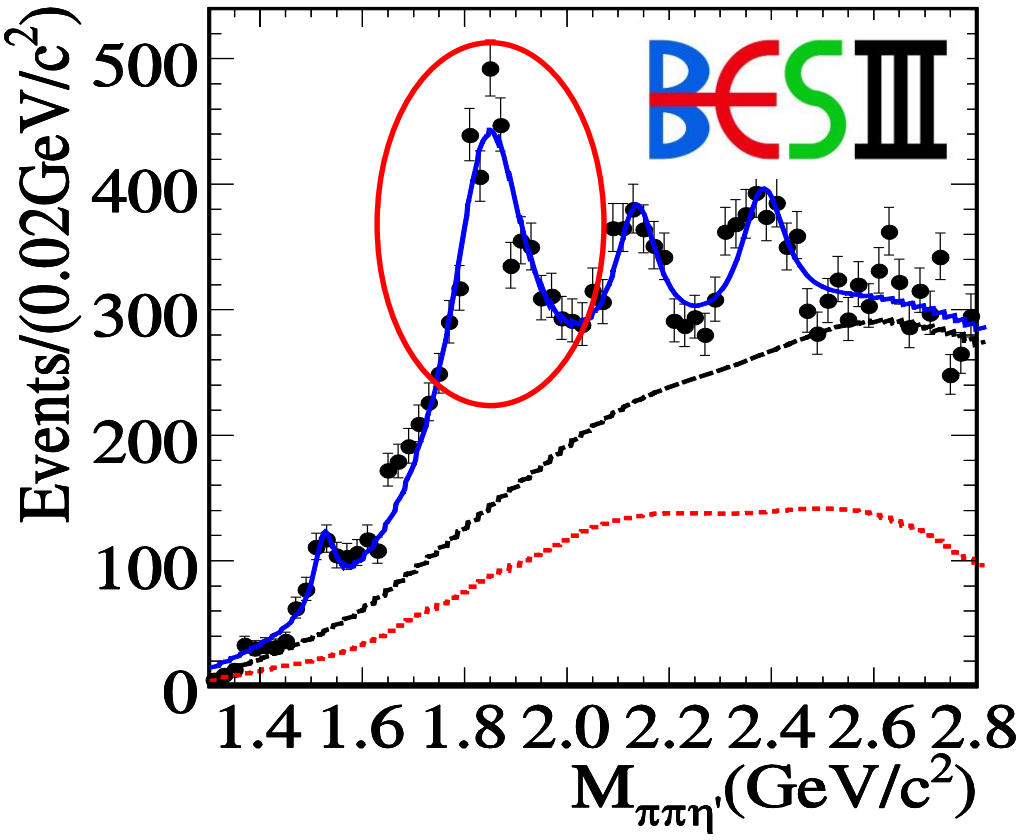


PhysRevD91, 074003 (2015), PRL106, 072002 (2011), PRL108, 112003 (2012).

Near $p\bar{p}$ threshold

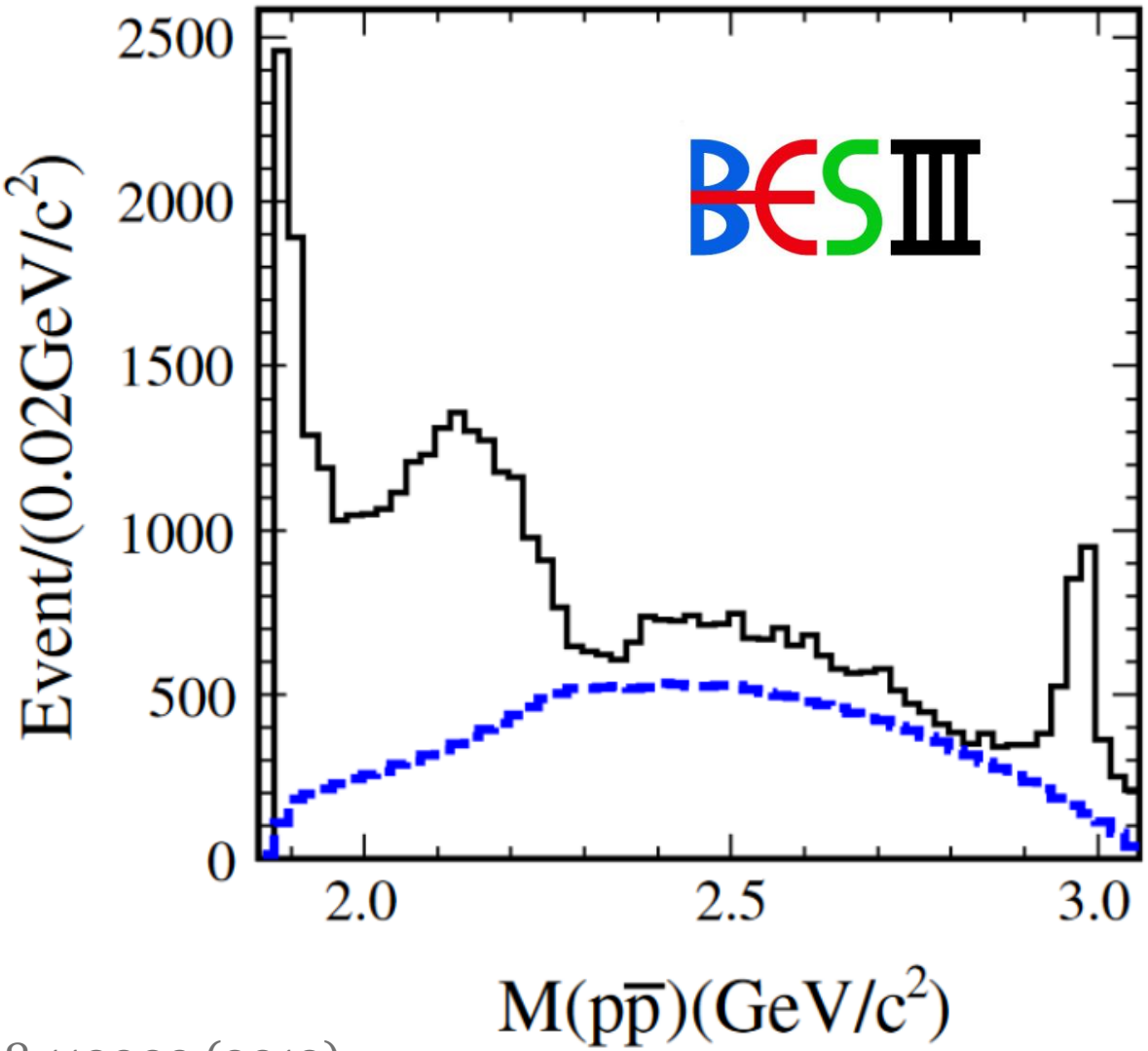
$J/\psi \to \gamma\pi^+\pi^-\eta'$

$X(p\bar{p})$?



PRL106, 072002, 2011

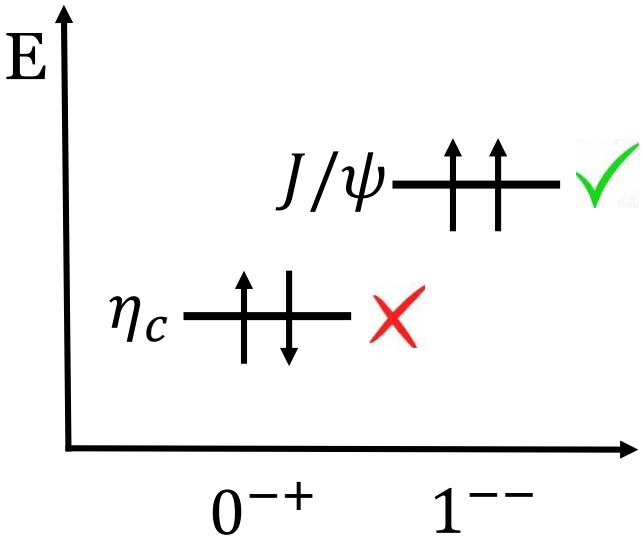
$J/\psi \rightarrow \gamma p\bar{p}$



PRL108,112003 (2012)

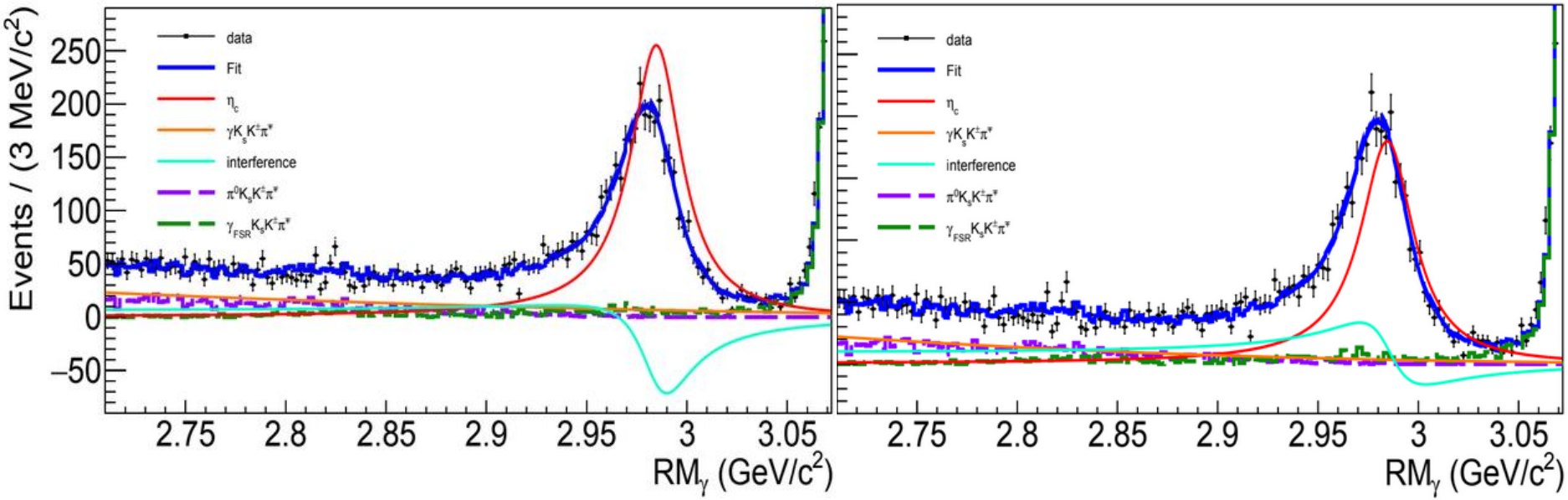
η_c

- Non-exotic (presumably)
- Groundstate of charmonium ($J/\psi, \psi', \dots$)
- Not fully understood yet
- Find hyperfine splitting
- Radiative transition:
  ideal probe to study wave function



QM interference of η_c

$J/\psi \rightarrow \gamma\eta_c$



Line shape not well understood: not a simple Breit Wigner! What else?

Zahra Haddadi (2017): A study of the ground-state properties of charmonium via radiative transitions in $\psi' \rightarrow \gamma\eta_c$ and $J/\psi \rightarrow \gamma\eta_c$.

My ultimate goals

1. PWA over η_c range
2. PWA over low E range, include $N\bar{N}$ FSI
3. PWA over full $p\bar{p}$ range

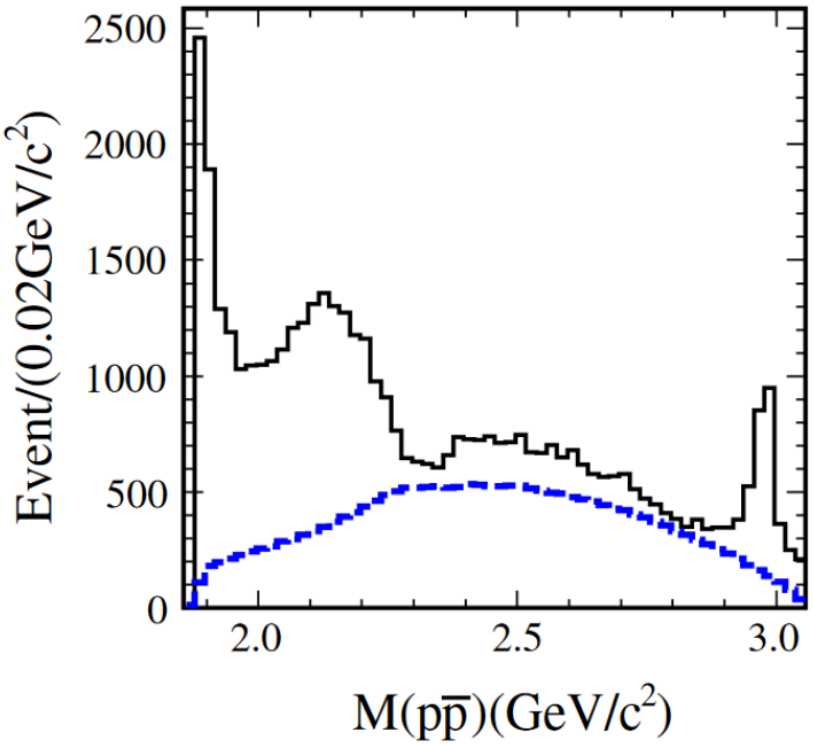


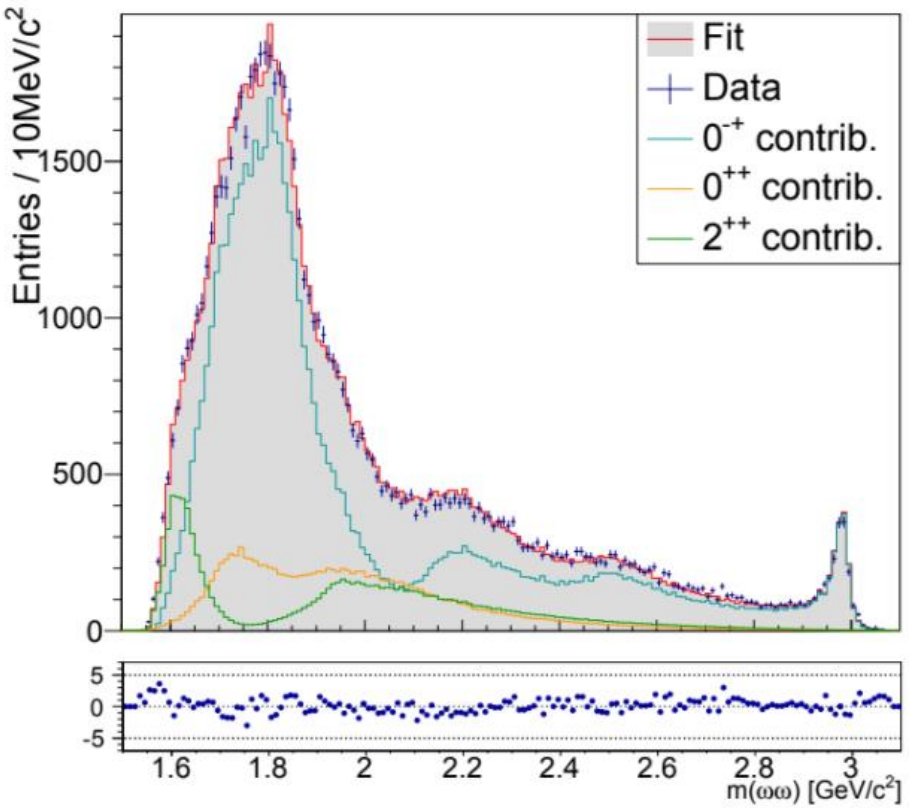
Fig.: PRL108,112003 (2012)
FSI: PhysRevC86(4), 044003 (2012); PhysRevC87(5), 054005 (2013)

Partial Wave Analysis (PWA)

- More model independent
- Describes all dimensions of phasespace
- Allows for interference between components
- Includes physical constraints (LS etc) and mathematical constraints (unitarity etc)

- Find all basic properties: mass, width, spin, parity
- PAWIAN: K-matrix, coupled channels, …

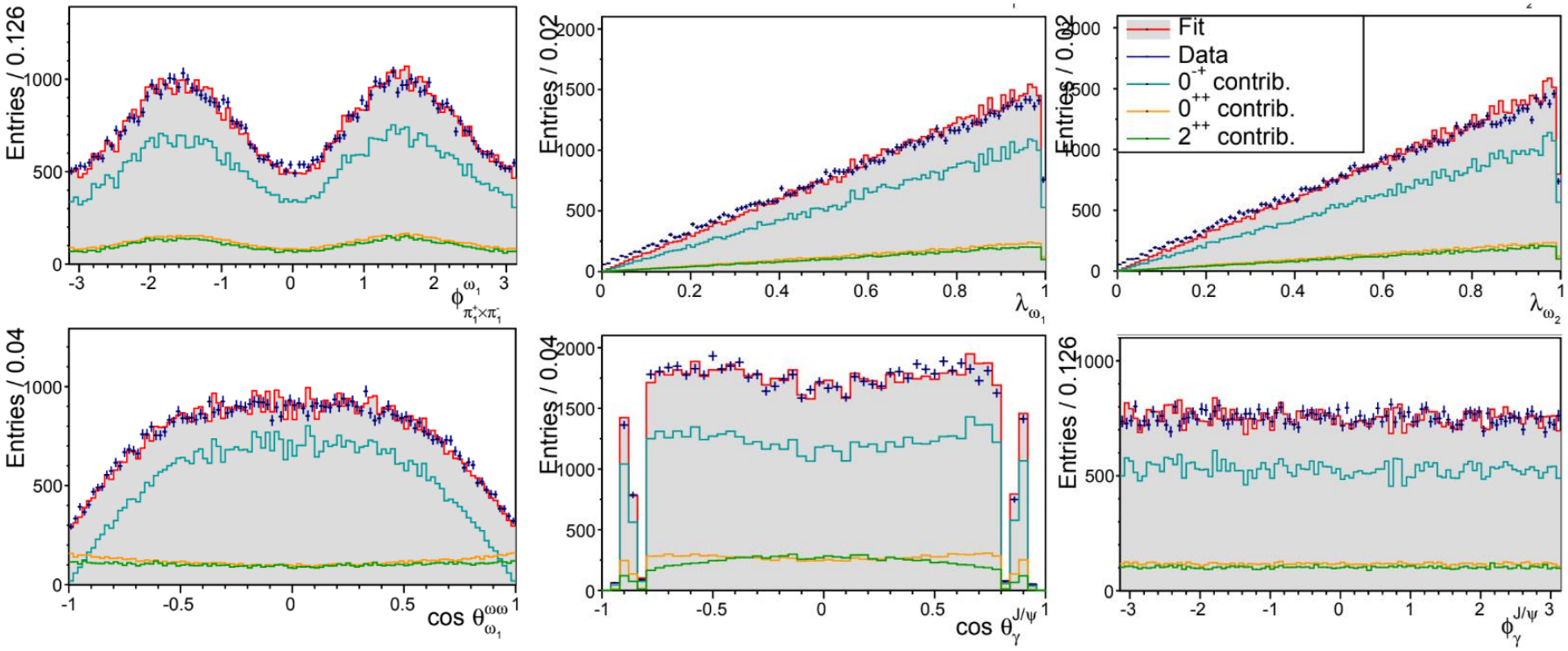
PWA: PAWIAN



Component	Contribution [%]
0^{-+} contrib.	70.3 ± 0.4
0^{++} contrib.	15.2 ± 0.5
2^{++} contrib.	13.9 ± 0.6
Sum	$\mathbf{99.5 \pm 0.5}$

Albrecht, M. (2016). Partial Wave Analysis of the Decay $J/\psi \to \gamma\omega\omega$ at BESIII and Developments for the Electromagnetic Calorimeter of the PANDA detector.

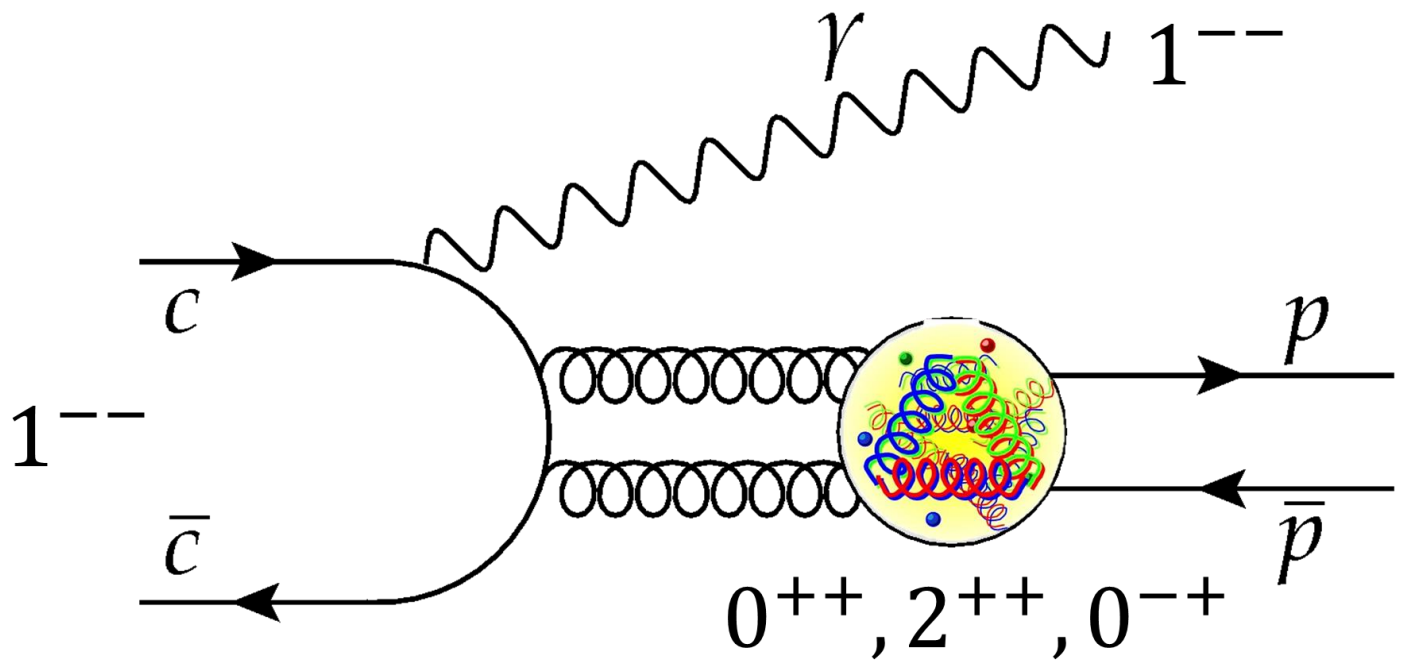
PWA: PAWIAN



Excellent fitting tool for further applications!

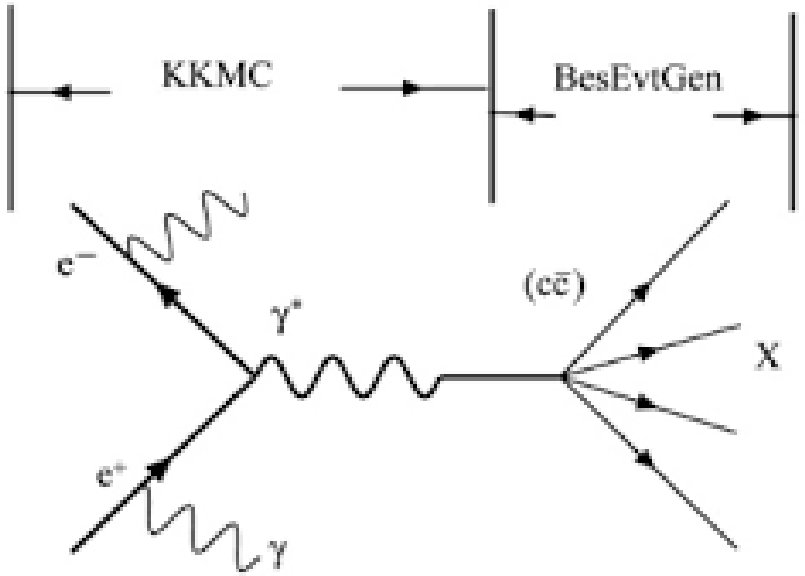
Albrecht, M. (2016). Partial Wave Analysis of the Decay $J/\psi \to \gamma\omega\omega$ at BESIII and Developments for the Electromagnetic Calorimeter of the PANDA detector.

Sensitive channel: $J/\psi \rightarrow \gamma\bar{p}p$



MC analysis

- Includes all known resonances and their decays
- PDG if known, otherwise models
- KKMC & BesEvtGen as generators
- Perfect tool to setup analysis methods and strategies

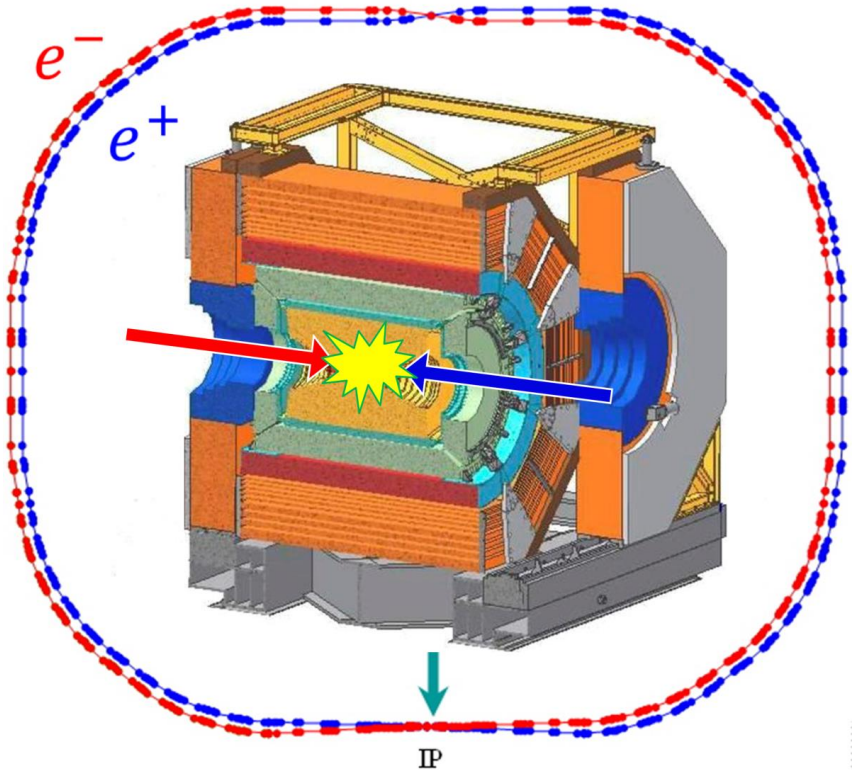


Chin. Phys. C 32 no. 8, (2008) 599.

Data selection

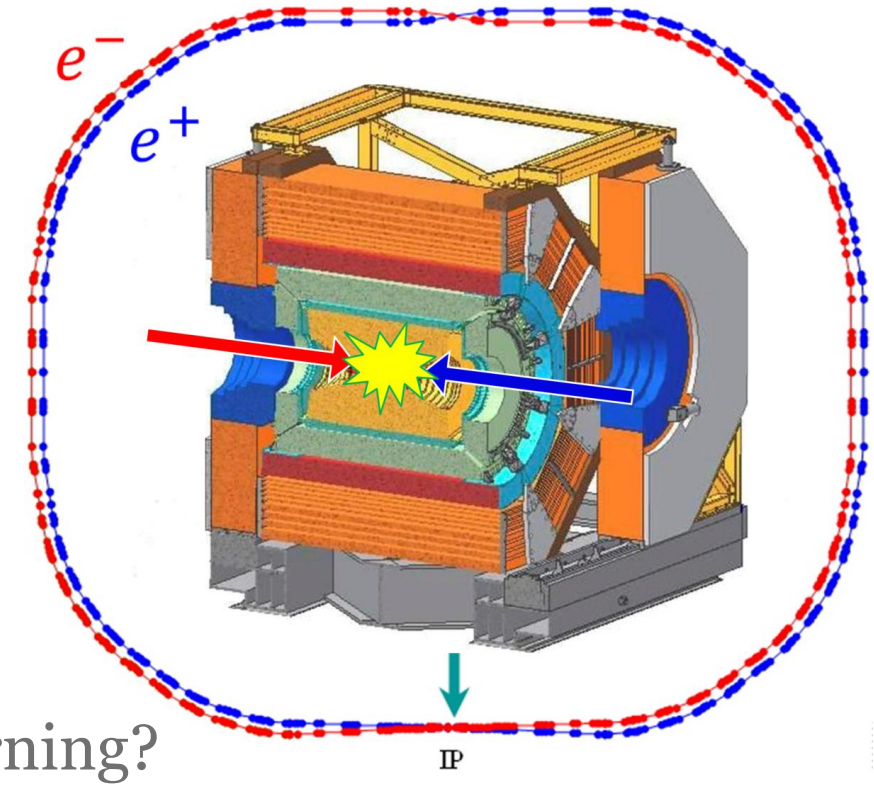
- Distance between IP and vertex:
  - Along beam < 10 cm
  - Tranverse < 1 cm
- $|\cos\theta| < 0.93$

- 2 charged tracks (+ and -)
- $N_\gamma \geq 1$
- Best χ^2 of 4C-fit



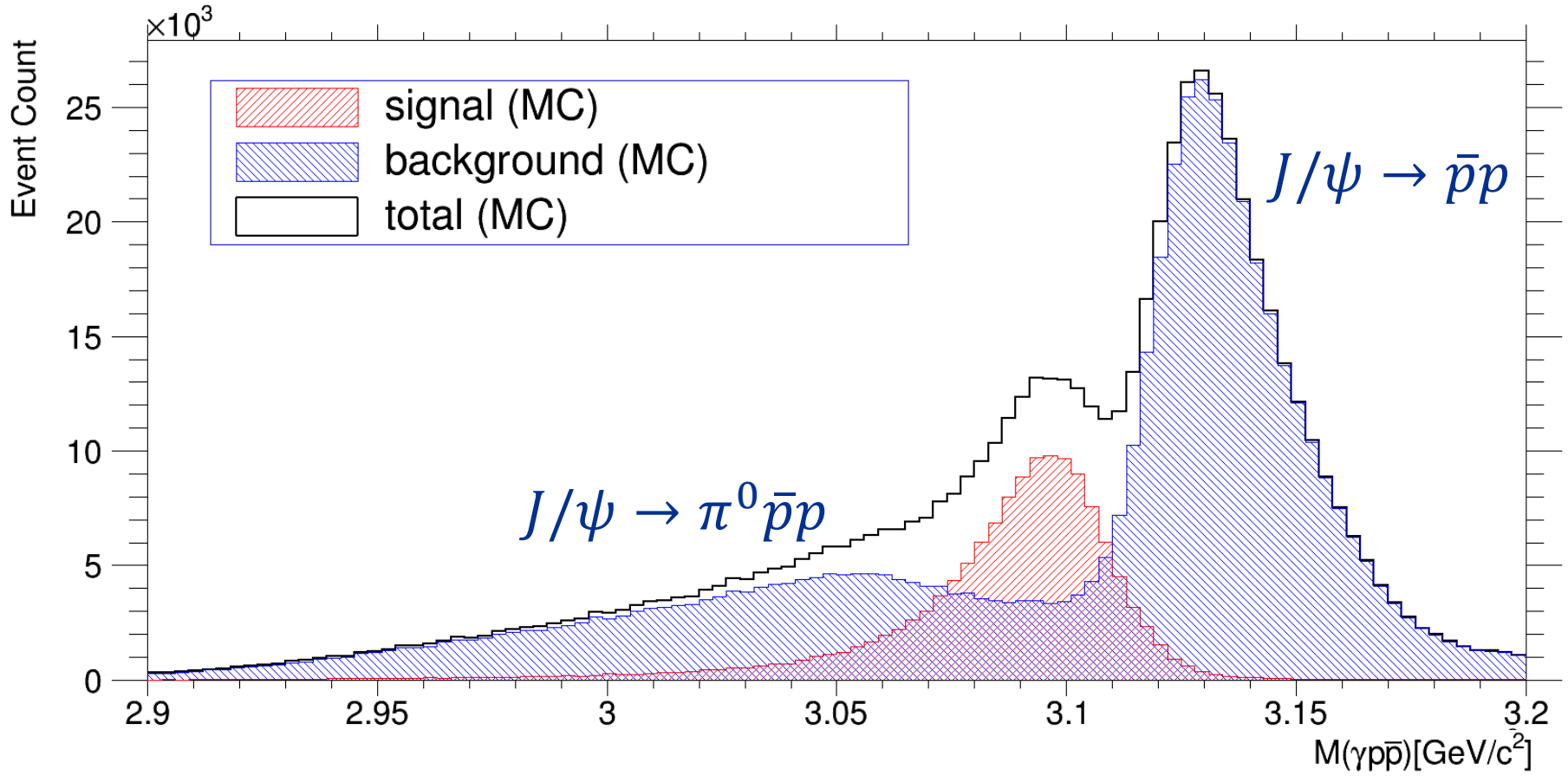
Data selection

- $PID_p > PID_K$
- $E_\gamma > 50$ MeV
- $\chi^2_{4C} < 17$

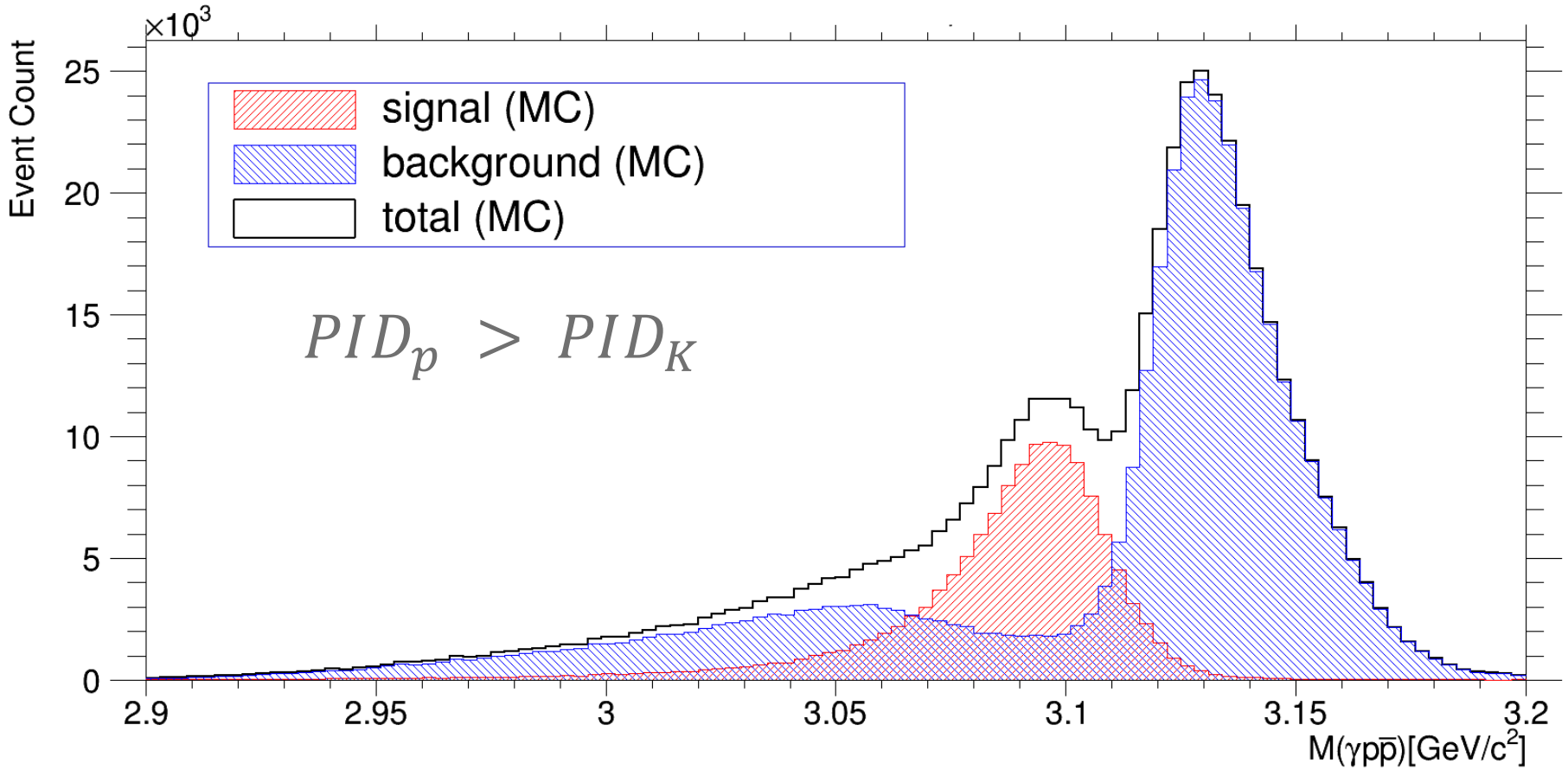


- Evaluate with machine learning?

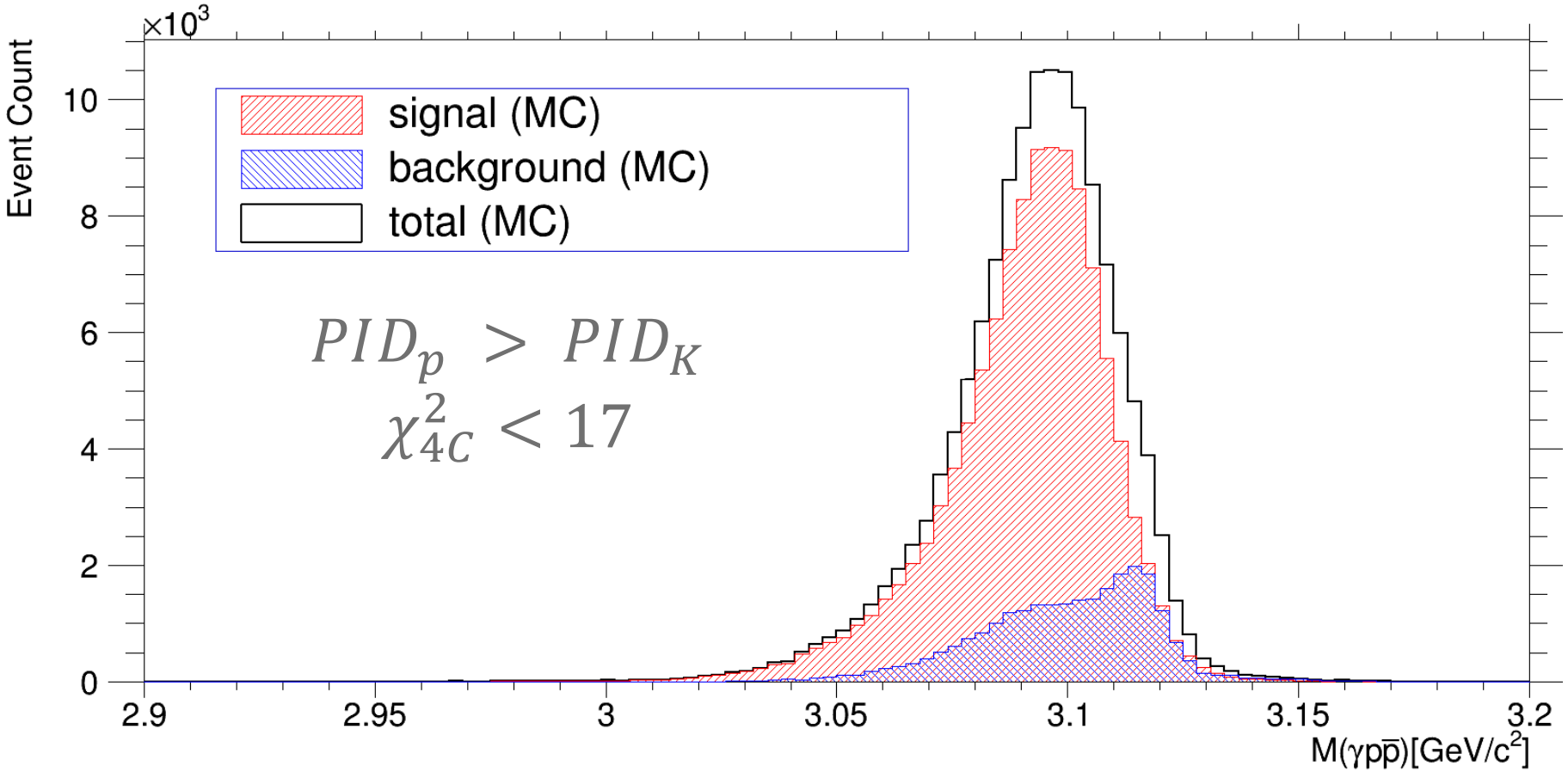
Data selection



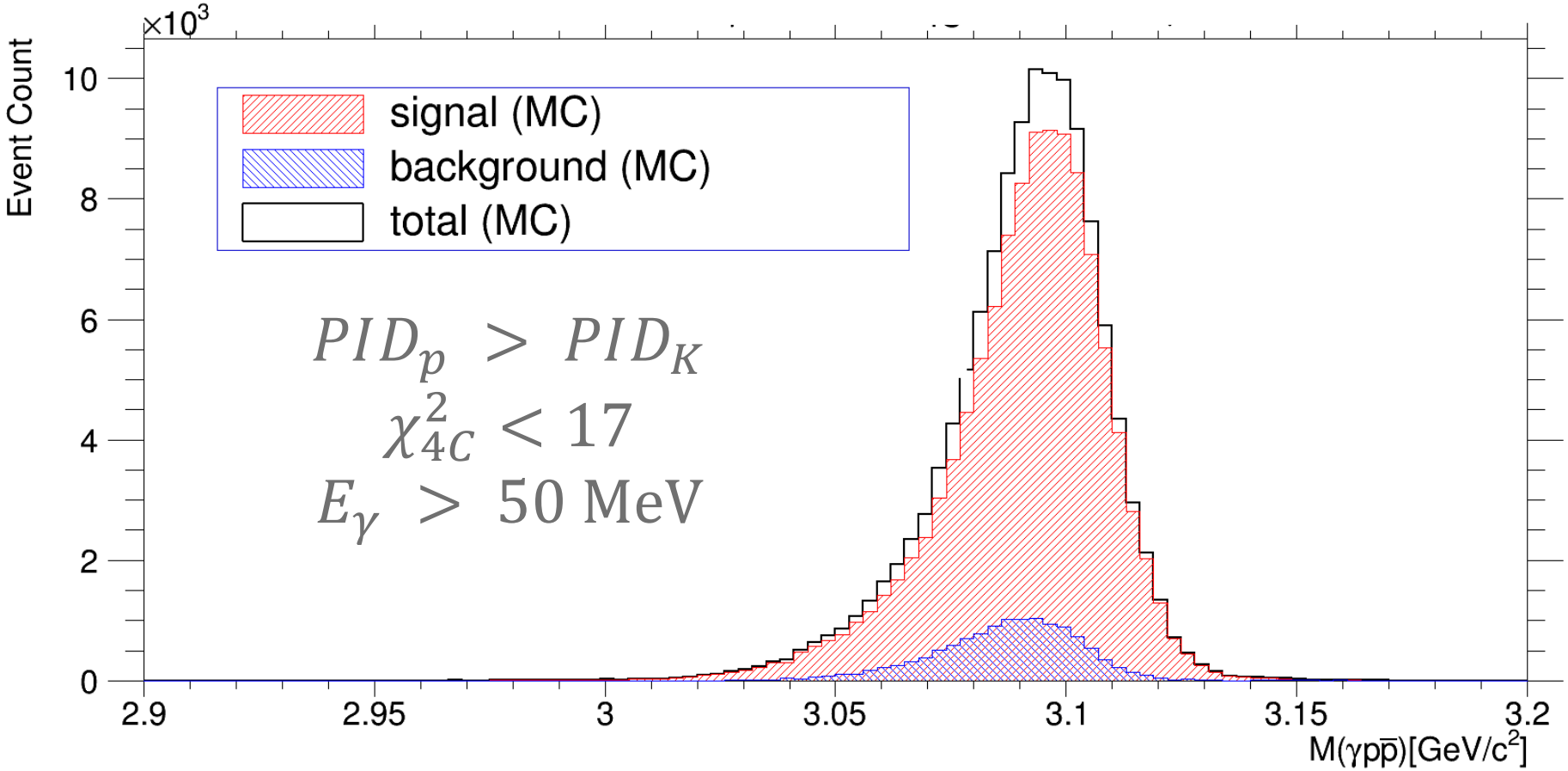
Data selection



Data selection



Data selection



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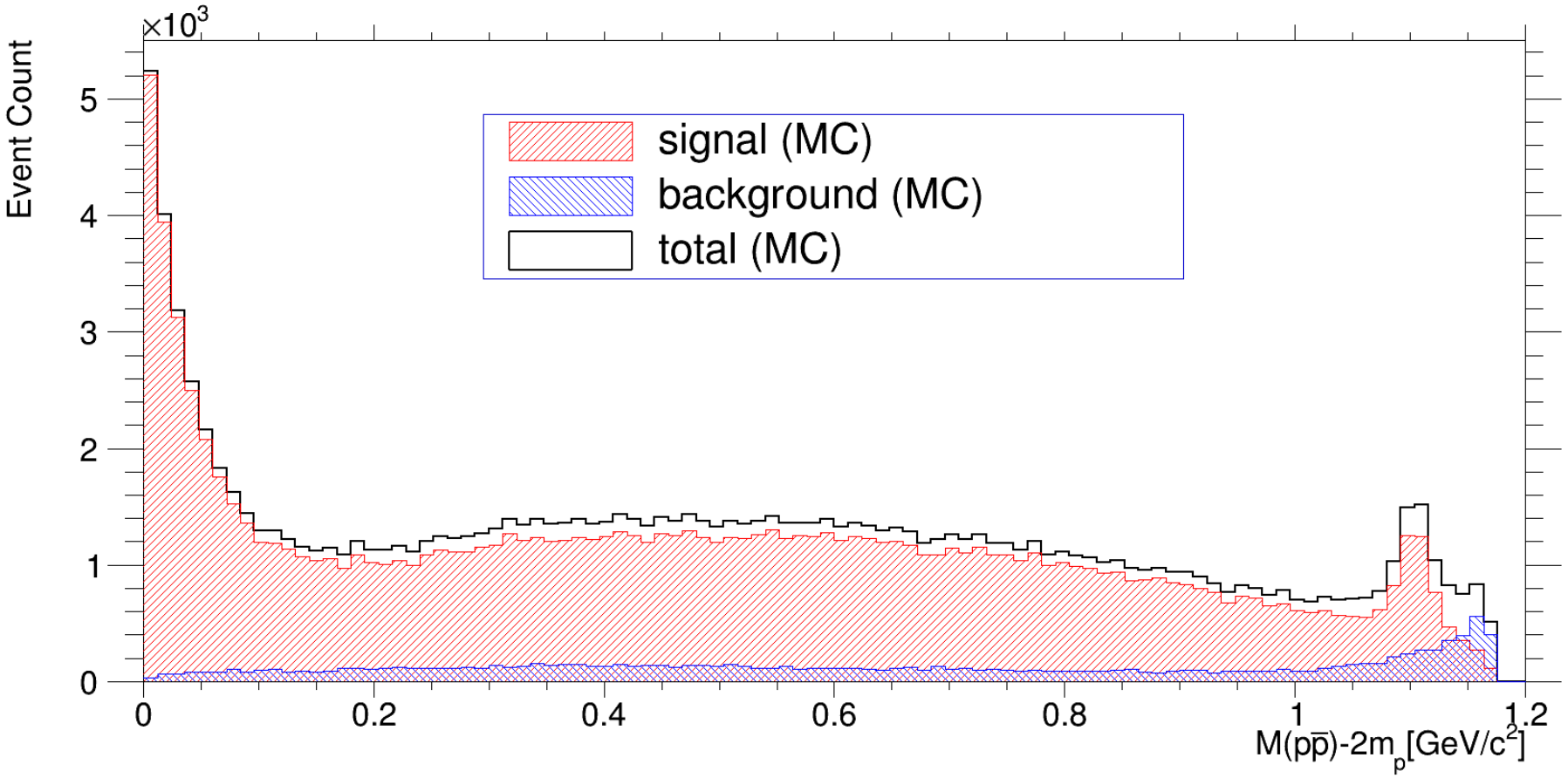


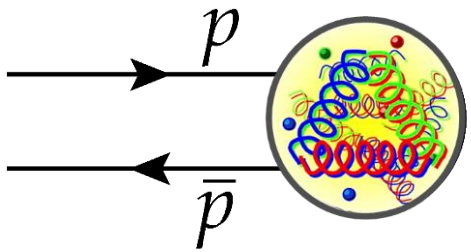
? = glueball: Phys.Lett. B642 (2006) 53-61 & Phys.Lett. B633 (2006) 283-288

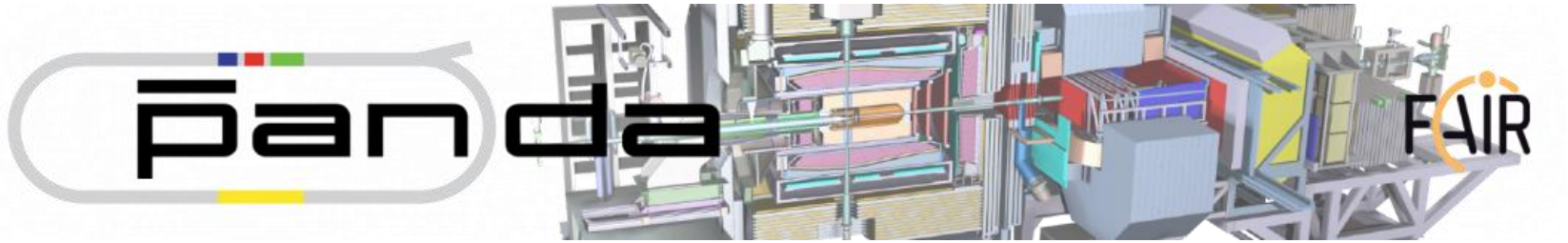
Summary&outlook

- Glueballs are worthwhile studying
- $J/\psi \to \gamma X$ ideal channel for glueball studies
- BESIII is the best place to do such research
- $X \to p\bar{p}$ in the past exciting near-threshold enhancement
- $X \to p\bar{p}$ clean channel with high efficiency
- Ultimate goal: carry out full-flashed PWA

FAIR: PANDA

› Resonance scan with $p\bar{p}$ in the initial state!





Thank you for your attention

Why BESIII?

- Worlds largest J/ψ sample (10^{10} per year)
- "glue"factory: $c\bar{c}$ almost always to gluons

Why PANDA?

- Higher mass accuracy (10 – 100 times)
- Higher interaction rate: 2×10^7 vs 4×10^3 per second
- Direct $q\bar{q}$ collision
- All non-exotic J^{PC} can be directly populated