Amplitude analysis of $\Lambda_b^0 \to J/\psi p \pi^-$

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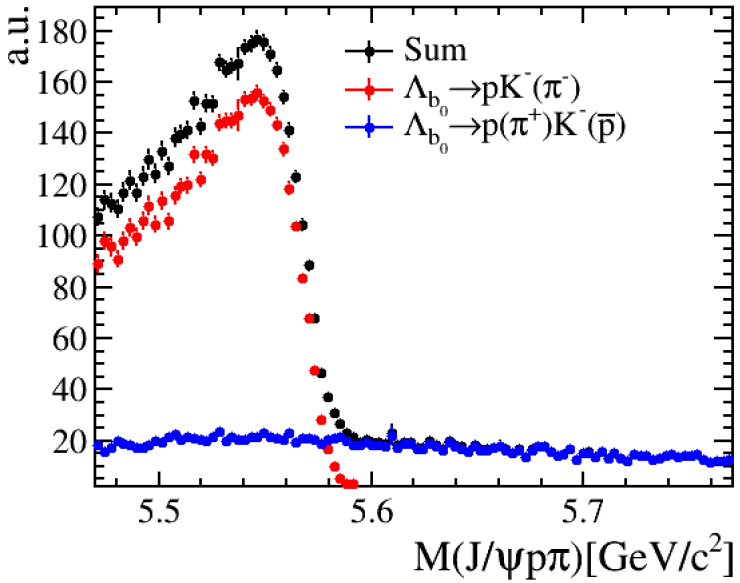
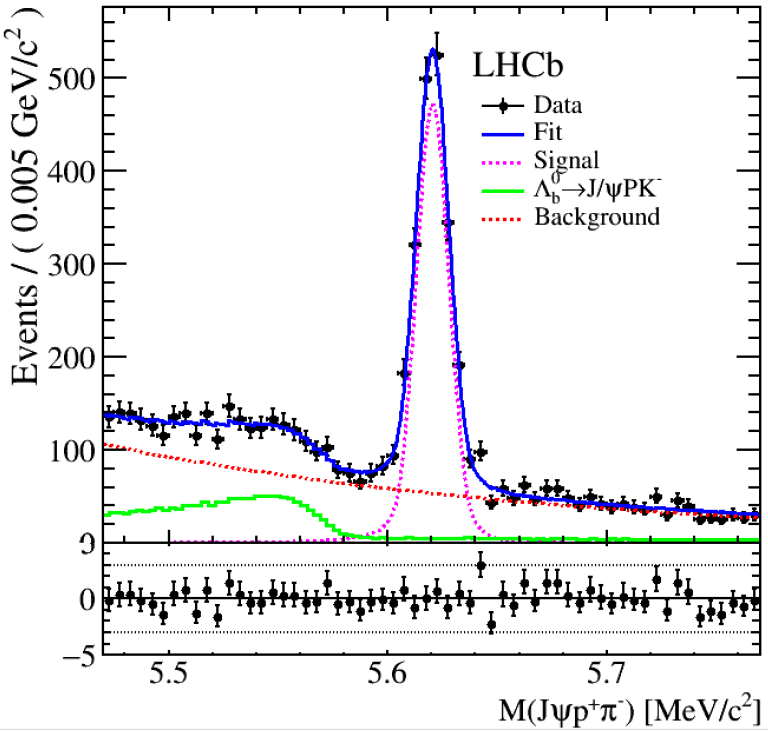
Remider

last presentation

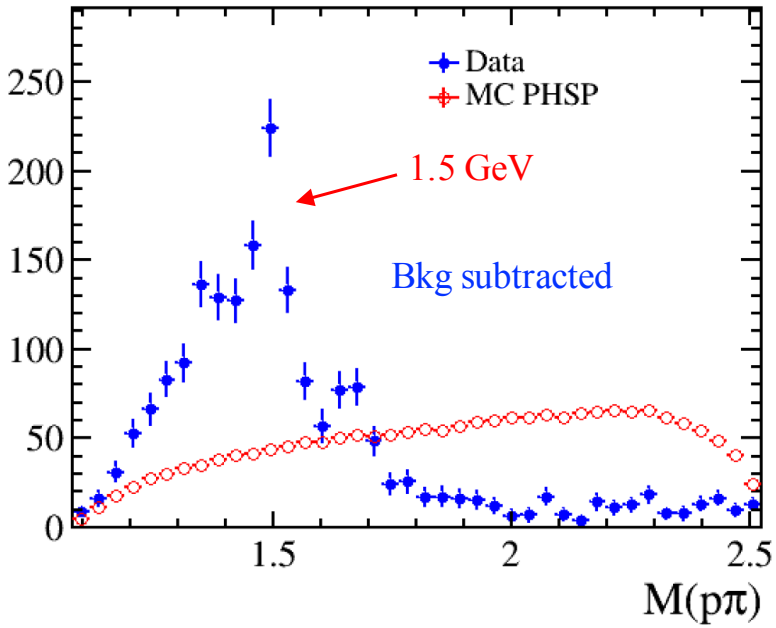
- Analysis of $\Lambda_b^0 \to J/\psi p\pi^-$ performed to study pentaquark states
  - Similar decay topology as $\Lambda_b^0 \to J/\psi pK^-$
- Selections developed to suppress backgrounds
  - BDT implemented
  - Apply PID cut to p and π^- to suppress misID background ($\Lambda_b^0 \to J/\psi pK^-$ single and double misID)
  - Reflections of $B_s^0 \to J/\psi K^+K^-$ and $B^0 \to J/\psi K^+\pi^-$ vetoed
- $\Lambda_b^0 \to J/\psi pK^-$ parameterized in invariant mass fit

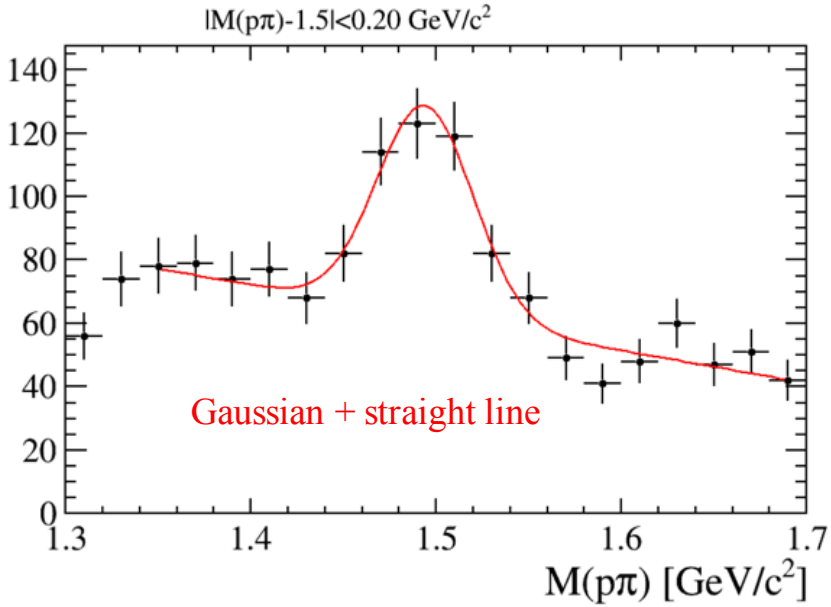




Narrow peak at $M(p\pi^-)\sim 1.5$ GeV

- A narrow peak seen in $p\pi^-$ invariant mass around 1.5 GeV
  - Coarse fit yields ~200 events in peak, $(M, \sigma) \sim (1.5, 0.03)$ GeV





- Nearby N* resonances $N(1520)$ and $N(1535)$ are quite wide, ≥ 0.1 GeV

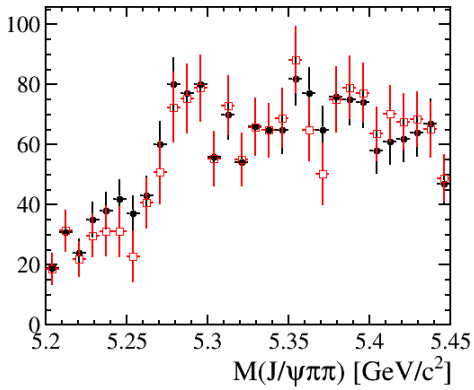
Narrow peak at $M(p\pi^-)\sim 1.5$ GeV

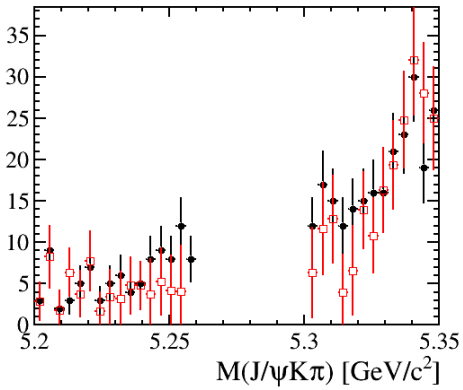
- It is not due to B meson reflections, and misID from $\Lambda_b^0 \to J/\psi p K^-$
- Inclusive $B \to J/\psi X$ samples also investigated, no peaking after selections

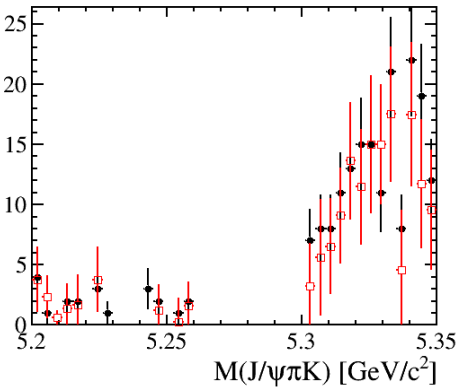
Red: sWeighted data

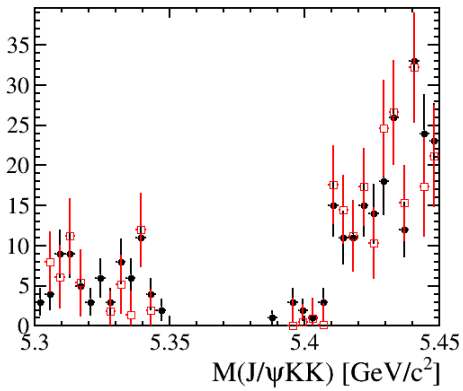
Black: Λ_b^0 signal region

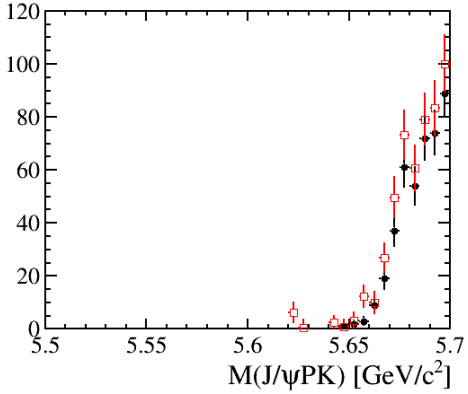
$J/\psi h^+ h^-$ invariant mass distributions with other PID hypothesis

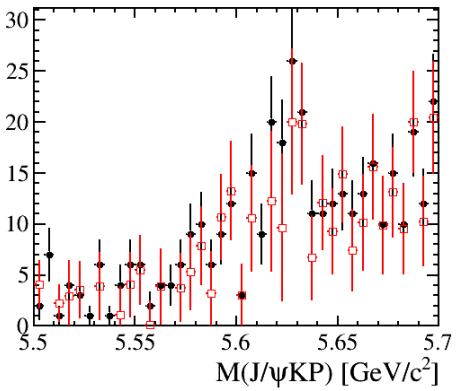










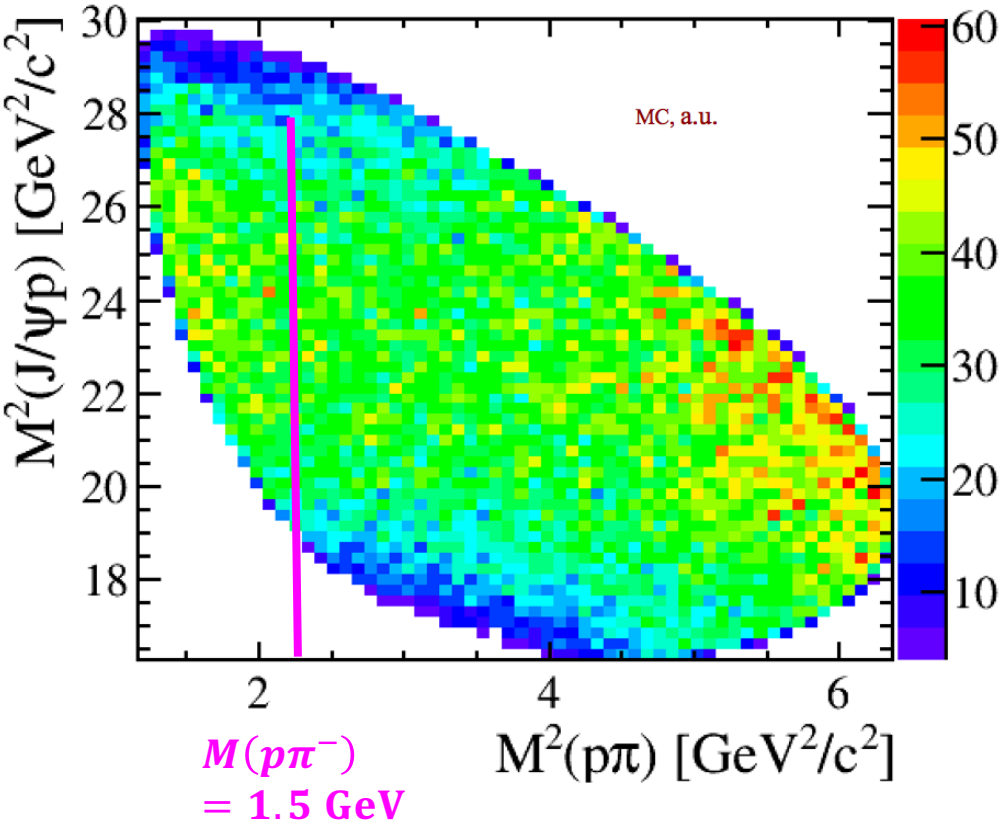


Narrow peak at $M(p\pi^-)\sim 1.5$ GeV

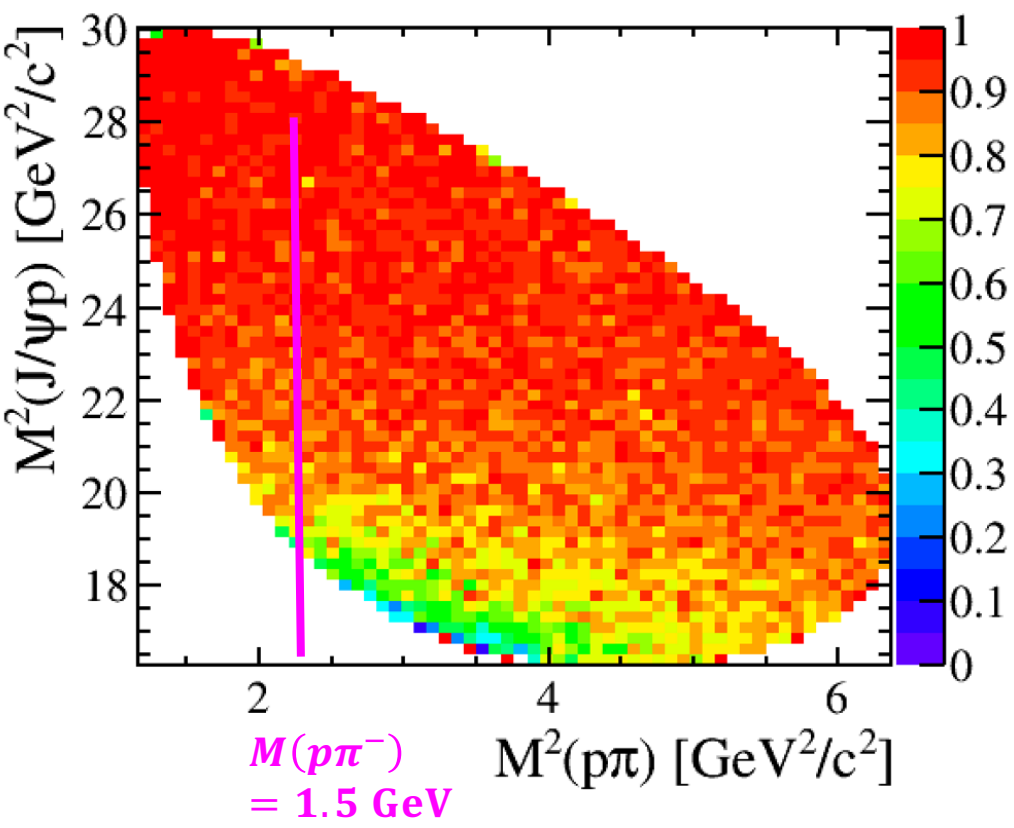
- It is not due to selections and vetoing of reflections

The efficiencies are very smooth

"Total efficiency"

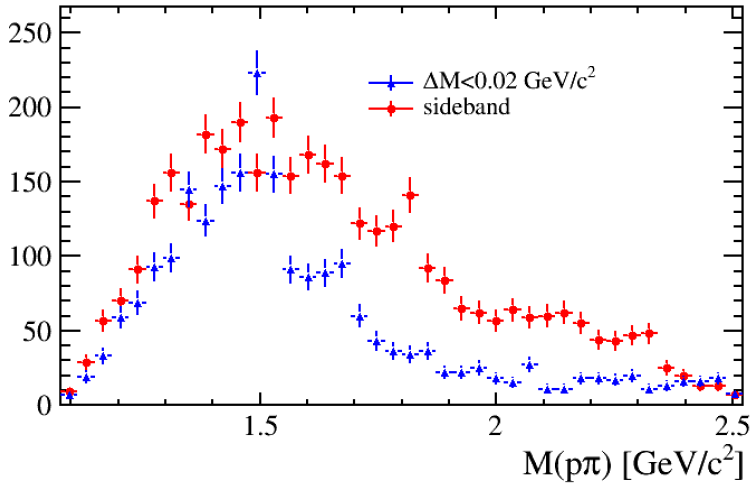


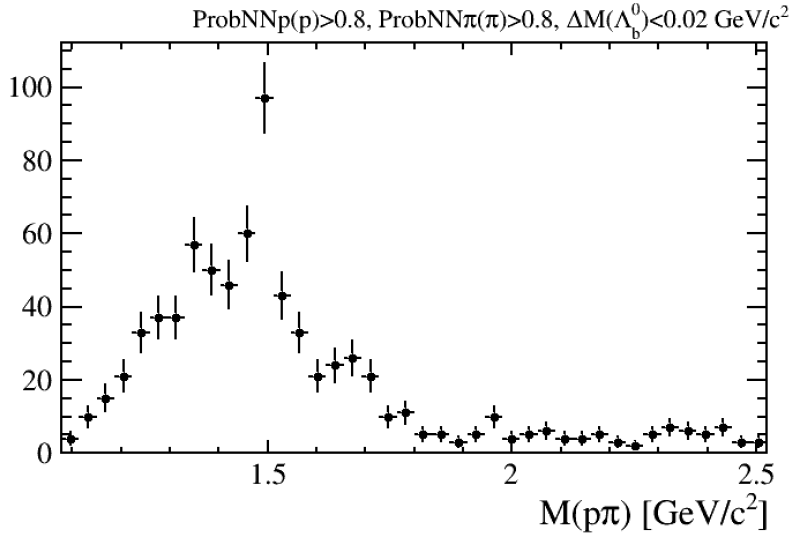
Vetoing efficiency

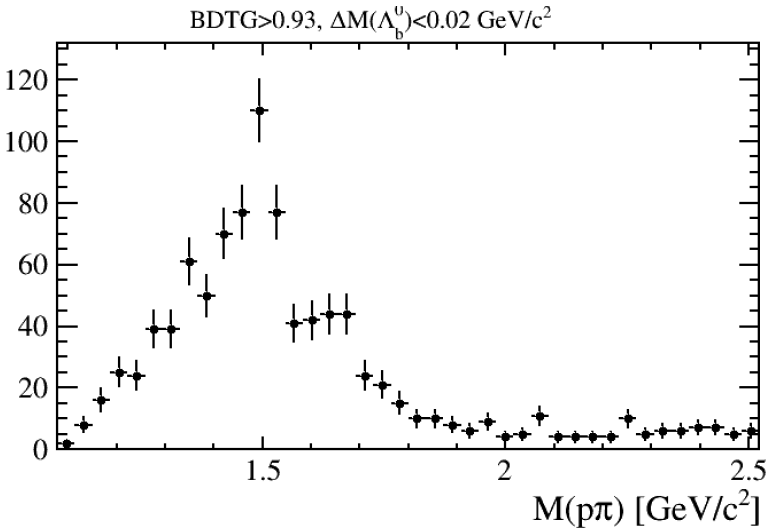


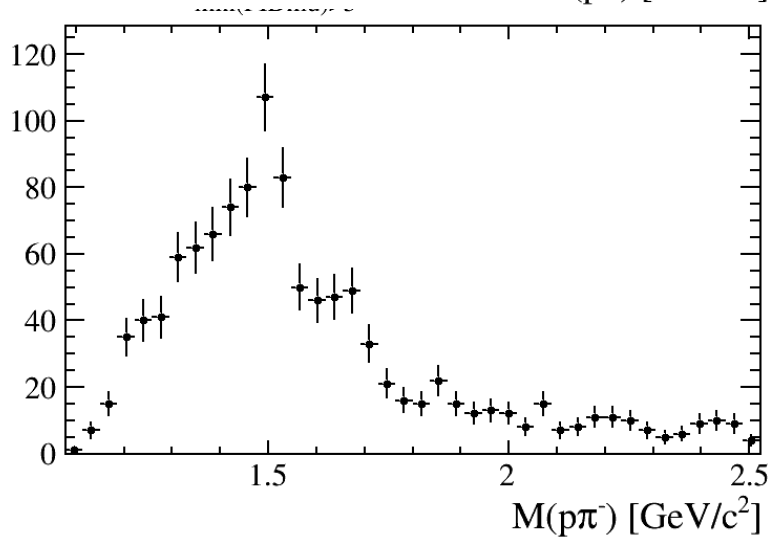
Narrow peak at $M(p\pi^-)\sim 1.5$ GeV

- Not caused by combinatorial backgrounds



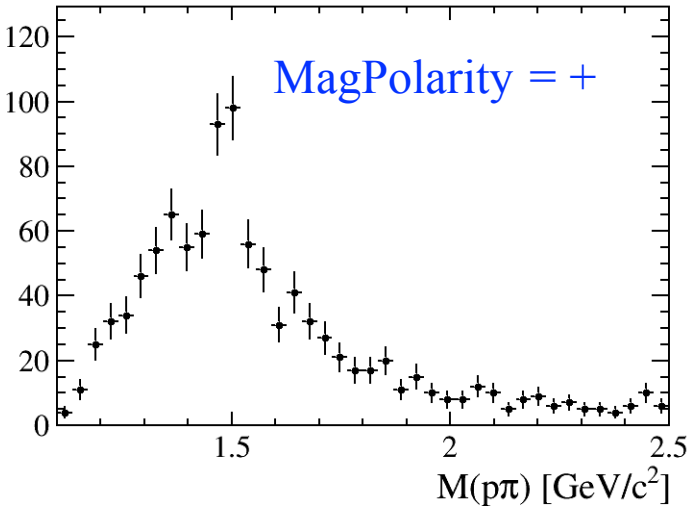


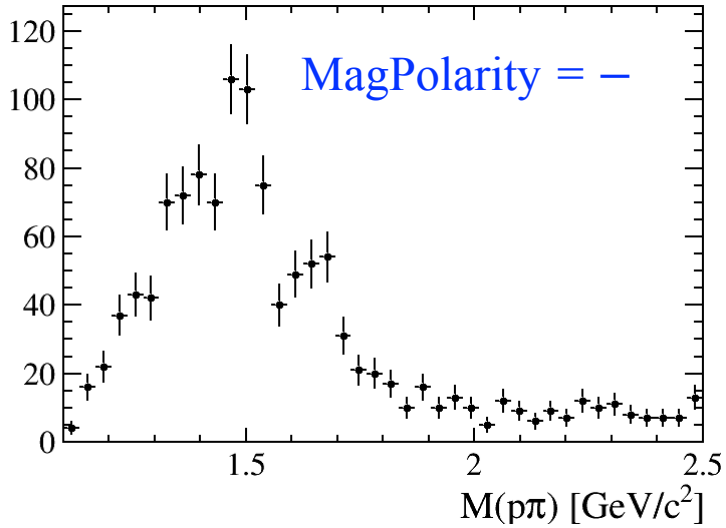


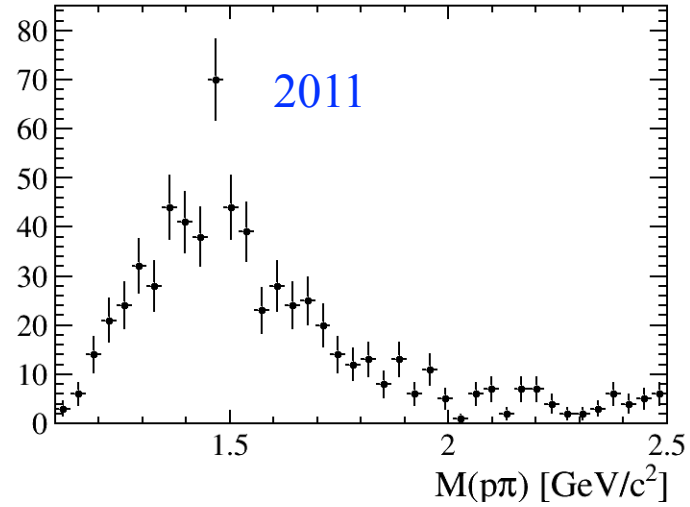


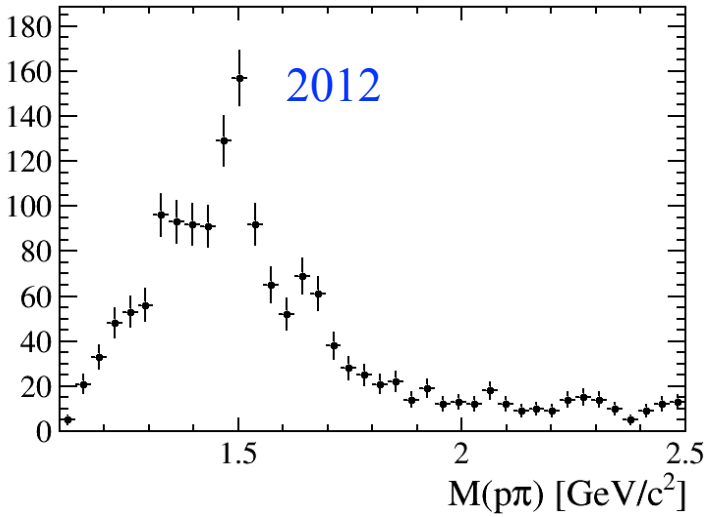
Narrow peak at $M(p\pi^-)\sim 1.5$ GeV

- Peak seen in different dataset



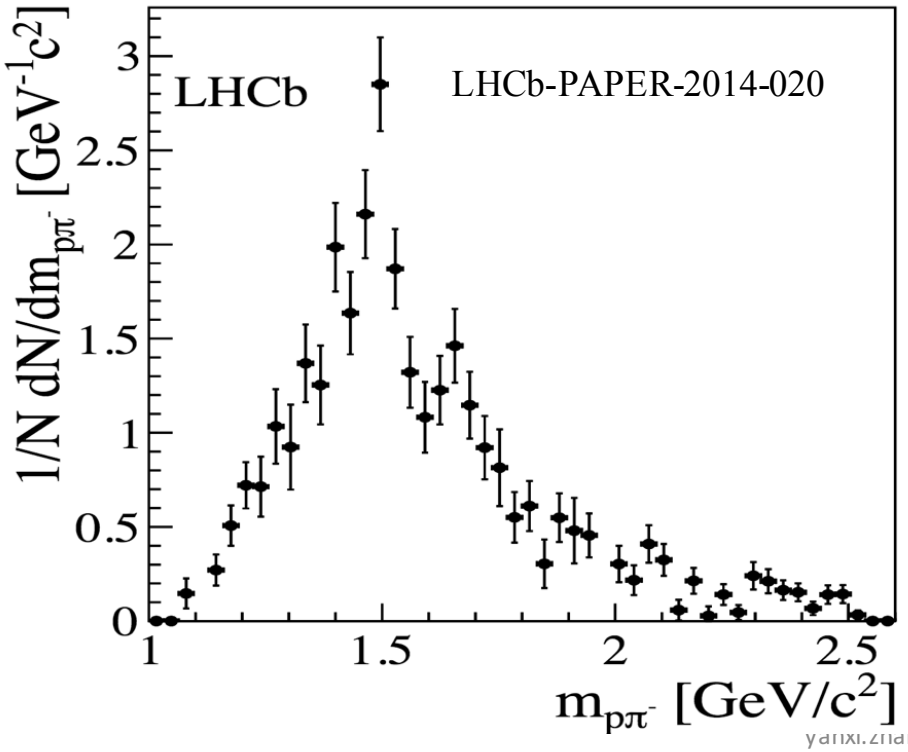




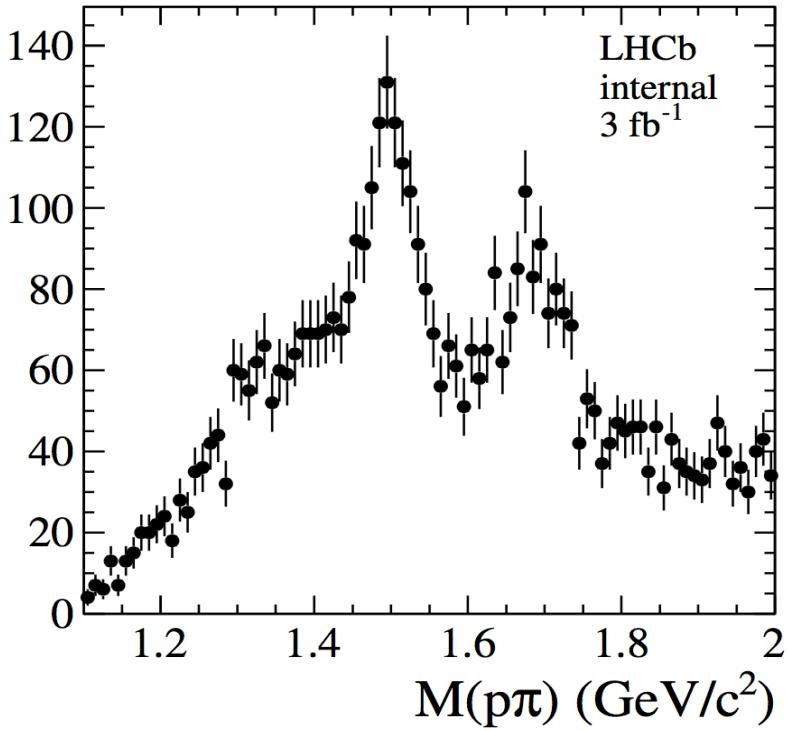


Narrow peak at $M(p\pi^-)\sim 1.5$ GeV

- Other studies include tightening variables in BDT, tightening $p\pi^-$ PID against muons, investigating $(J/\psi, \Lambda_b^0)$ mass constraint effect, the peak survives
- Similar narrow peak seen in dependent analysis, and $\Lambda_b^0 \to D^0 p\pi^-$ decay

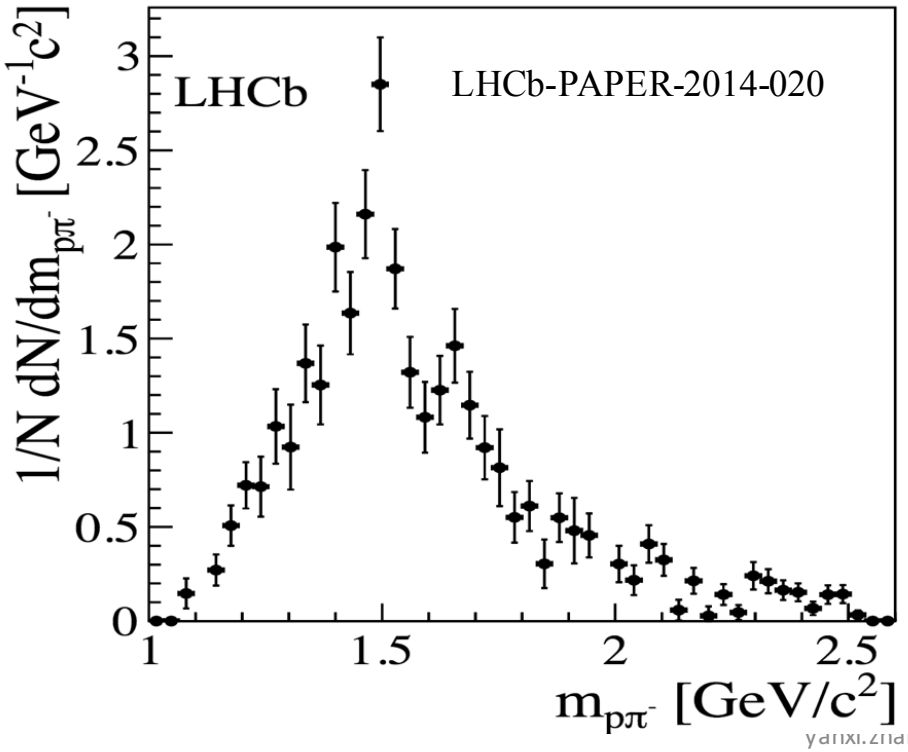


See slides by Anton



Narrow peak at $M(p\pi^-)\sim 1.5$ GeV

- Other studies include tightening variables in BDT, tightening $p\pi^-$ PID against muons, investigating $(J/\psi, \Lambda_b^0)$ mass constraint effect, the peak survives
- Similar narrow peak seen in dependent analysis, and $\Lambda_b^0 \to D^0 p\pi^-$ decay
  - Fit with $N(1520)$ not work well in $\Lambda_b^0 \to D^0 p\pi^-$ decay, too wide for it
- Consider as real Λ_h^0 decays, though not fully understood



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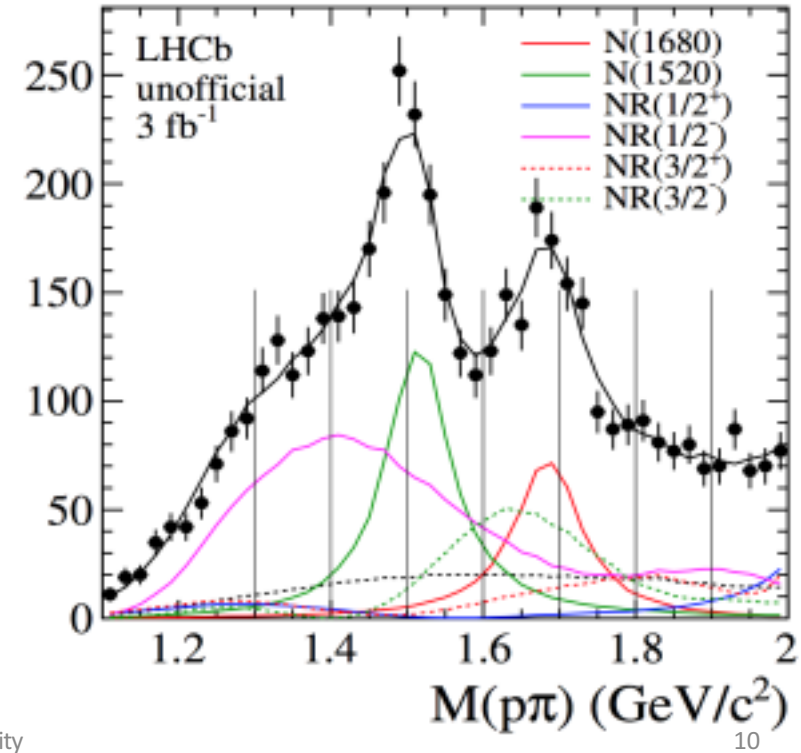
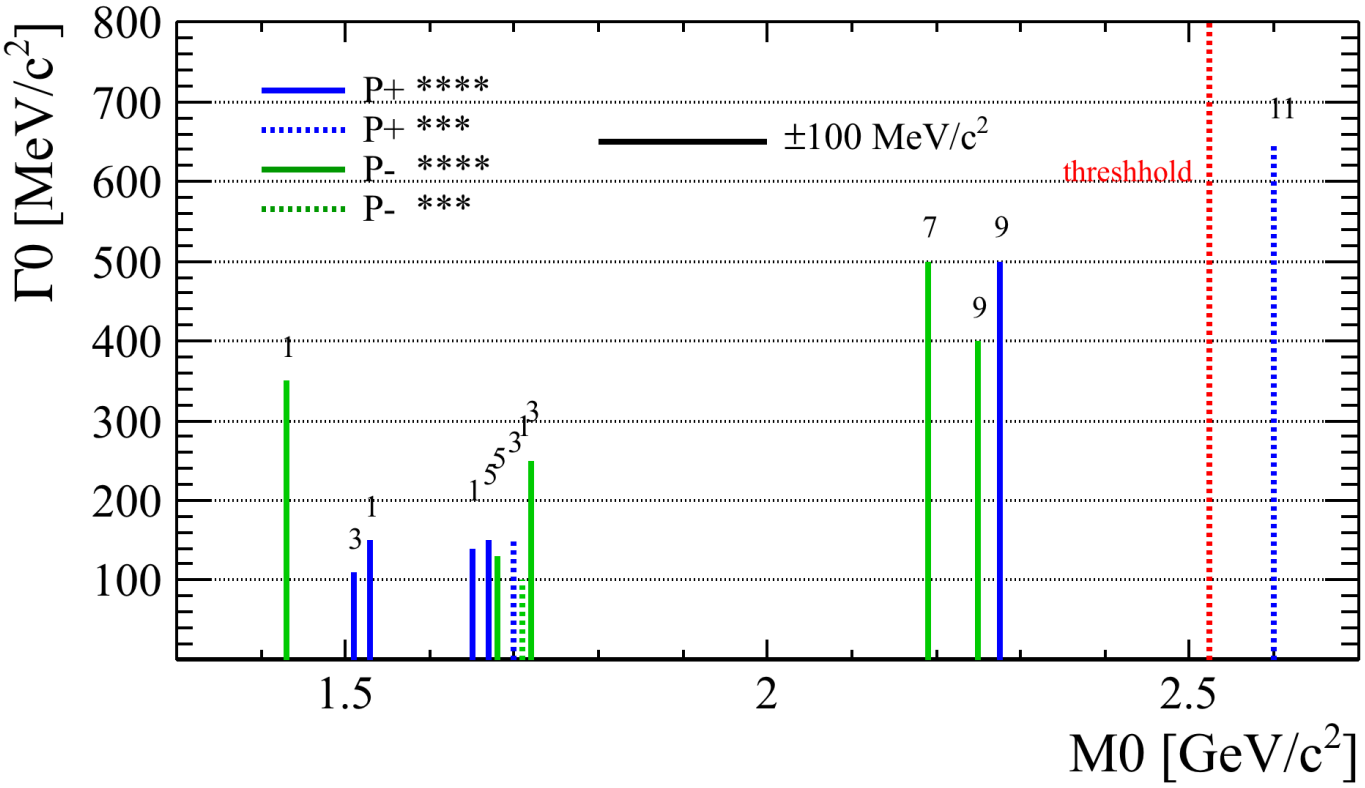


Narrow peak at $M(p\pi^-)\sim 1.5$ GeV

- Consider peak as real Λ_b^0 decays in amplitude fits, though not fully understood
- Initial urpose of this analysis is to check existence of $J/\psi p$ pentaquark in $\Lambda_b^0 \to J/\psi p\pi^-$ decays
  - By comparing the fit quality without/with adding pentaquarks
- The effect of $p\pi^-$ peak at 1.5 GeV needs to be addressed
  - By adding artificial structure here, and check again the significance of $J/\psi p$ pentaquarks under various JP assumption of this structure
- But this structure itself may also deserve more studies later

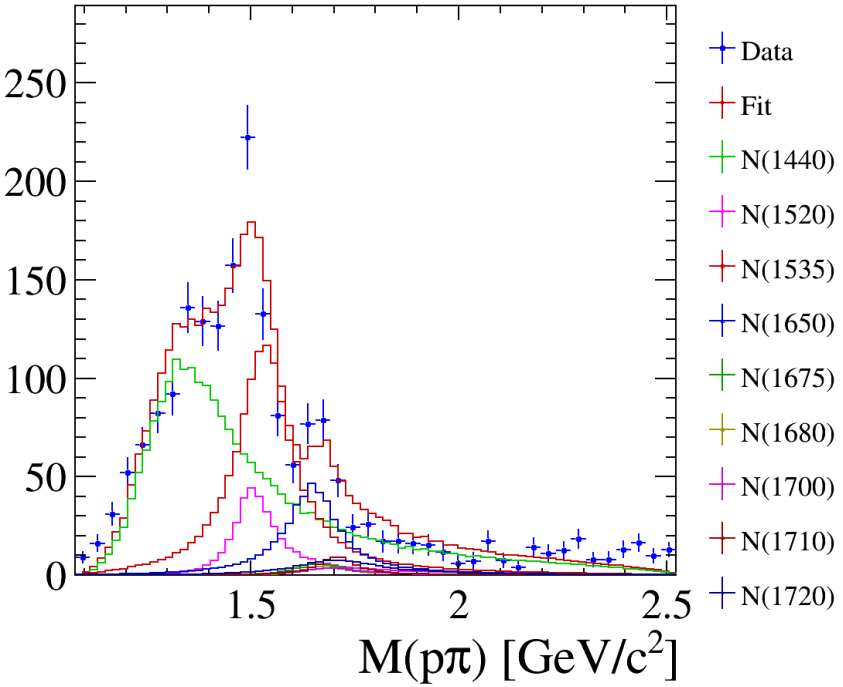
Amplitude with N* resonances

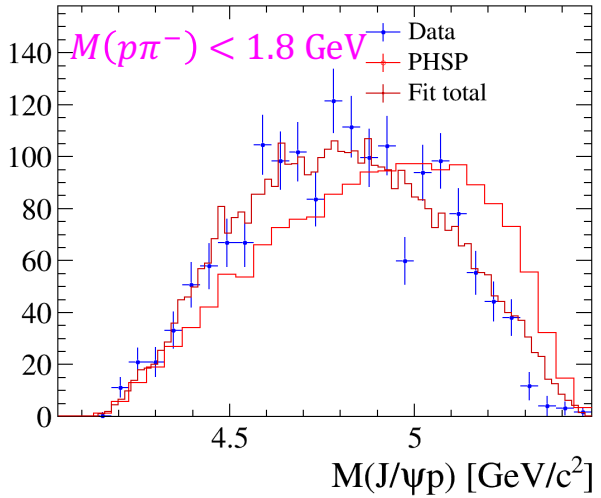
- Λ_b^0 isospin singlet, $\Lambda_b^0 \to J/\psi p\pi^-$ is $b \to c\bar{c}d$ $\Delta I = 1/2$ transition, $p\pi^-$ is isospin 1/2 (dominate?)
- Consider only N* resonances as a first step, $M0, \Gamma 0$ fixed to PDG estimations
- Reduced model: include resonances with $2J \leq 5$, 3 (1) waves for $2J = 1$ (3)

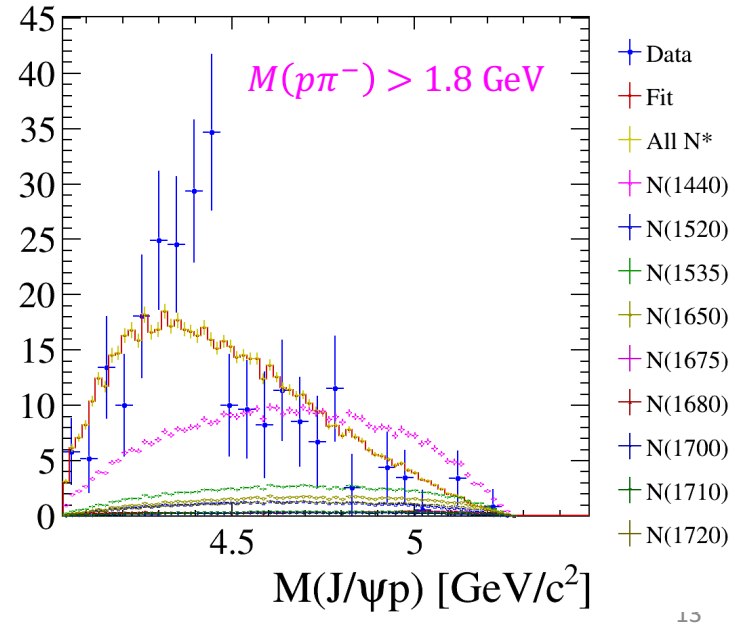


Amplitude with N* resonances

- $M(p\pi^-)$ high mass region, M$(J/\psi p)$ not modeled well
- $N(1520)$ too wide for $p\pi^-$ peak at 1.5 GeV
- Not perfect in $M(p\pi^-) < 1.2$ GeV, due to N(1440)?

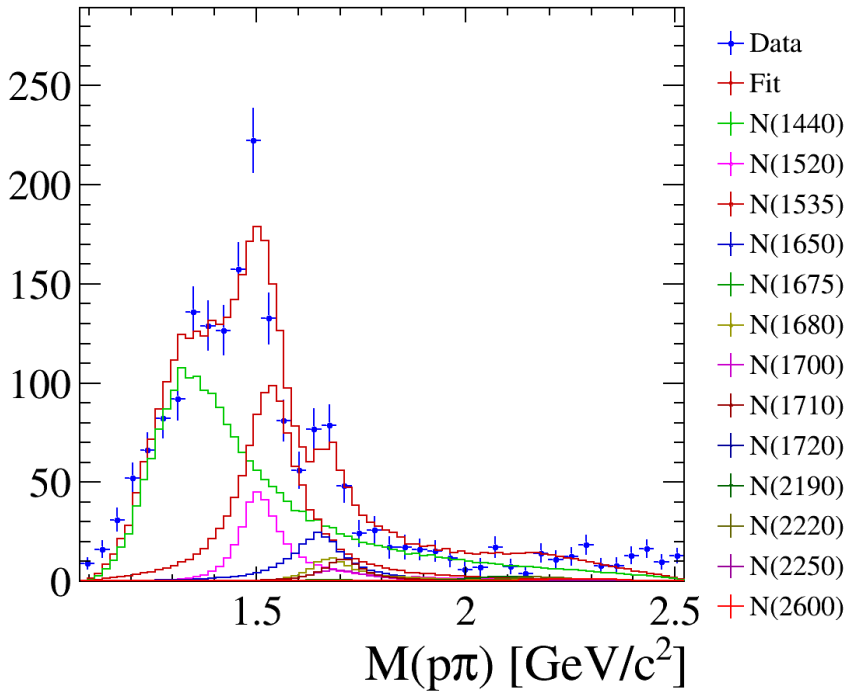


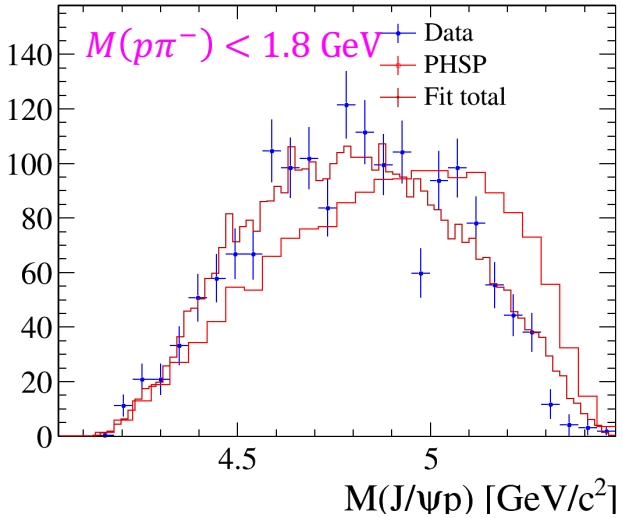


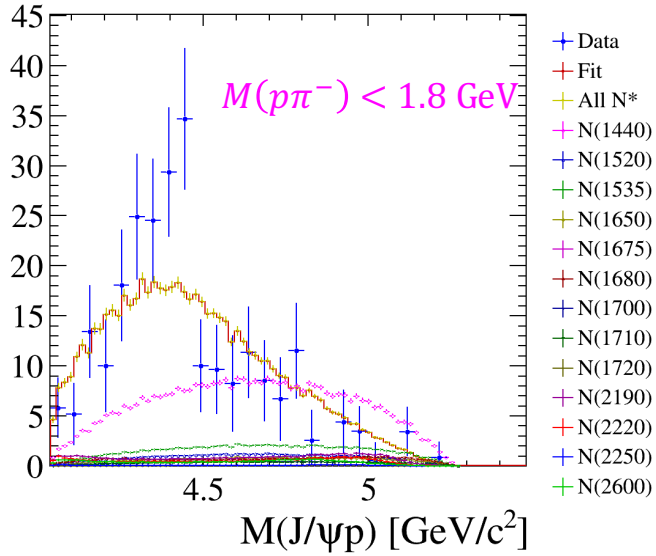


Amplitude with N* resonances

- Adding high spin states not improve too much
  - High mass region of $M(p\pi^-)$ no fitted well
  - M$(J/\psi p)$ not modeled well either



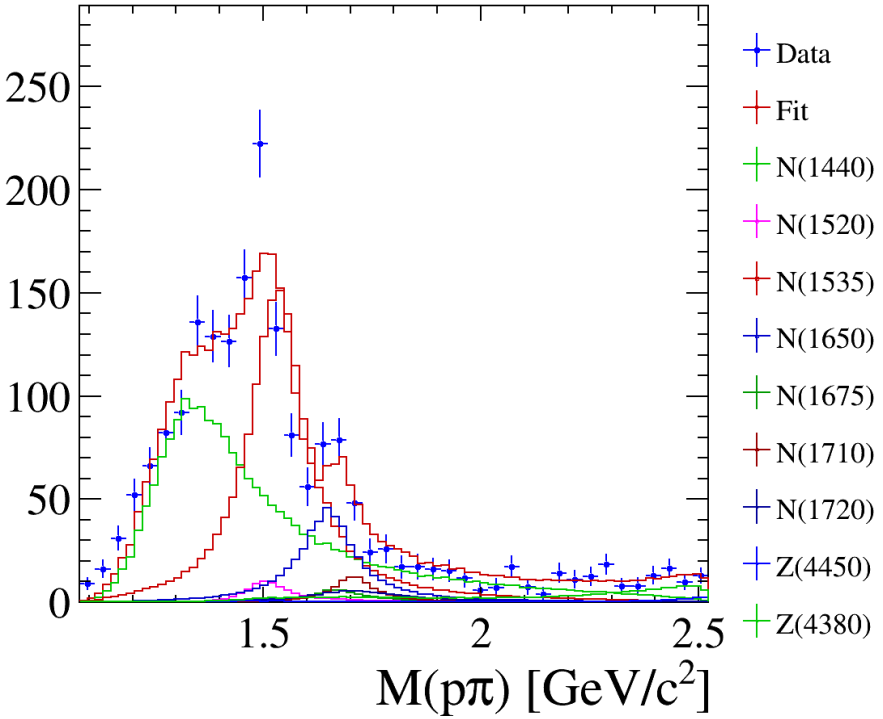


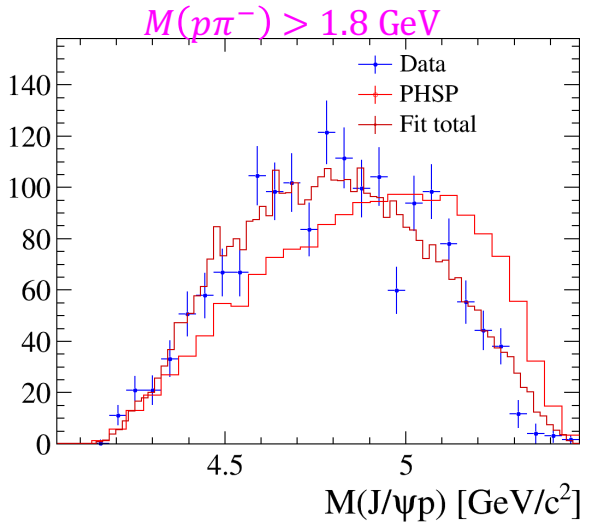


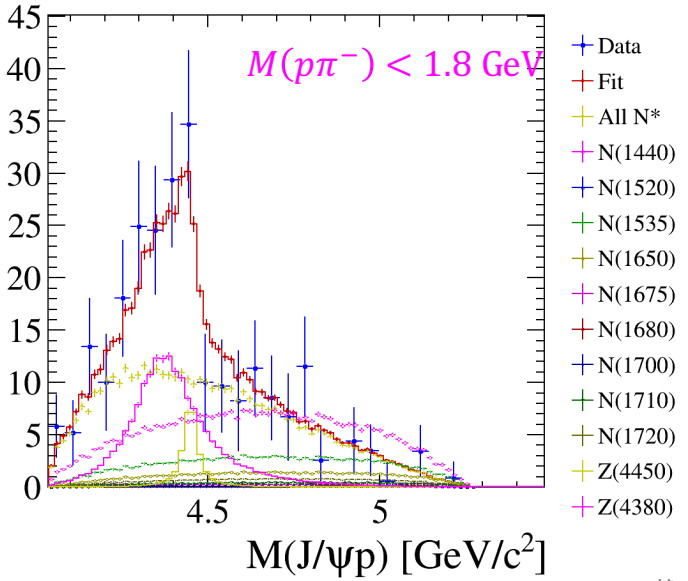
Amplitude with N* + 2Pc

- Floating all parameters of Pc is difficult due to limited statistics
  - Mass&width fixed to LHCb measurements
  - Most preferred JP tested, events not many enough to study the JP (?)
- $M(J/\psi p)$ described much better, although $M(p\pi^-)$ similar

  $\Delta 2LL = +9.2^2$, with 6 more free parameters





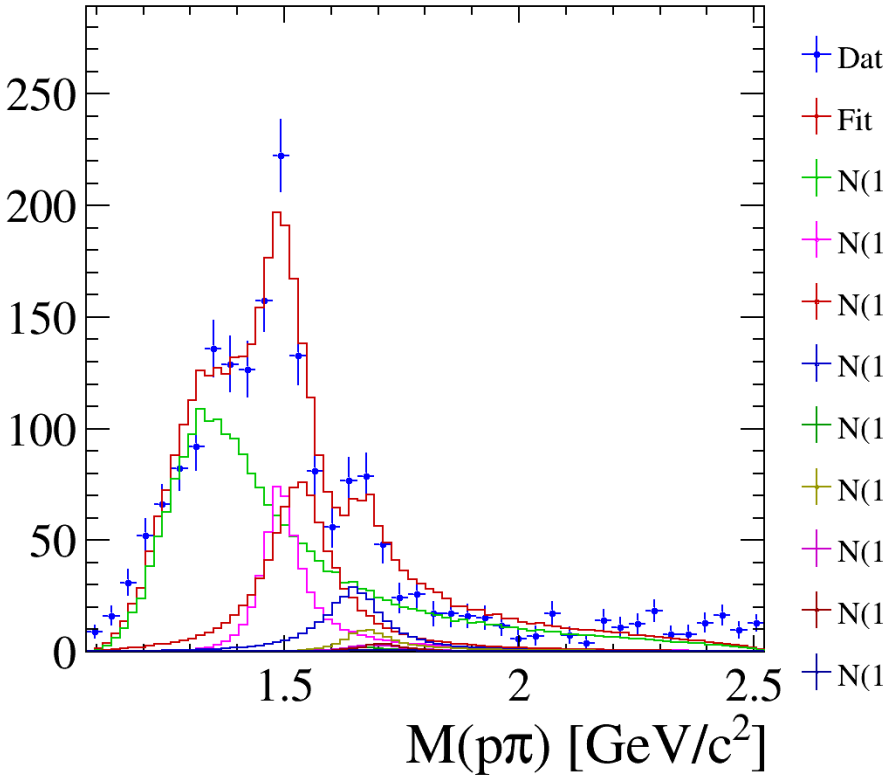


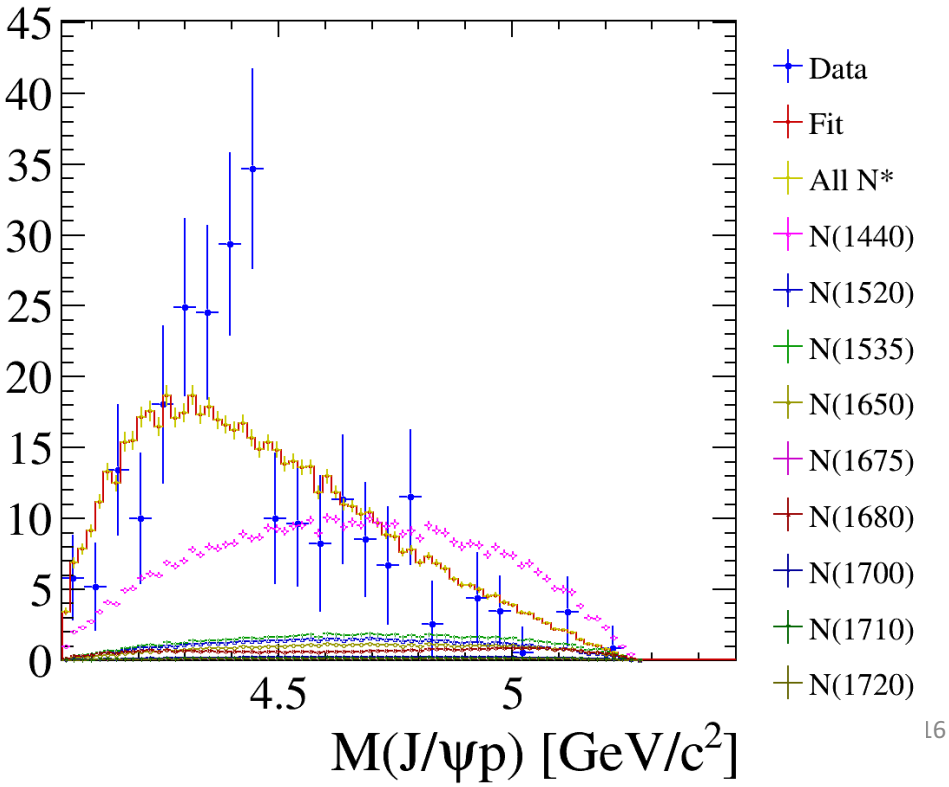
Fit with N* + Float N(1520)

- First solution to $M(p\pi^-)$ at 1.5 GeV: to float N(1520) mass and width
- Improvement in $M(p\pi^-)$ spectrum, but not perfect

$M0 = 1.494 \pm 0.008$ GeV, $\Gamma 0 = 0.087 \pm 0.034$ GeV

- $M(J/\psi p)$ almost identical



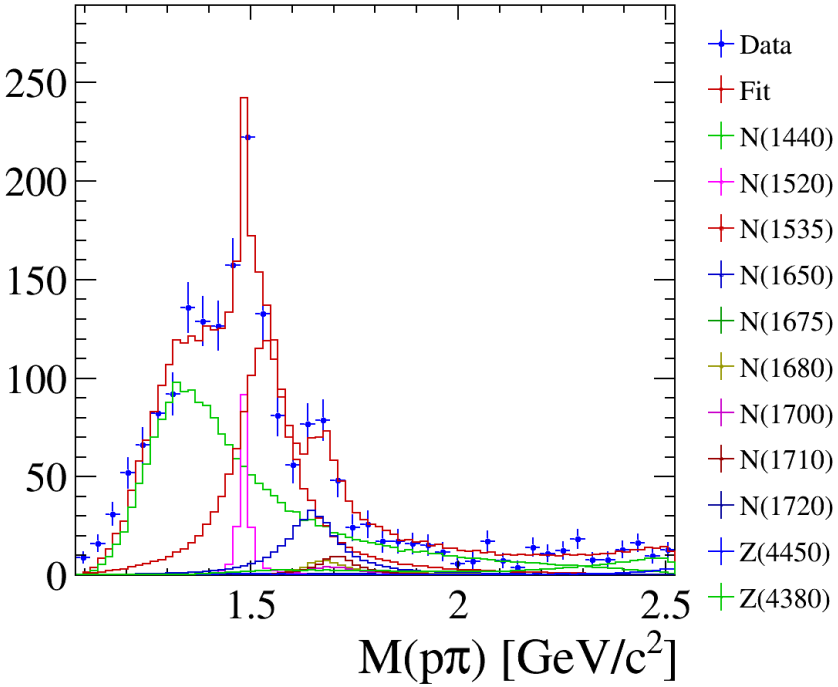


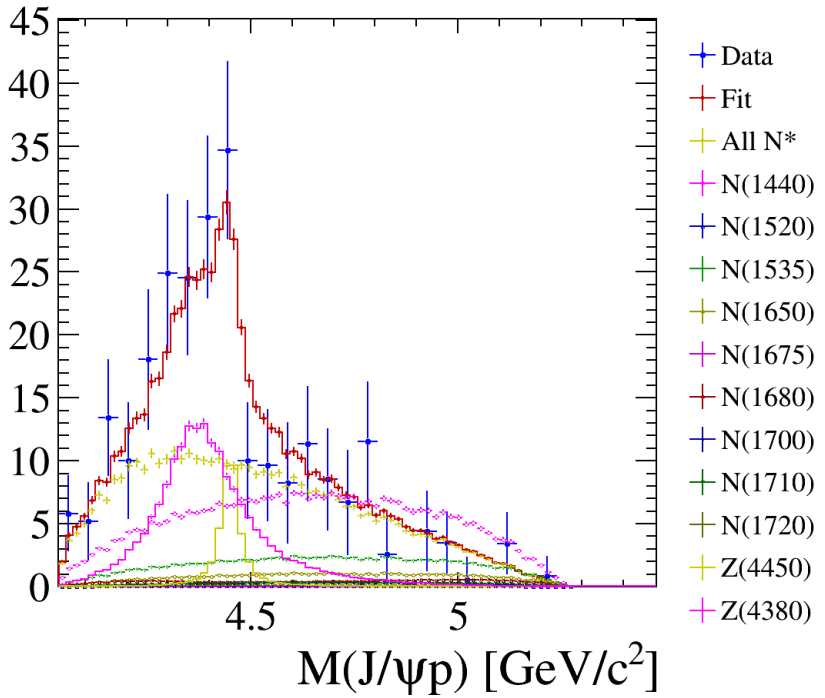
Fit with N* + Float N(1520)+2Pc

- Parameters of two Pc states also fixed
- The fit suggests a very narrow resonance at $M(p\pi^-) = 1.5$ GeV

$M0 = 1.484 \pm 0.002$ GeV, $\Gamma 0 = 0.017 \pm 0.009$GeV

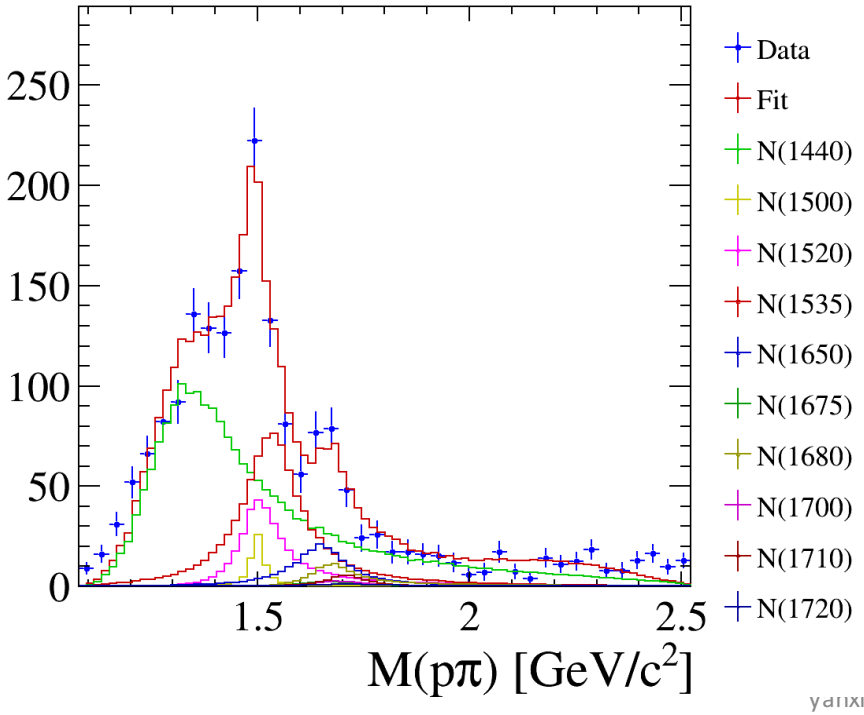
$\Delta 2LL = +9.6^2$, compared to fitting with N*+N(1520) floated

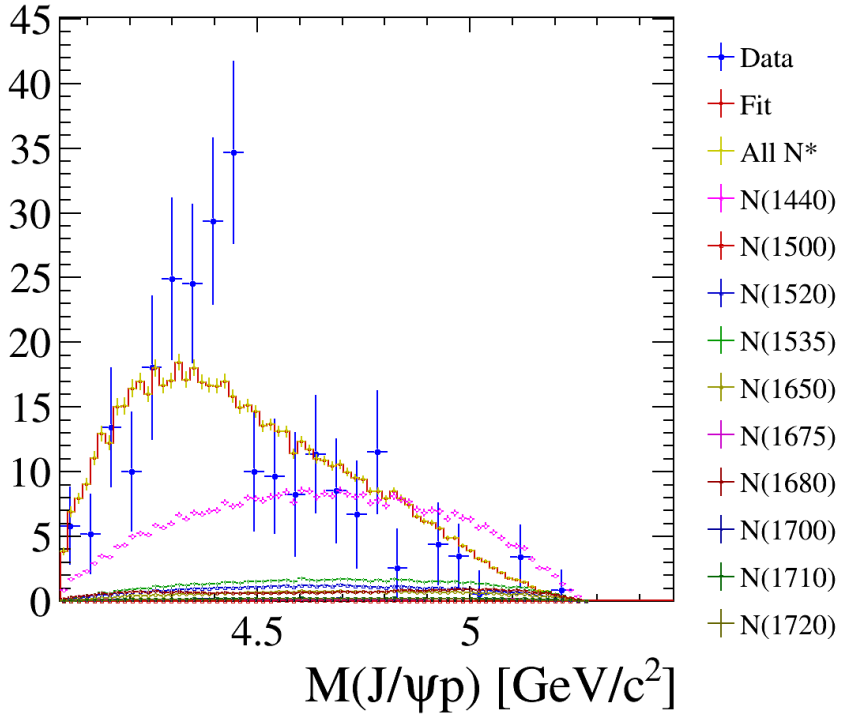




Fit with N* +N(1500)

- Arbitrarily introduce a N with $J^P = 1/2^+$, $M0, \Gamma 0$ fixed 1D fit numbers, i.e. (1.5,0.03) GeV
  - The fit at peak of $M(p\pi^-) = 1.5$ GeV improves
  - But M$(J/\psi p)$ not modeled well either
- More studies needed to float parameters of "N*(1500)"

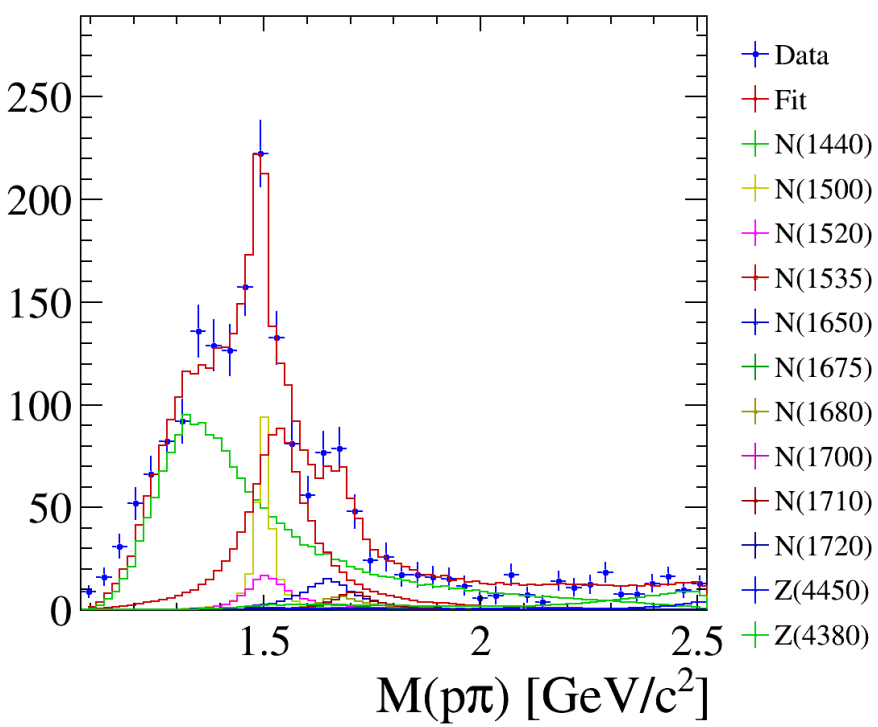


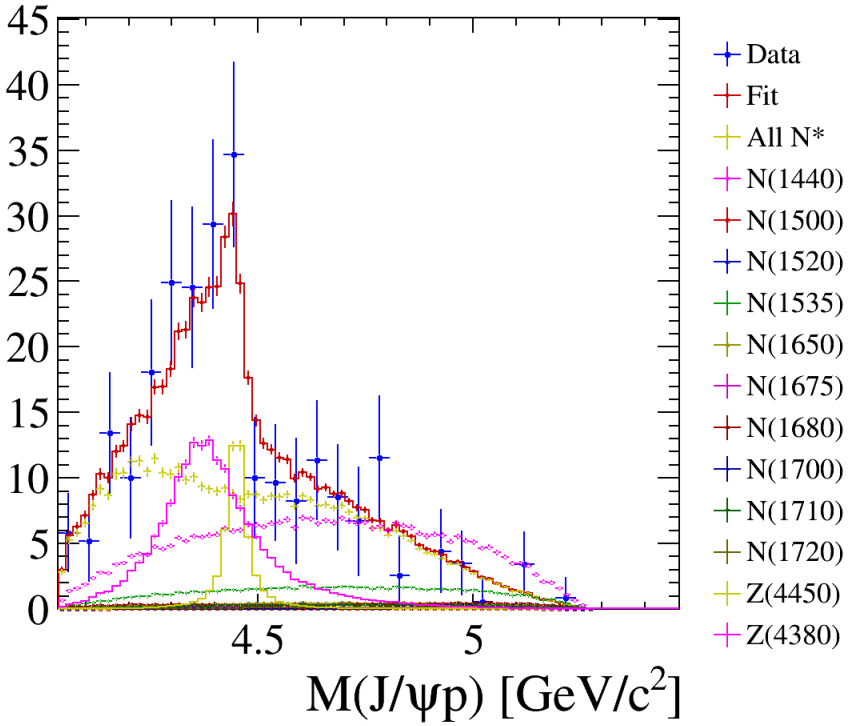


Fit with N* +N(1500)+2Pc

- Same parameters for "N*(1500)" fixed
- Both $M(p\pi^-)$ and $M(J/\psi p)$ modeled quite well

$\Delta 2LL = +9.1^2$, compared to fitting with N*+N(1500)
Same significance as the case without "N*(1500)"





Summary

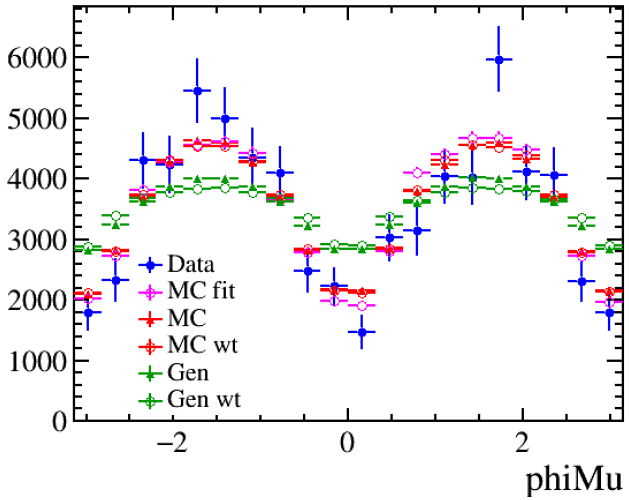
- Narrow structure seen in $M(p\pi^-) = 1.5$ GeV in Λ_b^0 decays survives investigations so far
  - Has to be considered as from real Λ_b^0 decays
- Amplitude analyses performed in $\Lambda_b^0 \to J/\psi p\pi^-$ decays
  - Fitting with only N* resonances not able to describe $M(J/\psi p)$ in high $M(p\pi^-)$ region well
  - Introduction of LHCb observed two Pc significantly improves the fit quality
  - The fit also suggests a narrow structure with $M(p\pi^-)$ at 1.5 GeV
  - Significance of LHCb pentaquarks not much affected by different treatment of structure $M(p\pi^-)$~1.5 GeV , not surprising, since Pc candidates located mostly in high $M(p\pi^-)$ region

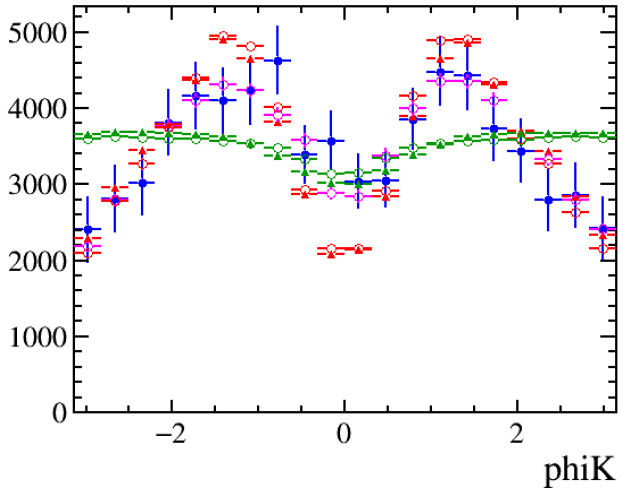
To do:

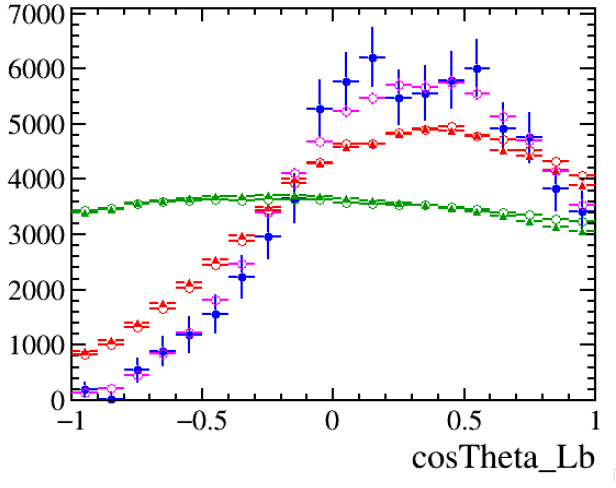
- Fit with more scenarios for $M(p\pi^-)$ peak at 1.5 GeV, may float its J^P

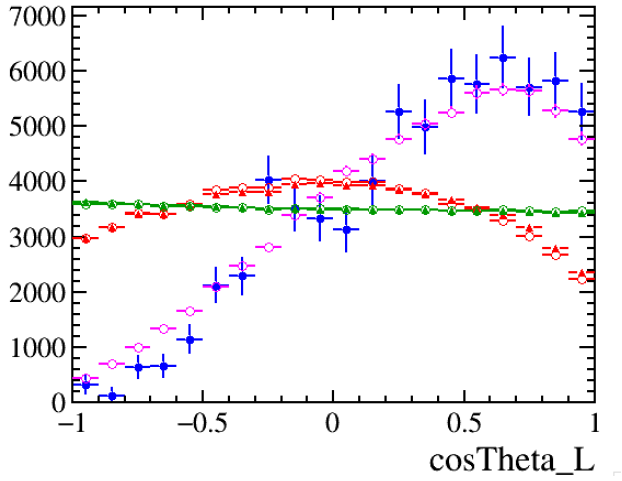
Backups

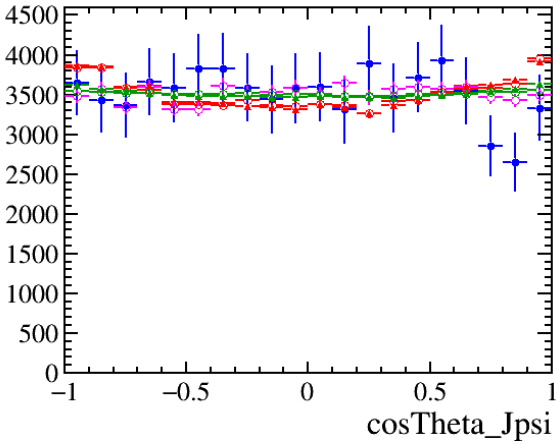
Amplitude with N* resonances



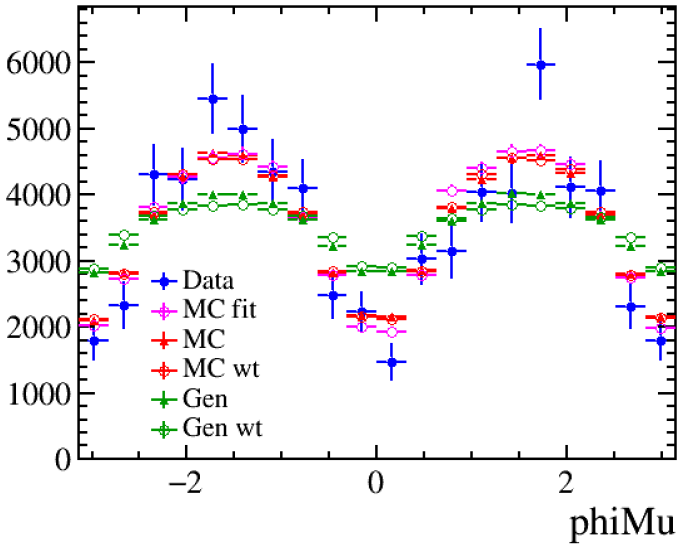


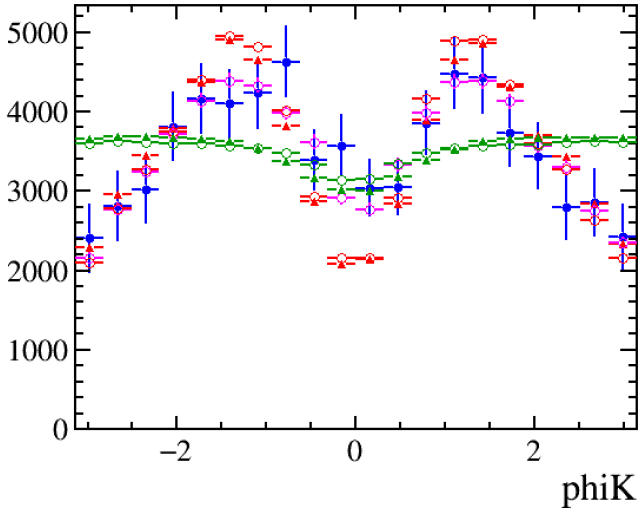


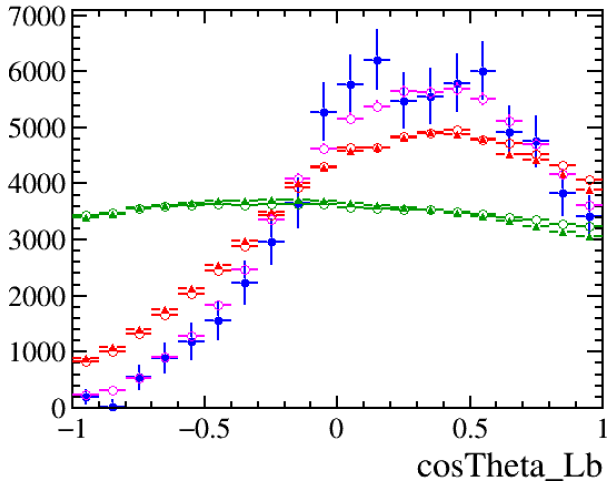


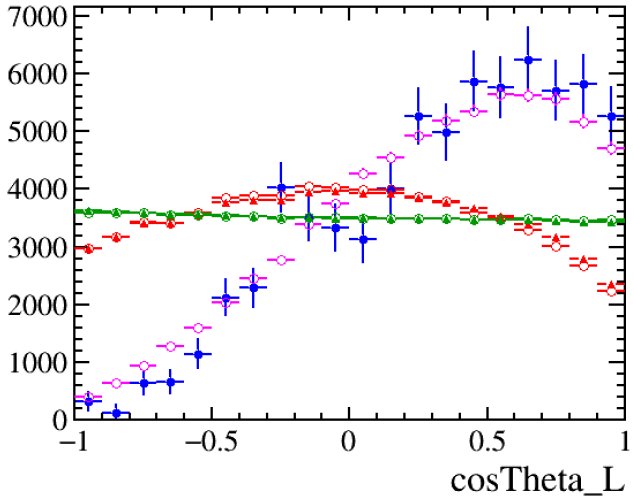


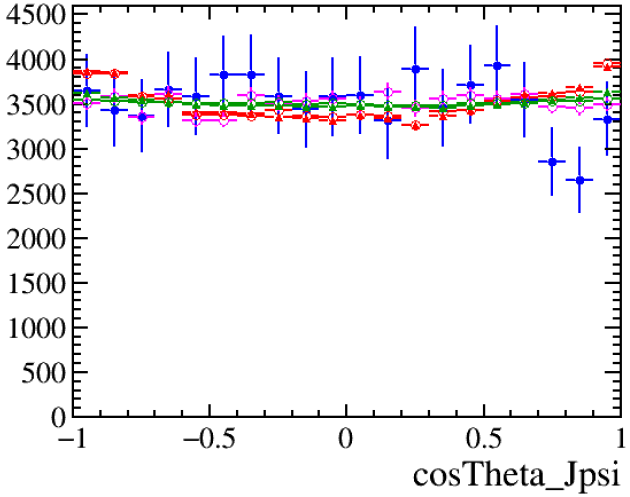
Amplitude with N*+2Pc





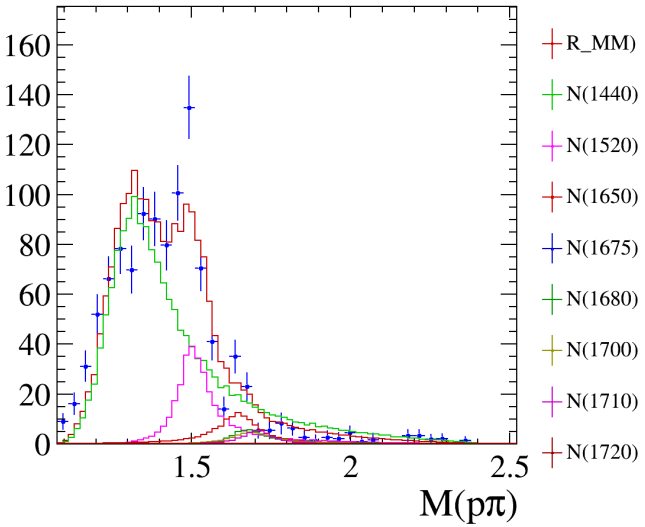




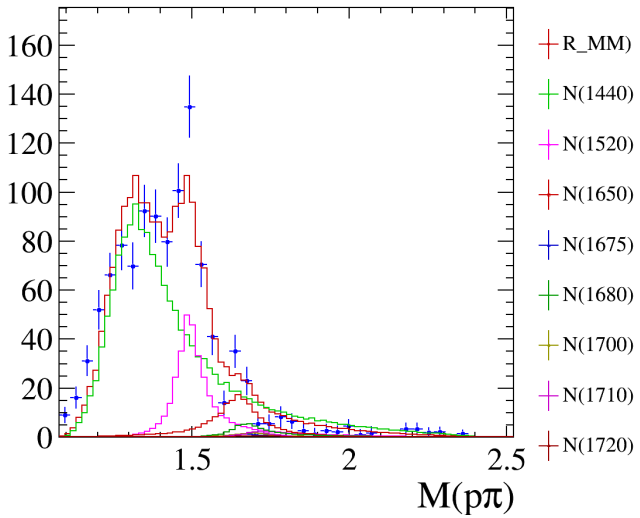


Amplitude with N* resonances

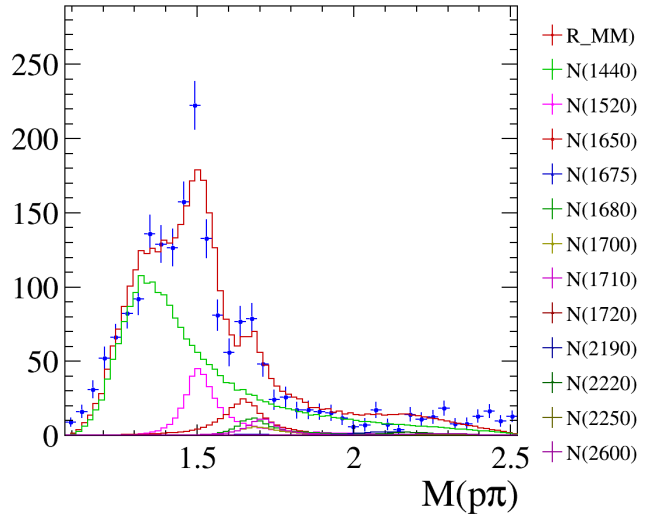
N*



Float N(1520)

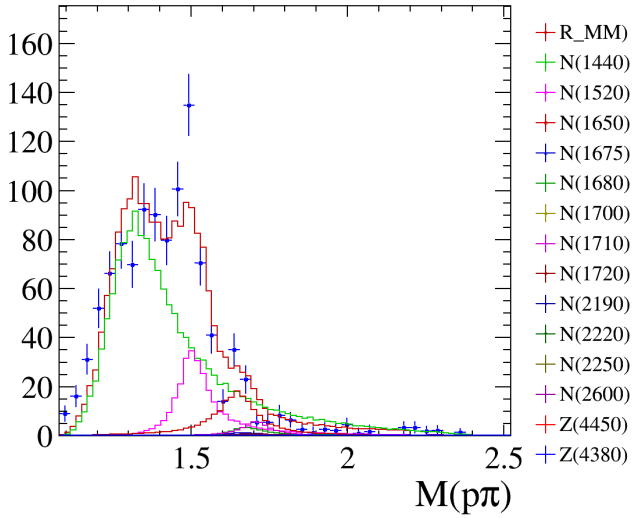


+high spin N*

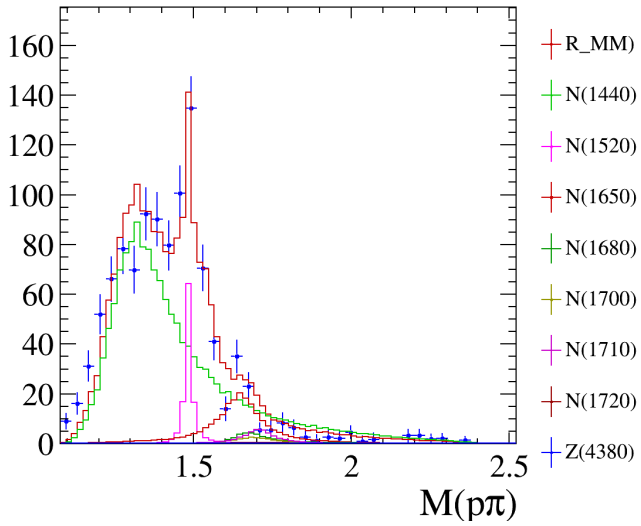


Amplitude with N* +Pc resonances

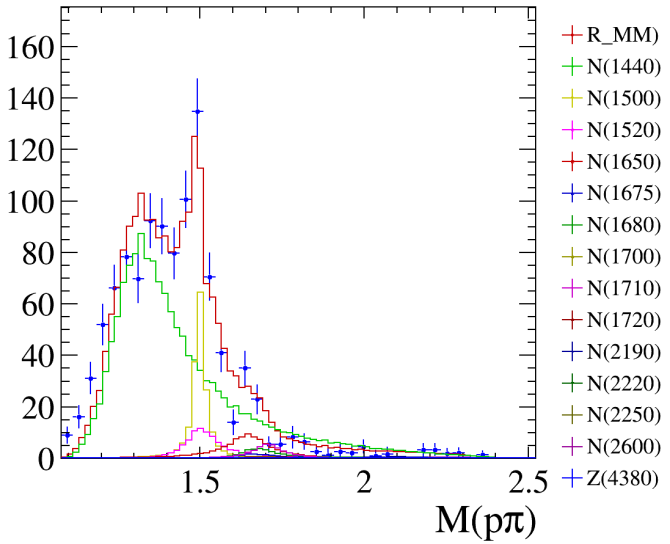
N*+2Pc



Float N(1520)



Fix N(1520) +N (1500)



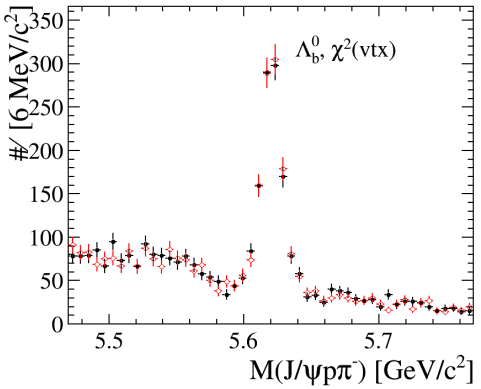
Further check of peak at $M(p\pi^-)\sim1.5$

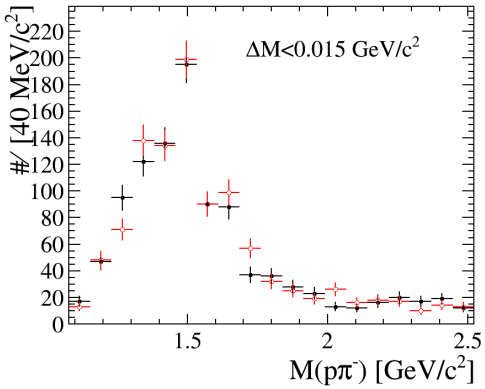
- For each variable used in BDT, divide final dataset into two samples: more/less signal enriched

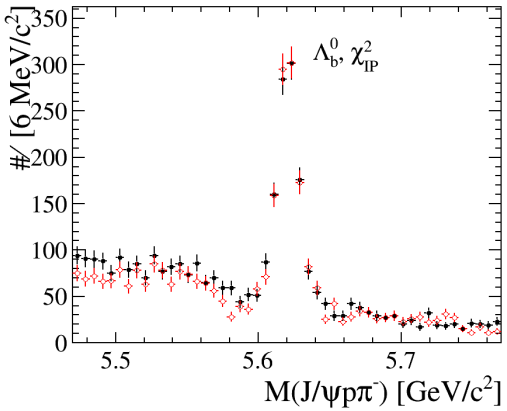
Red: signal more enriched ($\chi^2_{IP}(\Lambda_b^0) < X$)

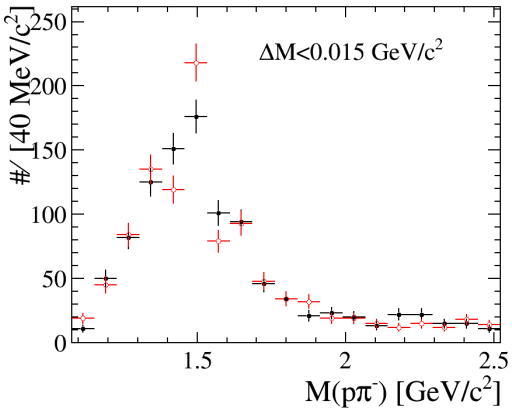
Black: signal less enriched ($\chi^2_{IP}(\Lambda_b^0) > X$)

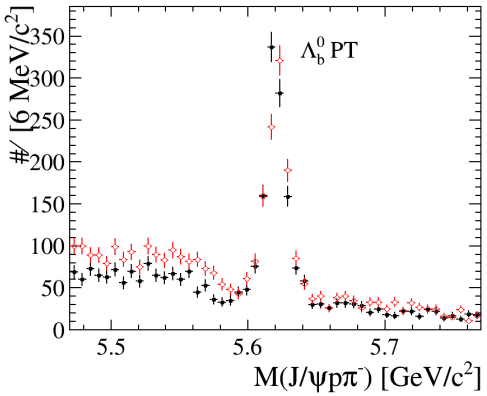
They are not so powerful after BDT optimization.

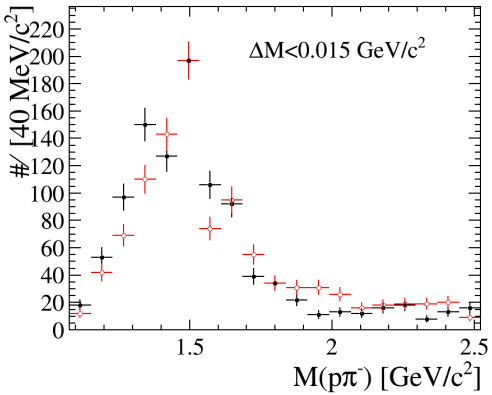






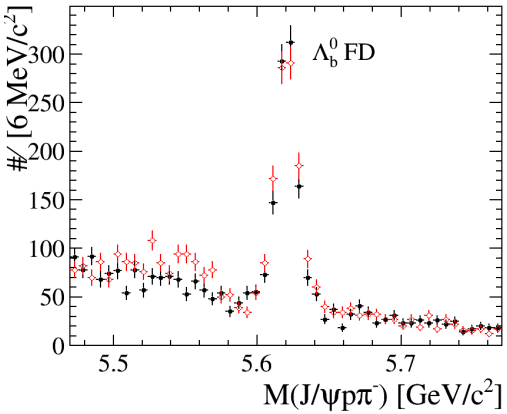


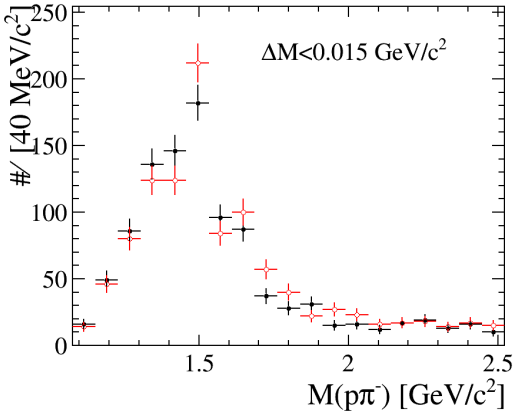


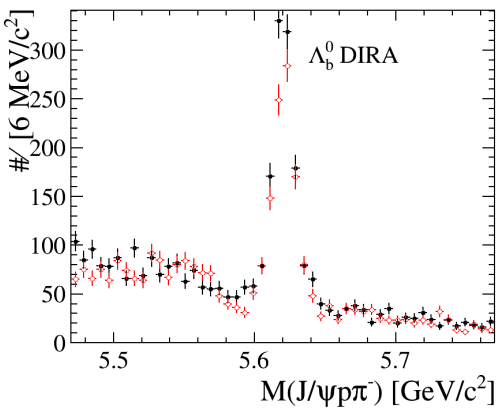


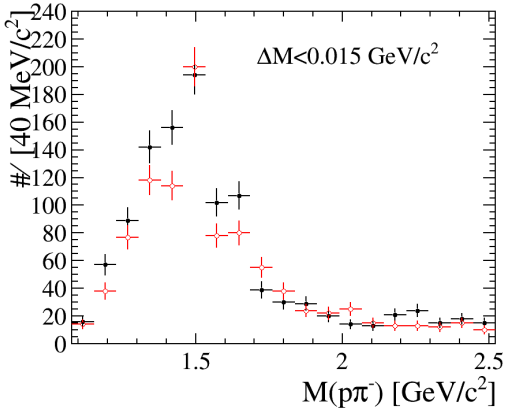
Further check of peak at $M(p\pi^-)\sim1.5$

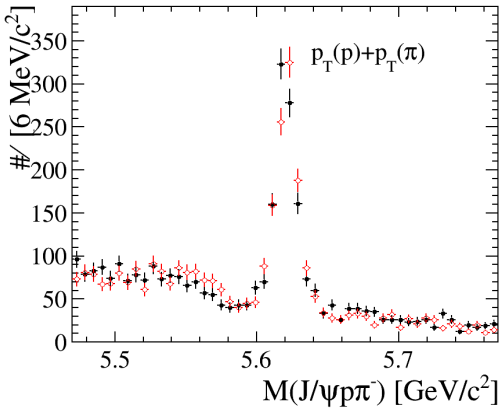
- For each variable used in BDT, divide final dataset into two samples: more/less signal riched

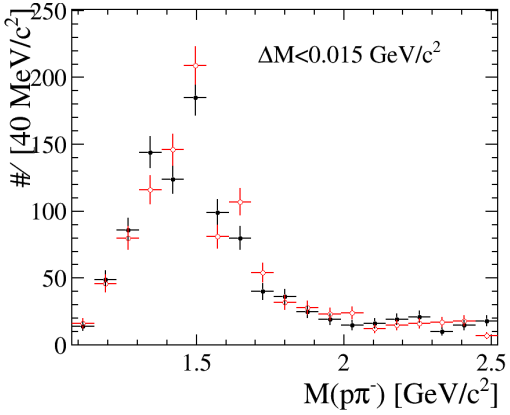


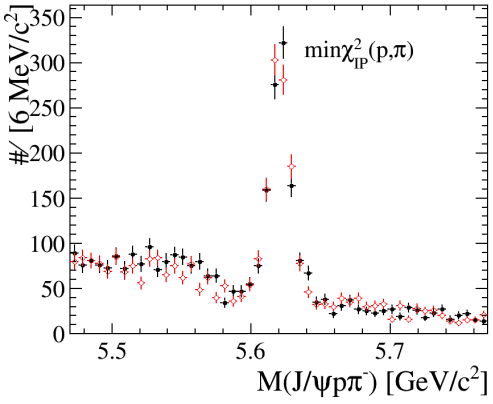


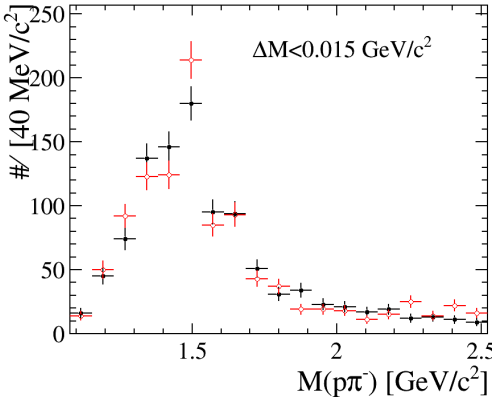












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