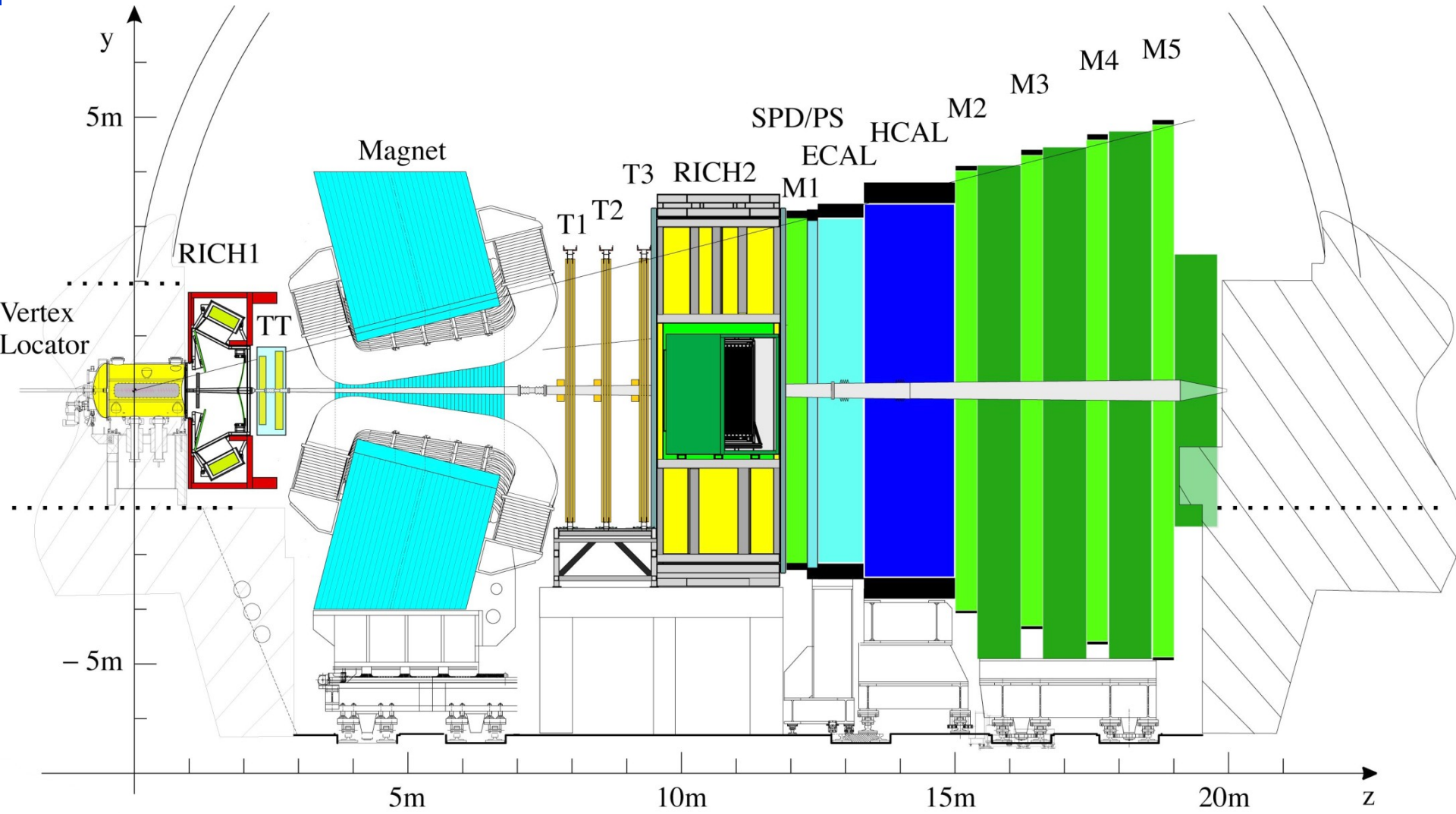
S. Stone

LHCb Physics

As You Like It

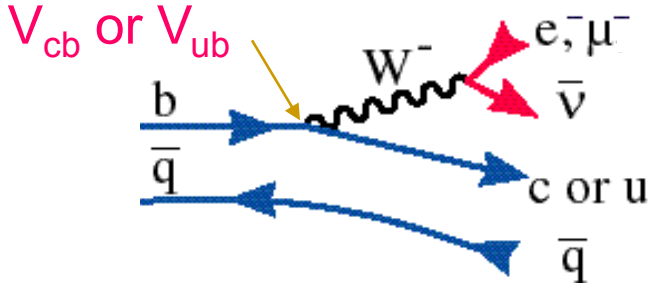
For the LHCb Collaboration

The LHCb Detector

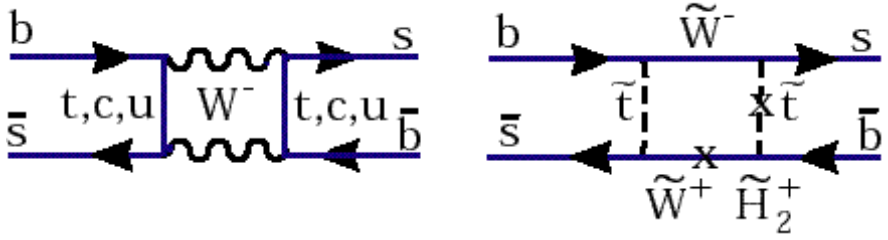


Limits on New Physics

- It is oft said that we have not seen New Physics, yet what we observe is the sum of Standard Model + New Physics. How to set limits on NP?
- Assume that tree level diagrams are dominated by SM and loop diagrams could contain NP



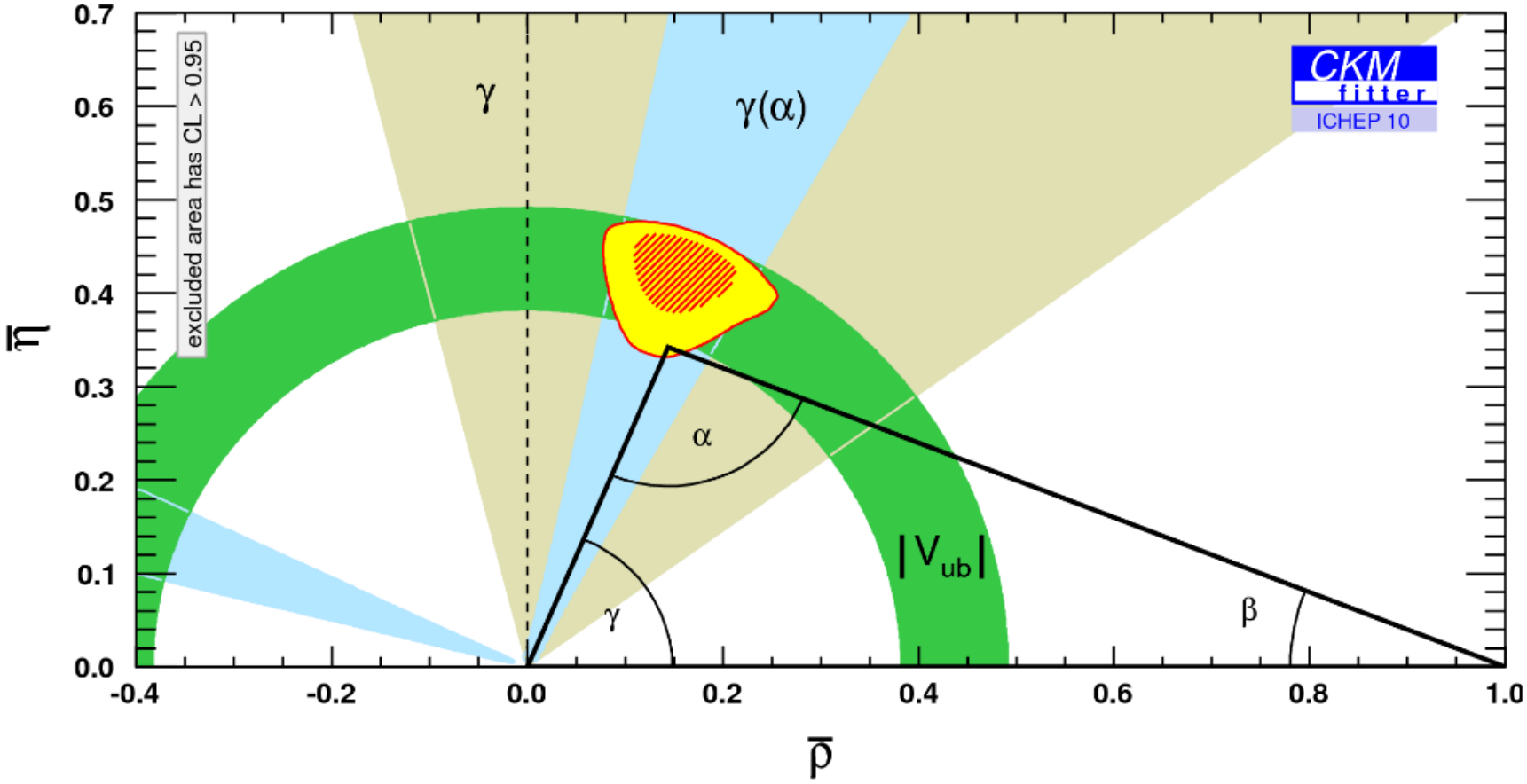
Tree diagram example



Loop diagram example

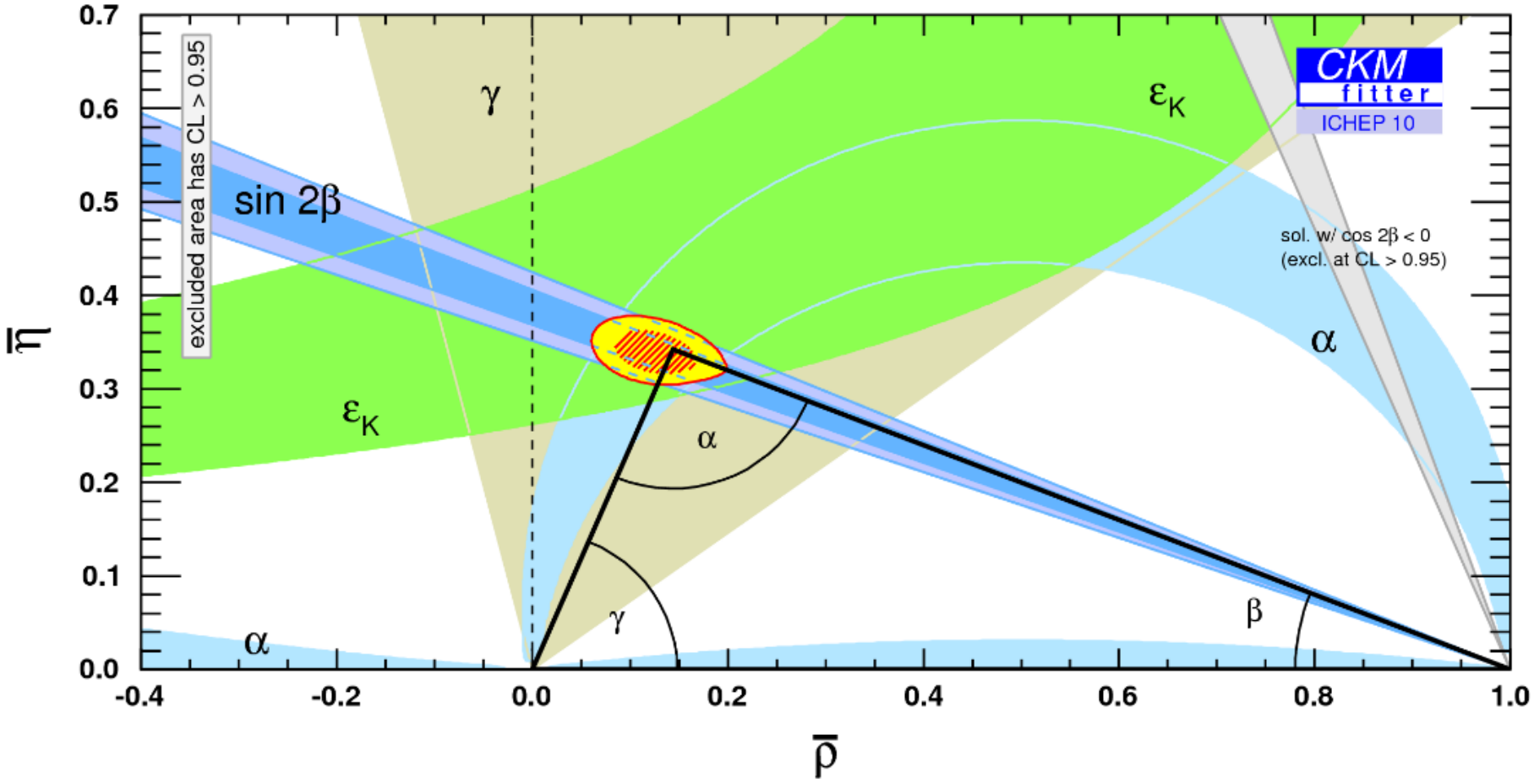
What are limits on NP from quark decays?

- Tree diagrams are unlikely to be affected by physics beyond the Standard Model

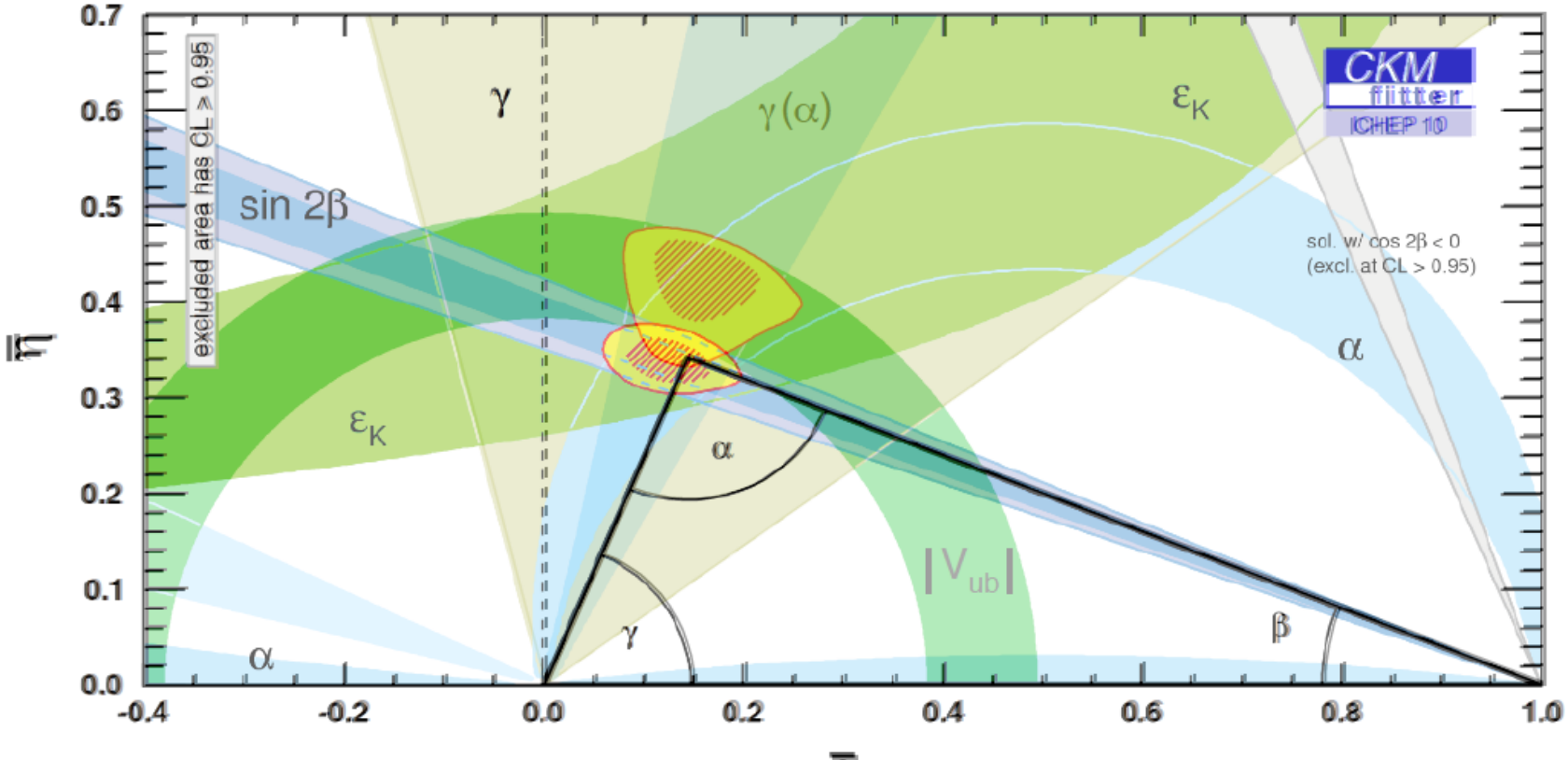


CP Violation in B° & K° Only

- Absorptive (Imaginary) of mixing diagram should be sensitive to New Physics. Lets compare



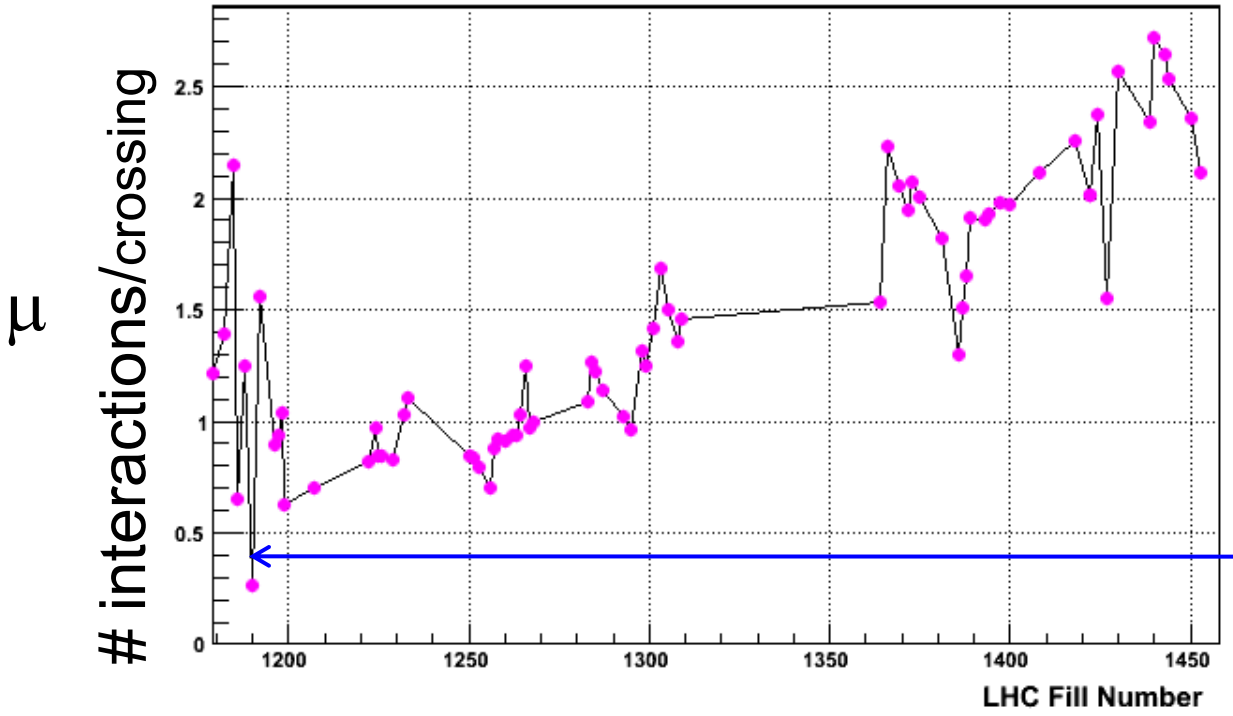
They are Consistent



- But consistency is only at the 5% level
- Same for B_s – CP violation in $J/\psi\,\phi$ (not including D0 A_{sl}) $\Rightarrow$limits on NP are not so strong

Running Conditions

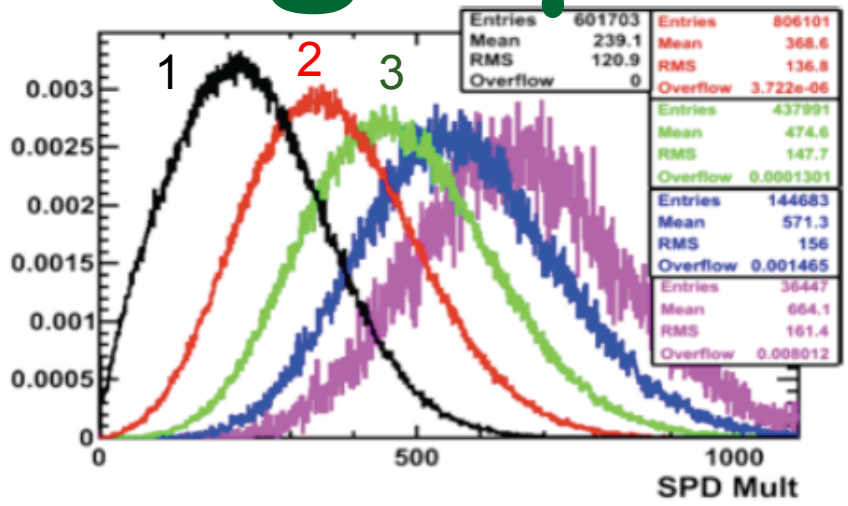
- Because the # of bunches in the LHC was limited we decided that the trigger had enough time to process data with multiple interactions per crossing

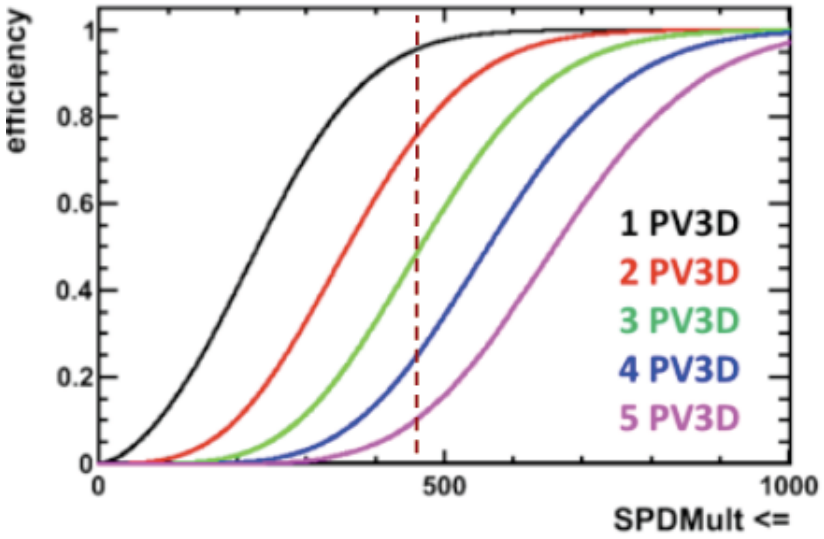


This gets to 6x larger μ than design

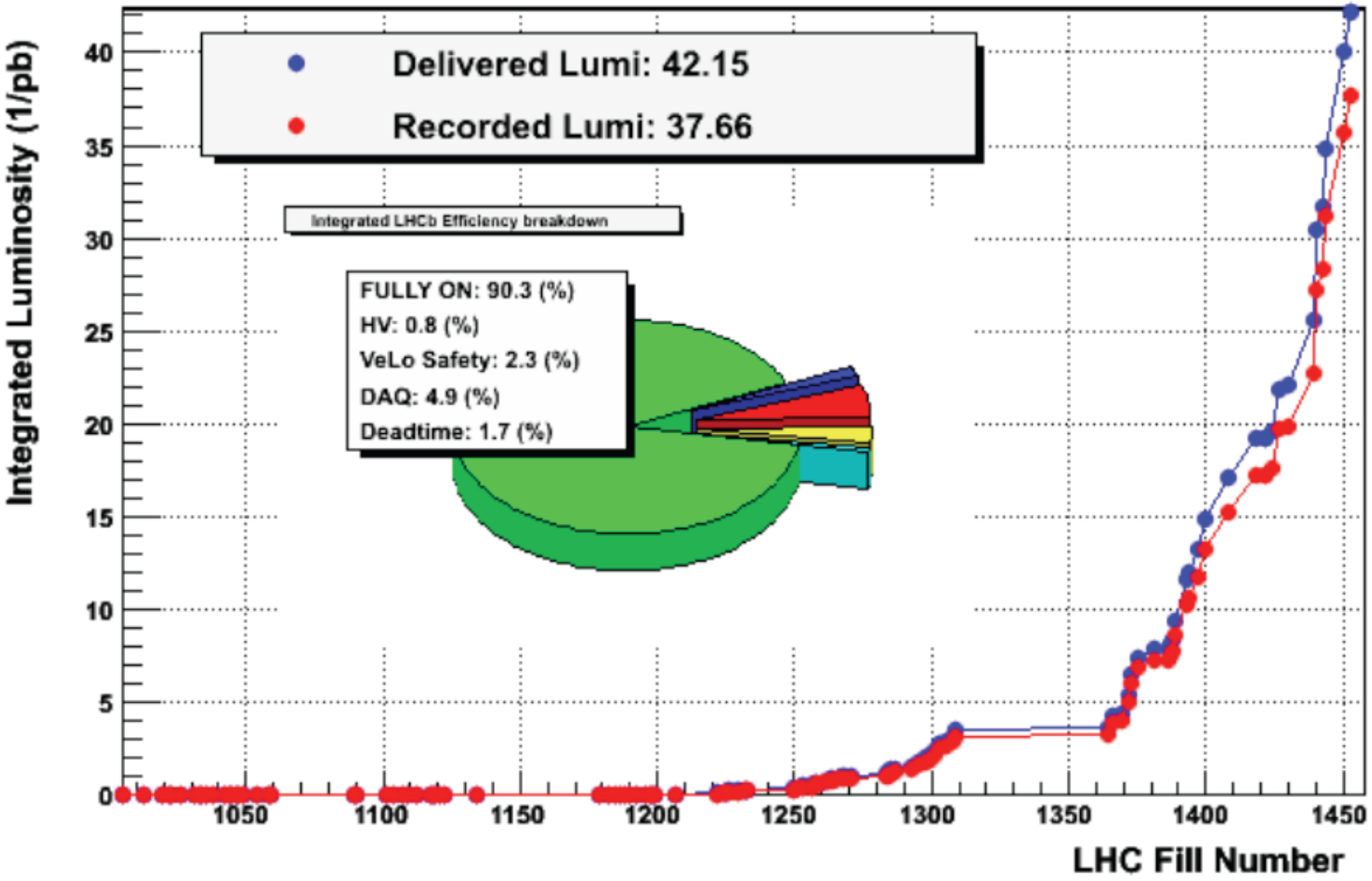
Life at large μ

- For $\mu^+\mu^-$ triggers, take almost everything, SPD<900. Other triggers require rejecting events with large numbers of tracks. Cut on SPD multiplicity as it correlates well & is provided in L0; the cut value changed with L
- This still is a large gain for all modes than the original plan of μ=0.4

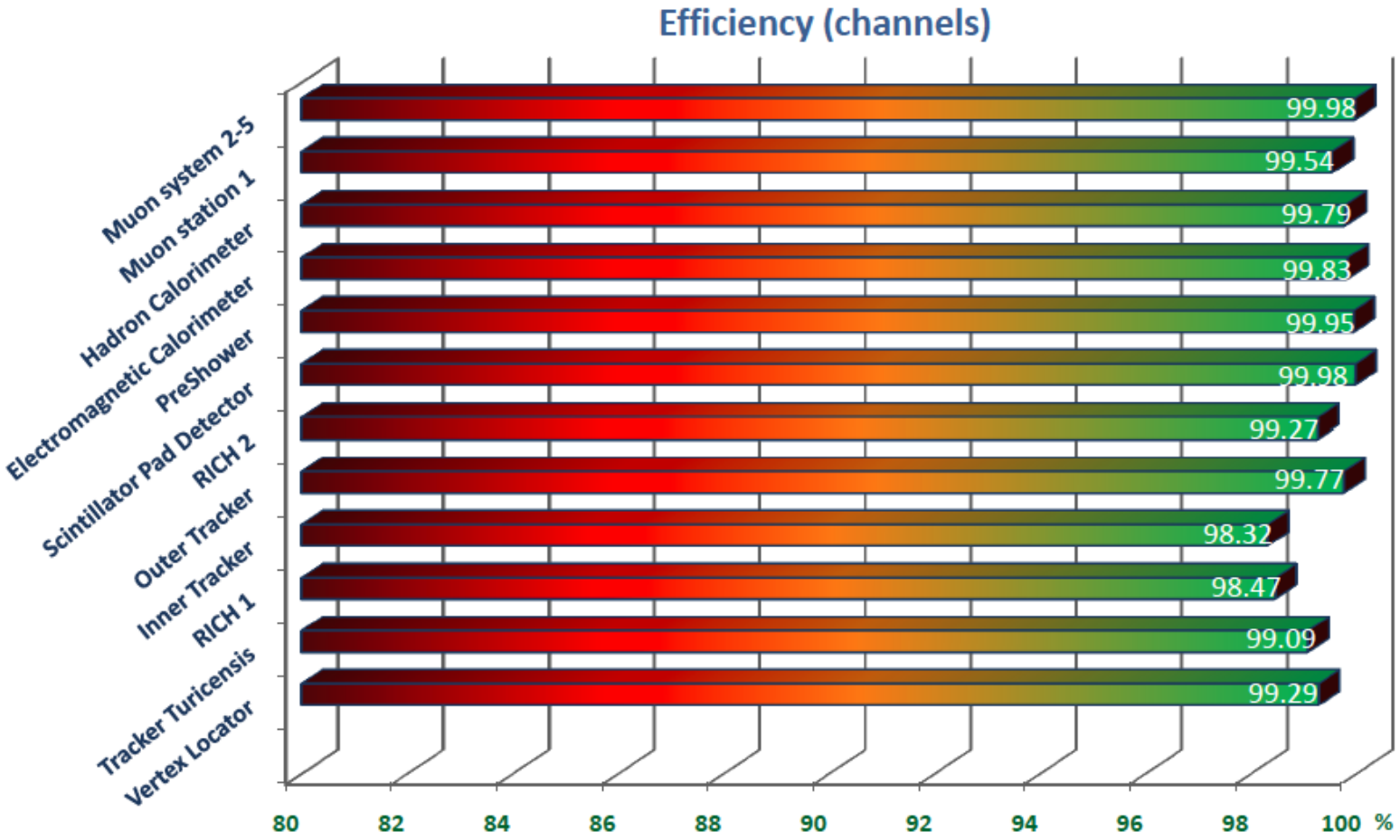




Integrated Luminosity

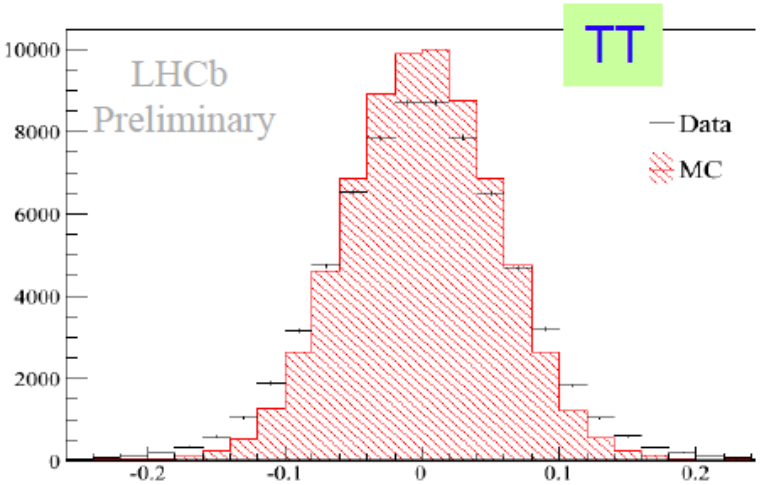


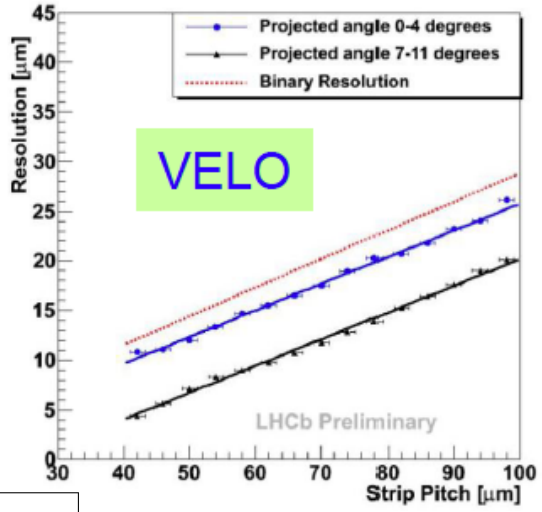
Sub-detector efficiencies

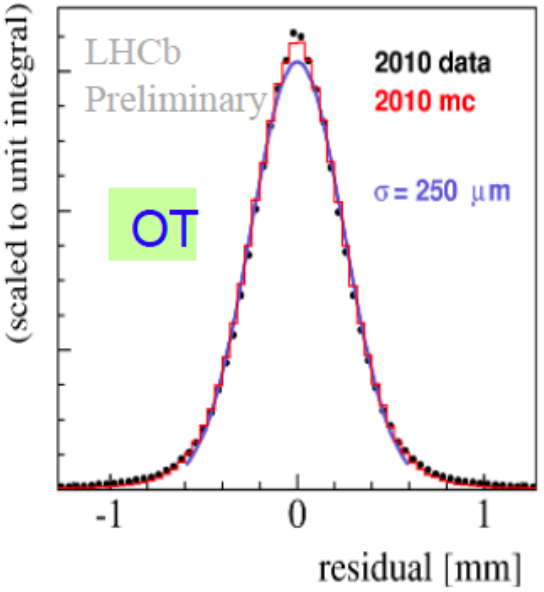


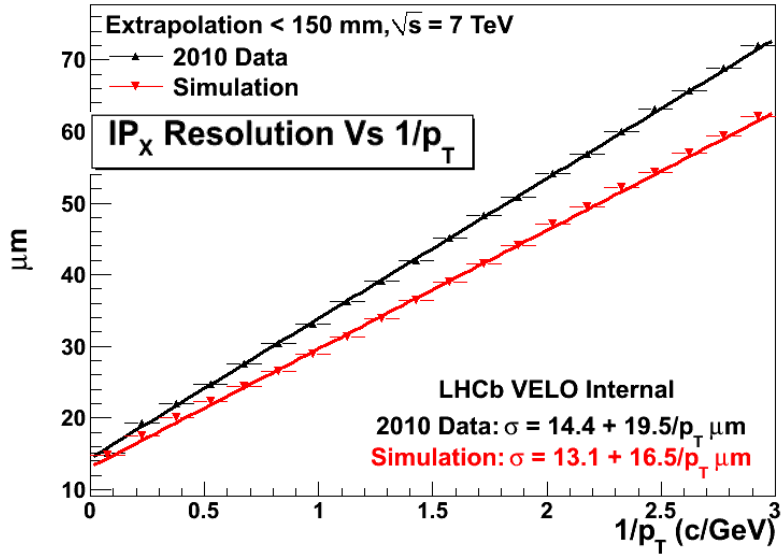
- Some “small” problems: VCSELs in several systems, HV & high current problems in a few systems

Detector Performance





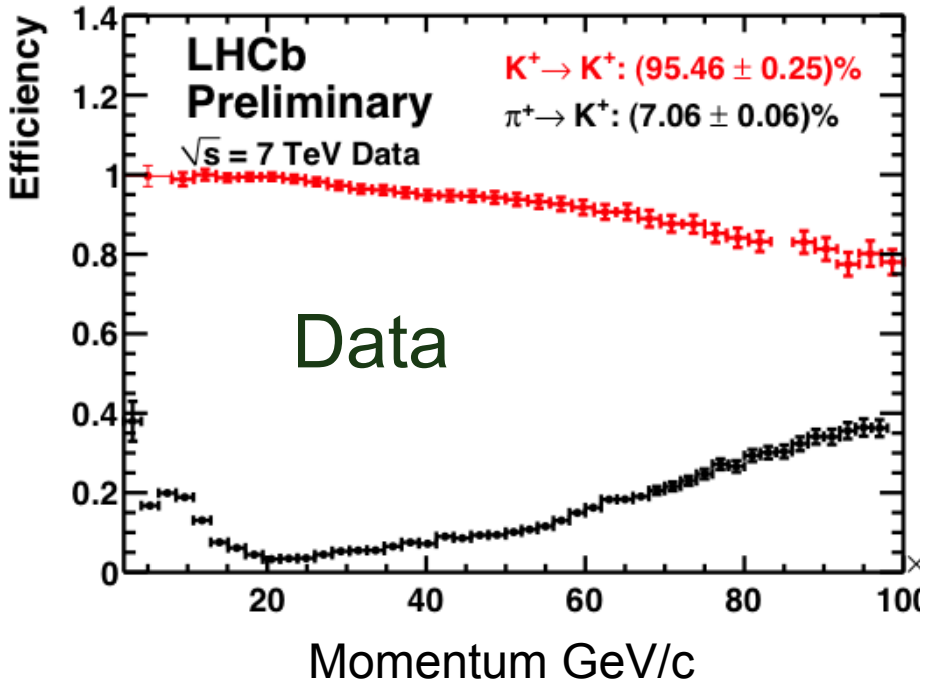


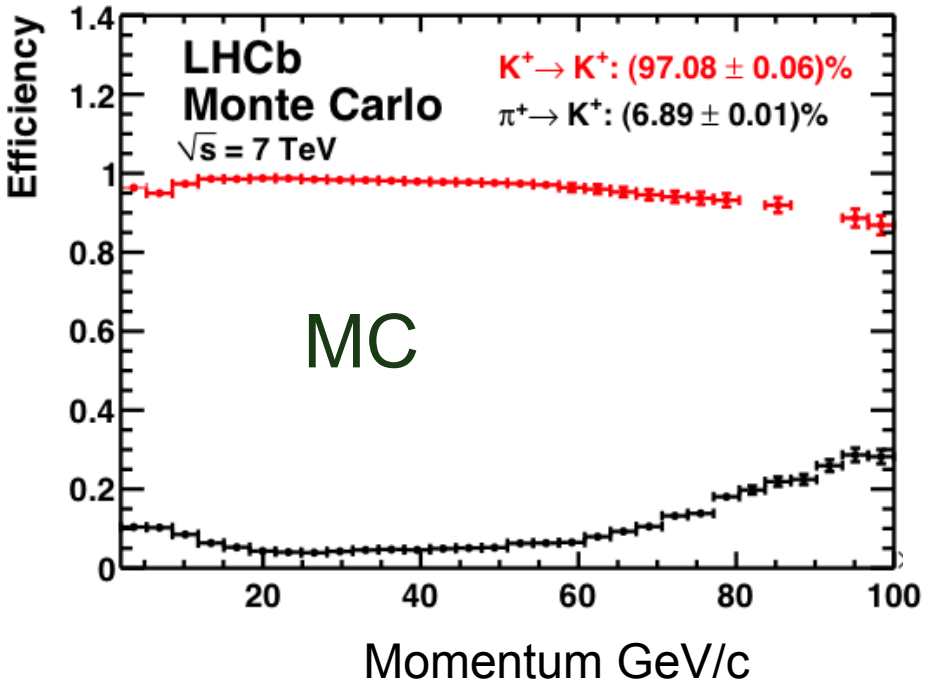


- Time resolution on typical B decay modes is ~60 fs, very good but, worse than the expected ~40 fs

Particle ID

- PID performing well





- Close to MC level performance

Some Interesting Near Future Measurements & Sensitivities

LHCb expectations: 37 pb^{-1} in 2010 ✓

~ 2 fb^{-1} for nominal yr

~ 6 fb^{-1} for "1st run"

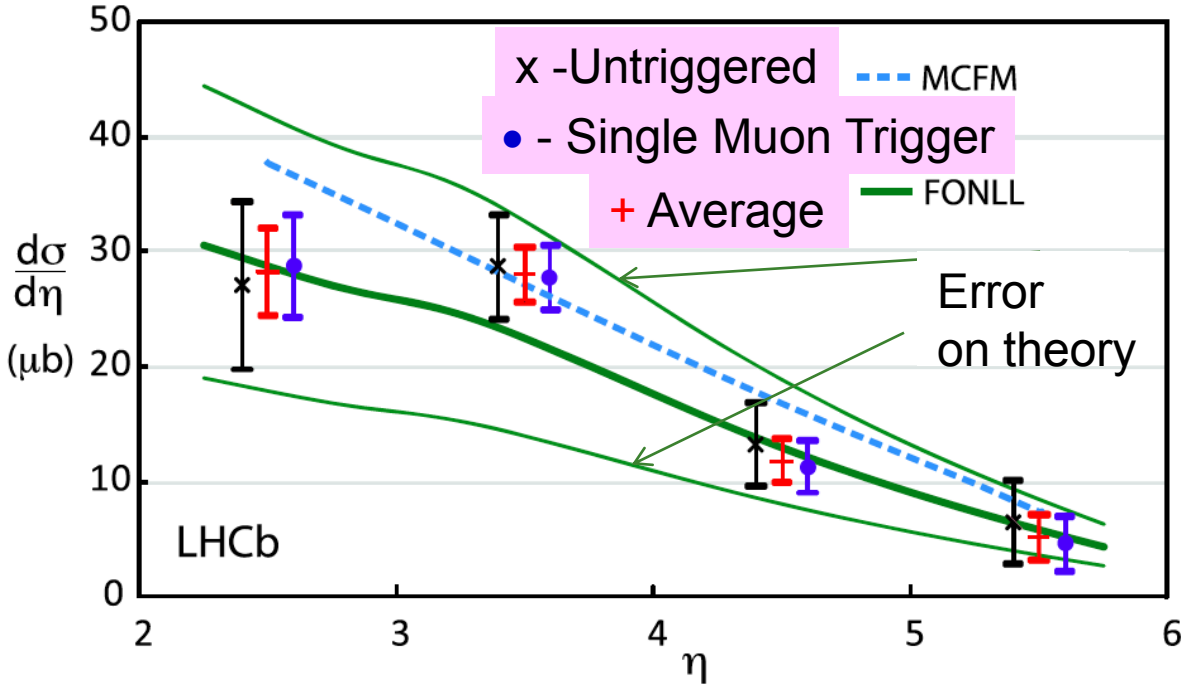
~60 fb^{-1} for upgrade

Infancy: 15 nb^{-1}

- Measure $\sigma(pp \to b\bar{b}X)$ using $b \to D^0 X \mu^- \nu$, $D^o \to K^- \pi^+$,

  ~280 events

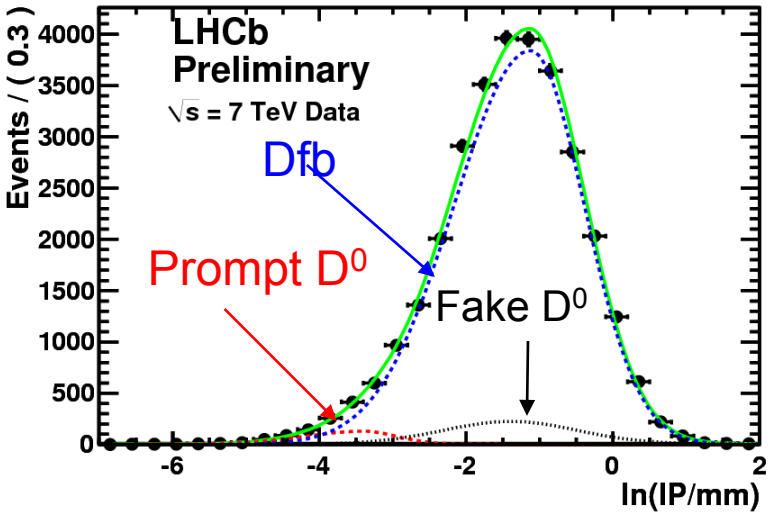
$$\sigma = \frac{\#\ \text{of detected}\ D^0\mu^- \ \&\ \bar{D}^0\mu^+}{L \times \text{efficiency} \times 2}$$

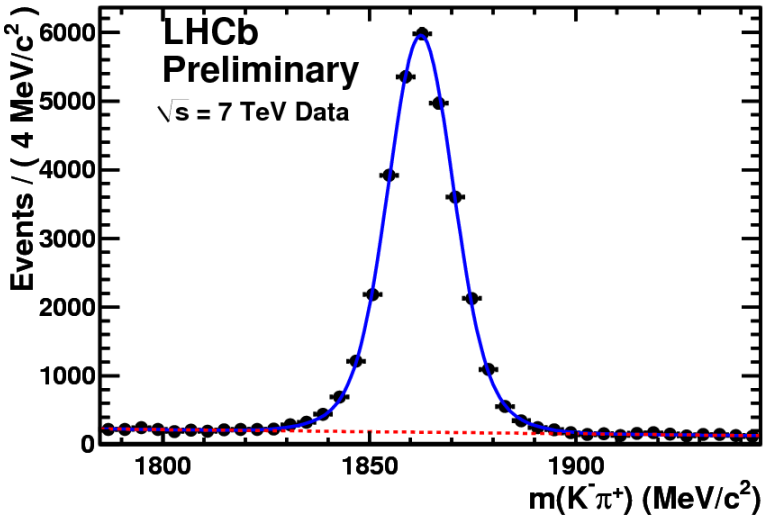


- In $2<\eta<6$, $(75.3 \pm 5.4 \pm 13.0)$ μb LEP frag
- In $2<\eta<6$, 89.6 μb Tevatron frag
- Also measured charm cross-section, ~20x b

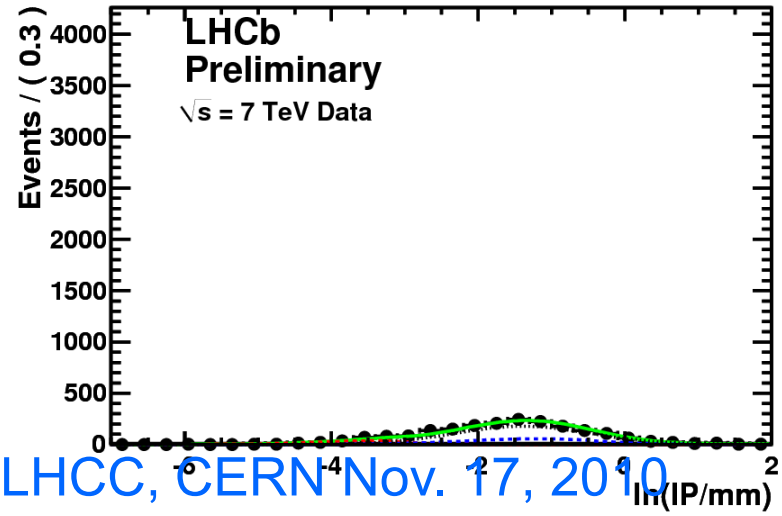
Childhood 3 pb^{-1}

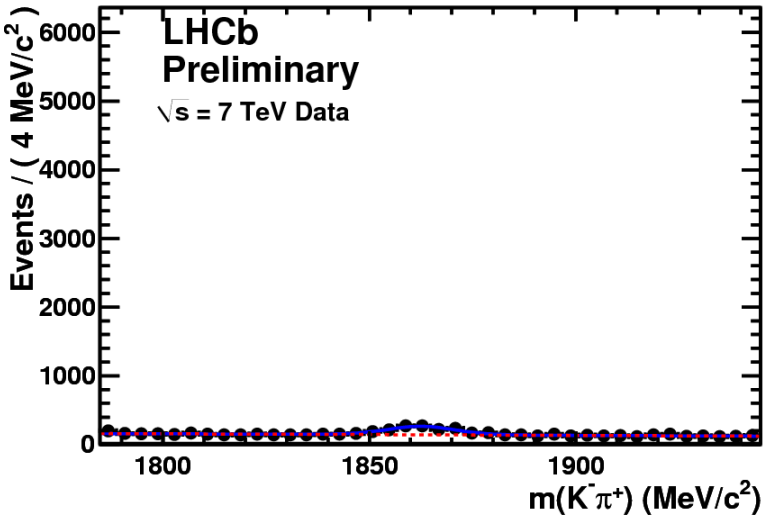
RS Dfb = 28531±193 Prompt = 715±44 sideband = 1776±33



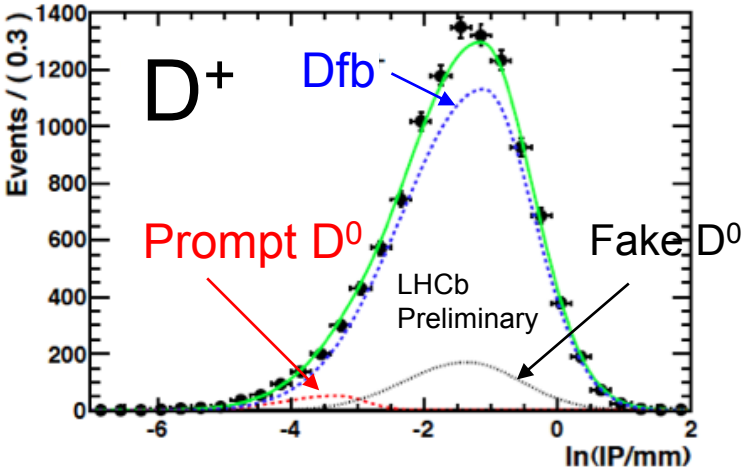


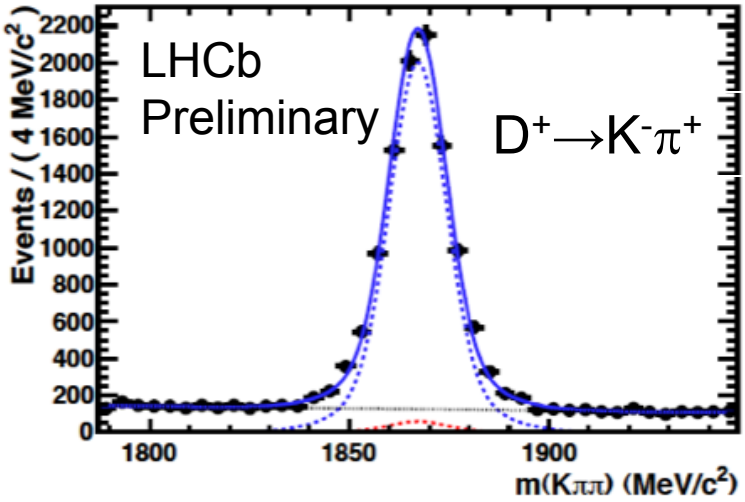
WS Dfb = 422±43 Prompt = 204±19 sideband = 1410±21



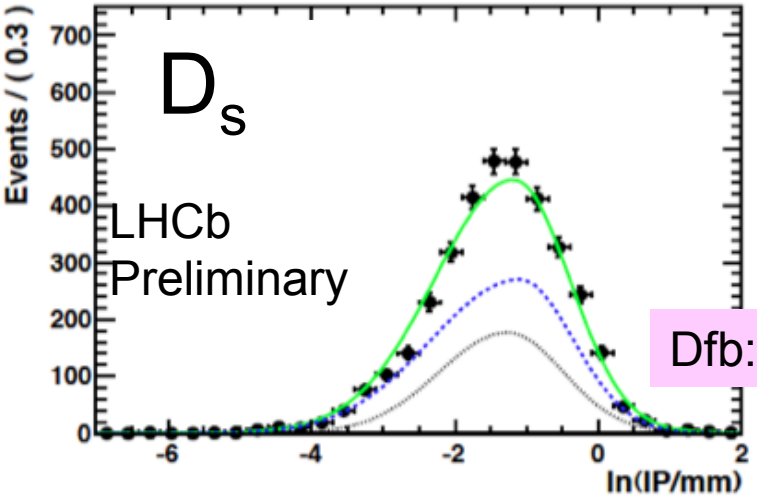


Also D^+, D_s, Λ_b

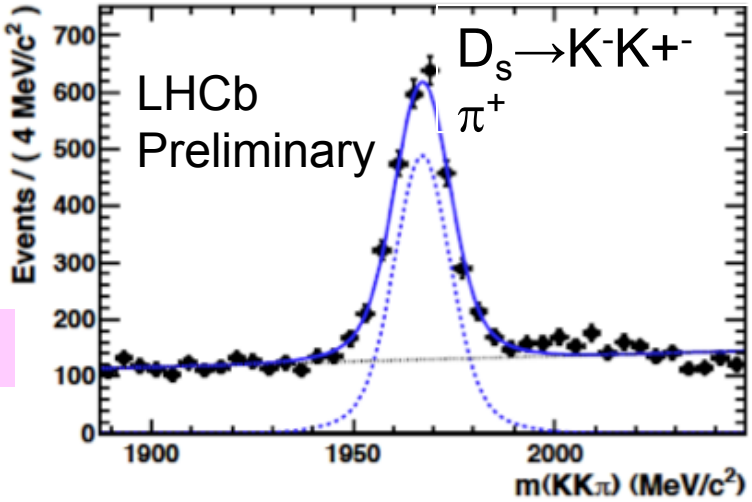




Dfb: 9406±110

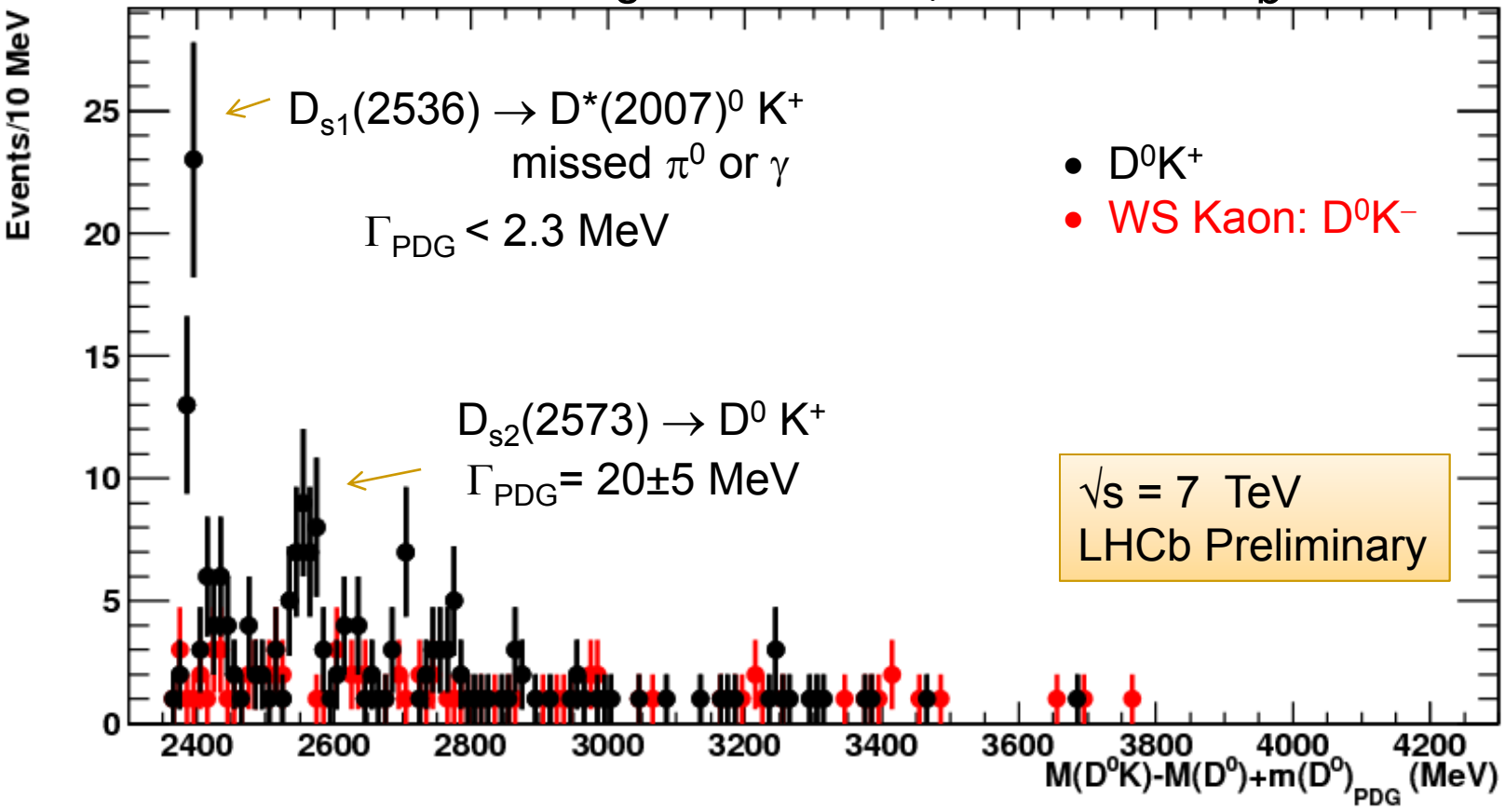


Dfb: 2446±60



Extract B_s fraction

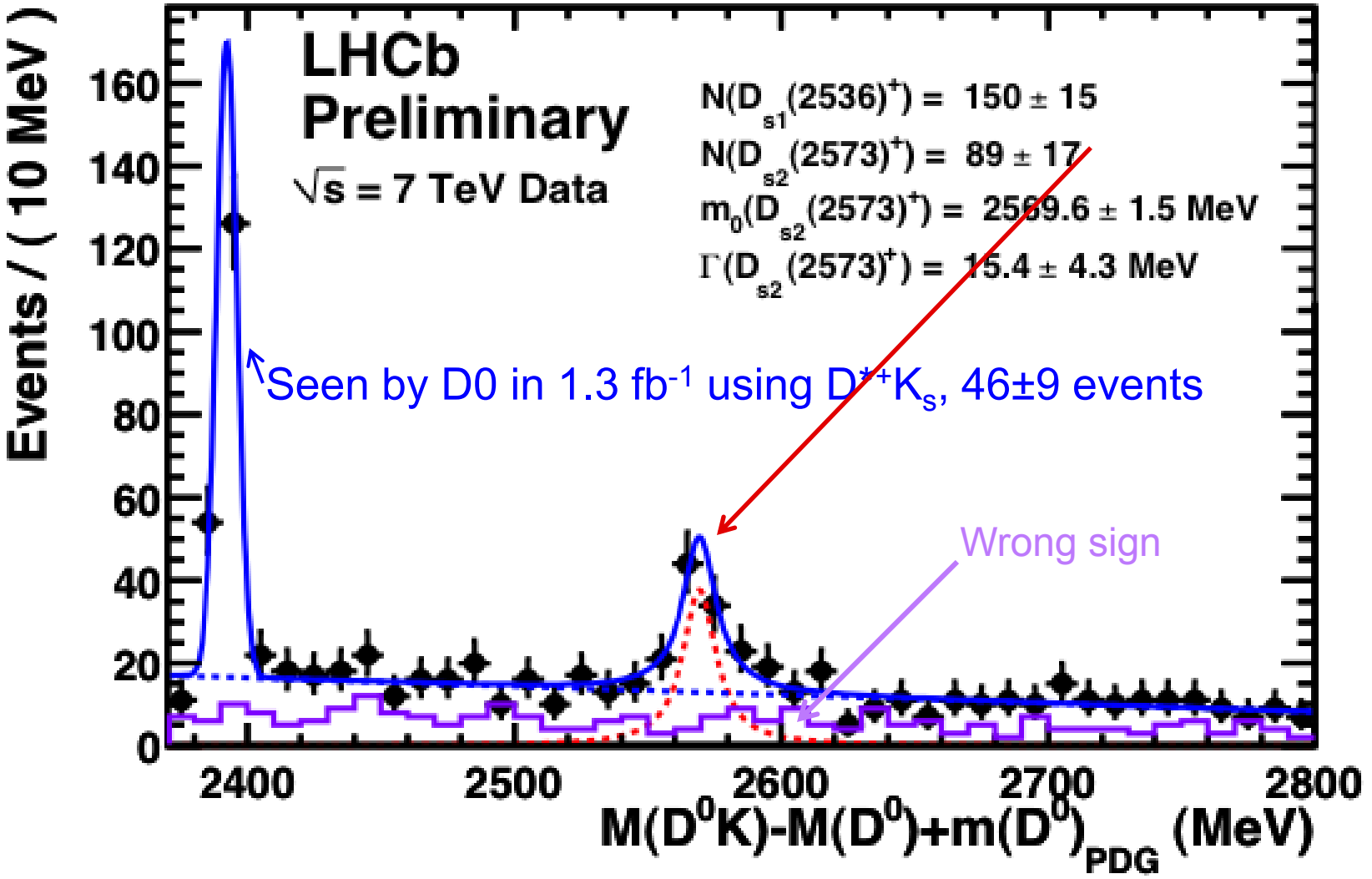
- Must correct for $B_s \to D^o K^+ X \mu \nu$, also $\Lambda_b \to D^o p X \mu \nu$



- Will use to determine $f_s/(f_d+f_u)$

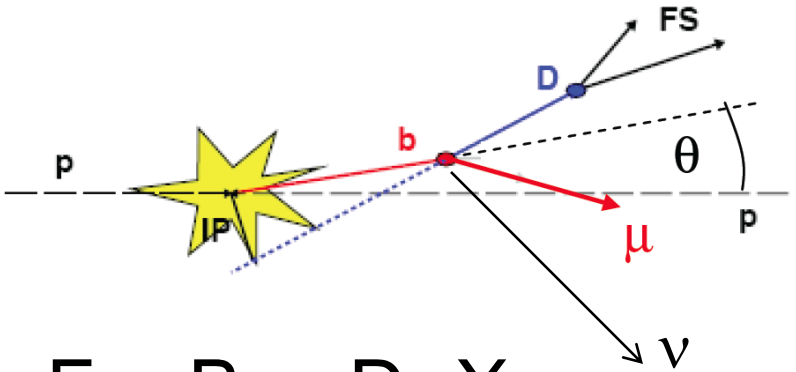
$B_s \to D_{s2} X \mu \nu$, $D_{s2} \to D^0 K^+$

- New decay mode observed using 20 pb^{-1},



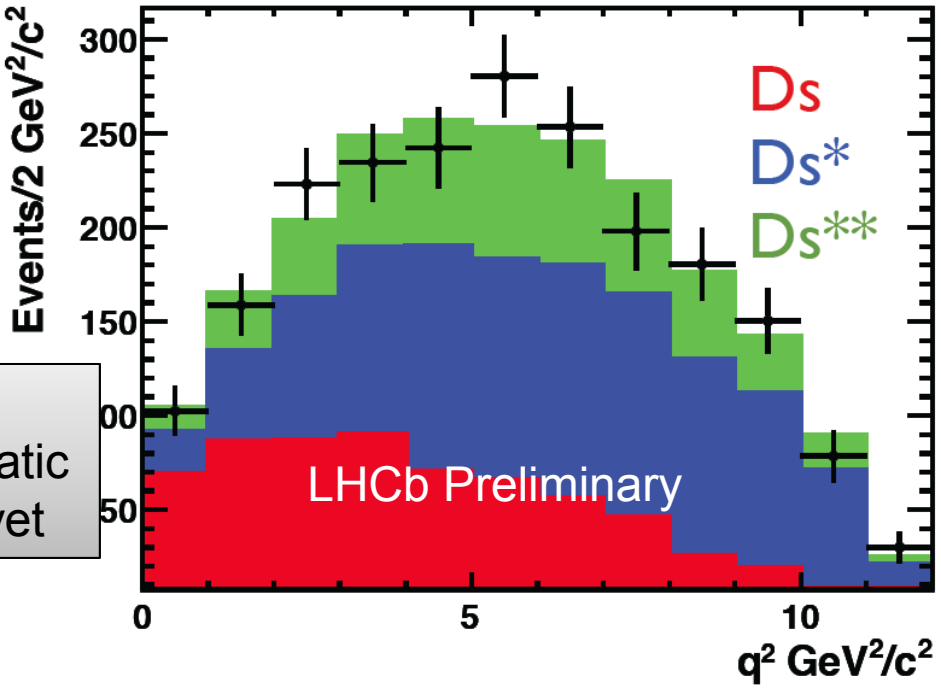
Exclusive semileptonic decays

- Accurate measurement of B-flight direction allows missing neutrino reconstruction



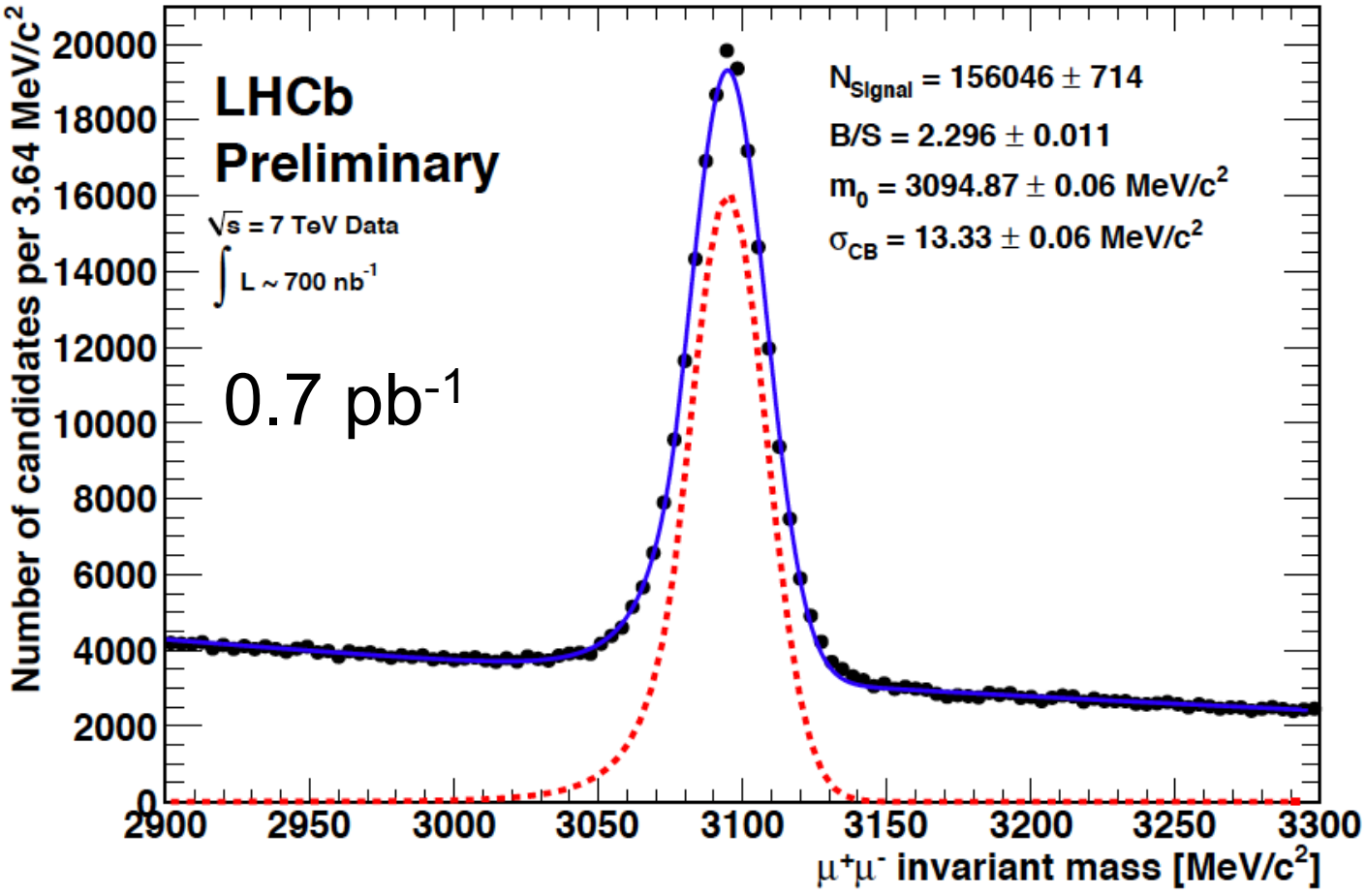
- For $B_s \rightarrow D_s$ X $\mu\nu$
  - D_s: 0.26±0.06
  - D_s^*: 0.49±0.069
  - D_s^{**}: 0.25±0.12
  - LHCb preliminary

No systematic errors yet

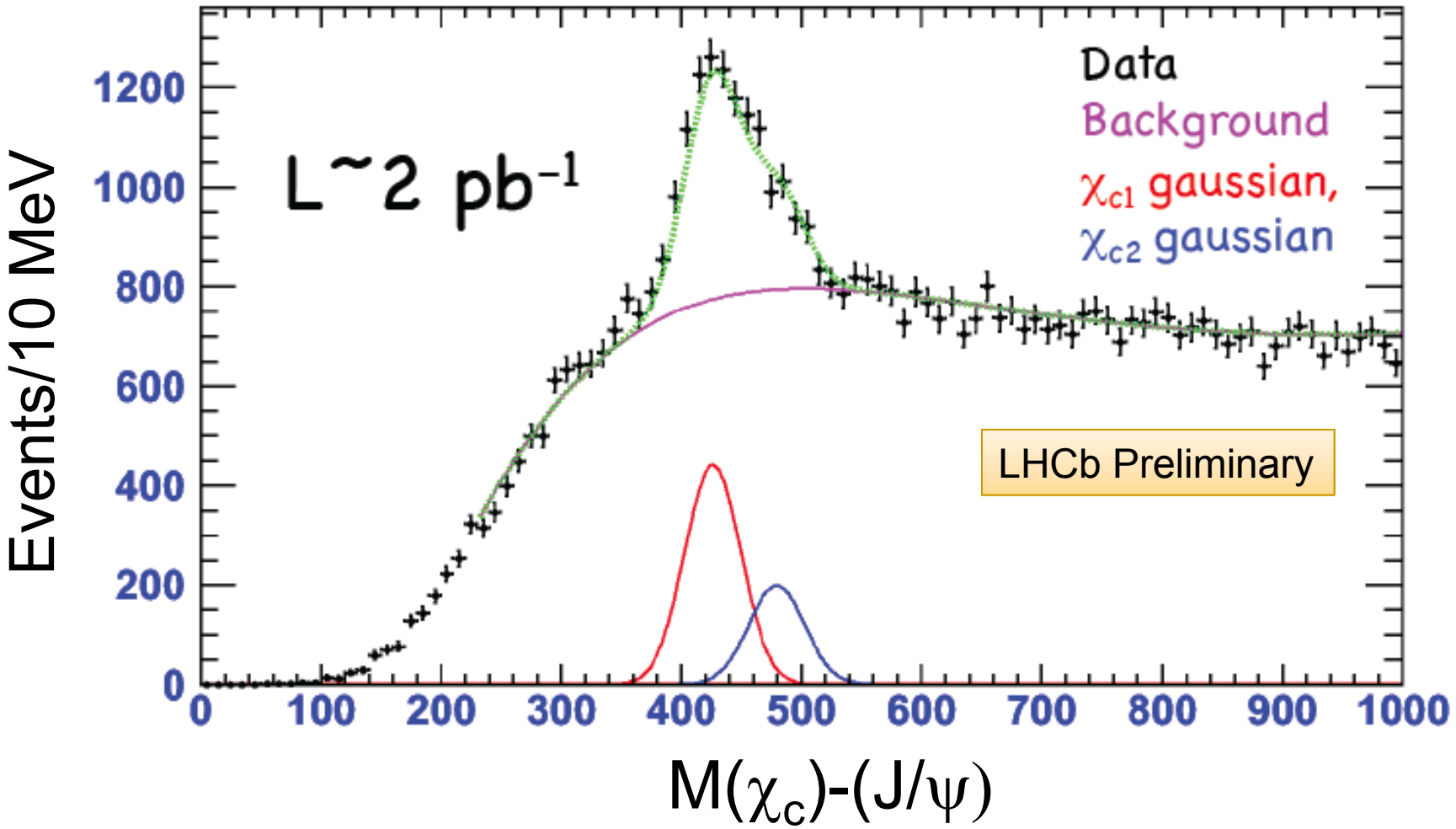


Adolescence: $\mu^+\mu^-$

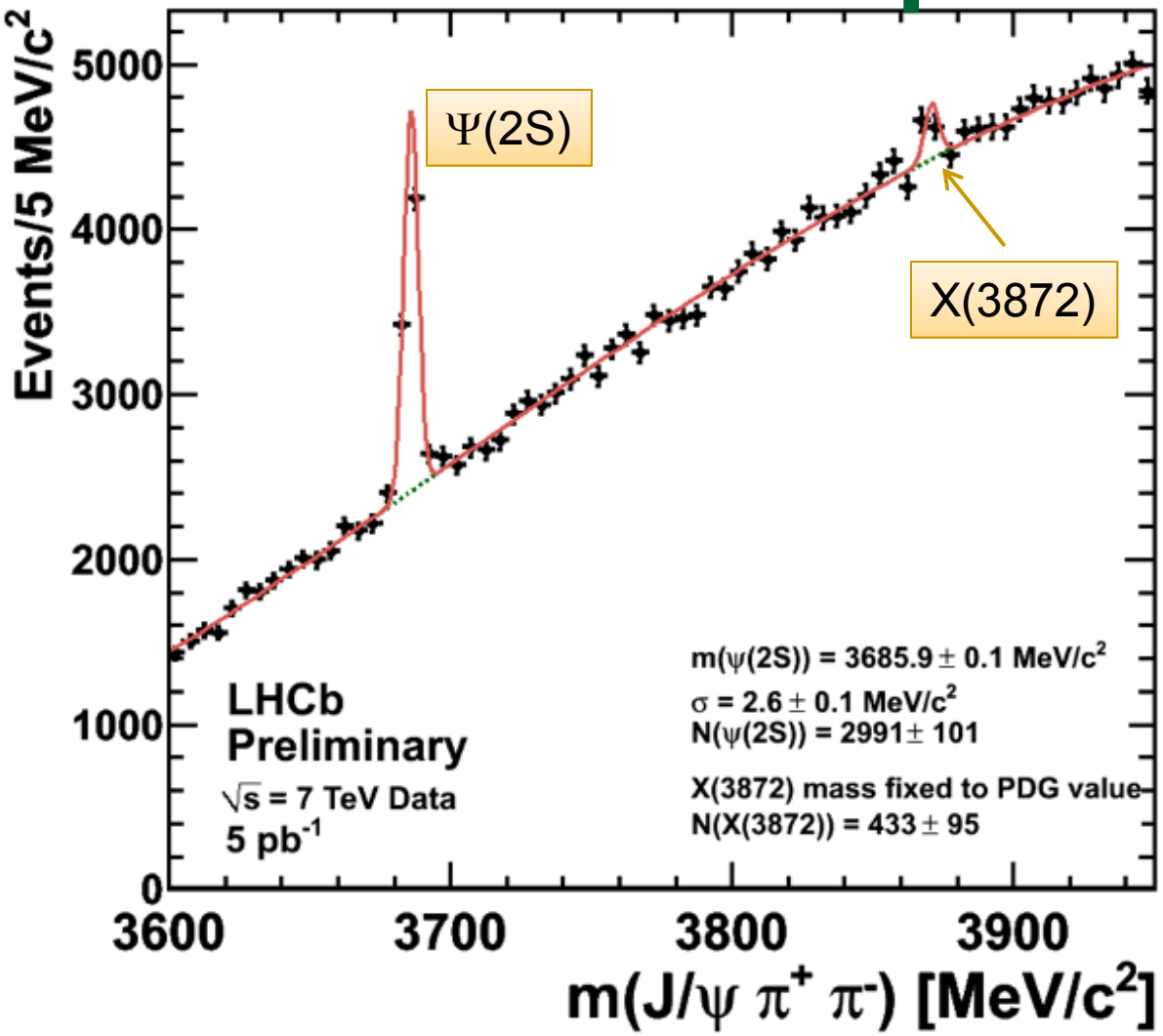
- Inclusive $J/\psi \rightarrow \mu^+\mu^-$



$\chi_c \rightarrow \gamma$ J/ψ

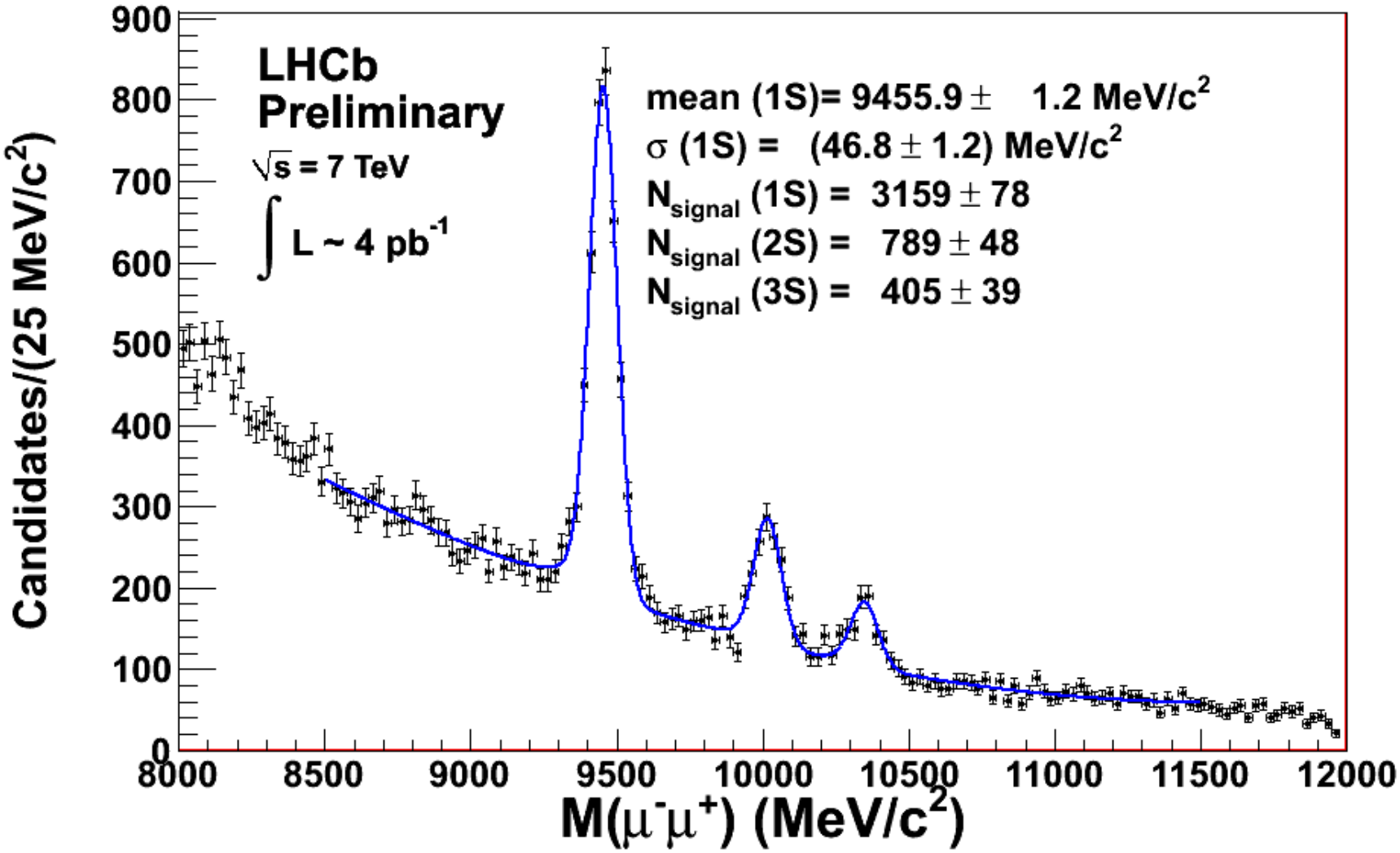


$J/\psi\pi^+\pi^-$



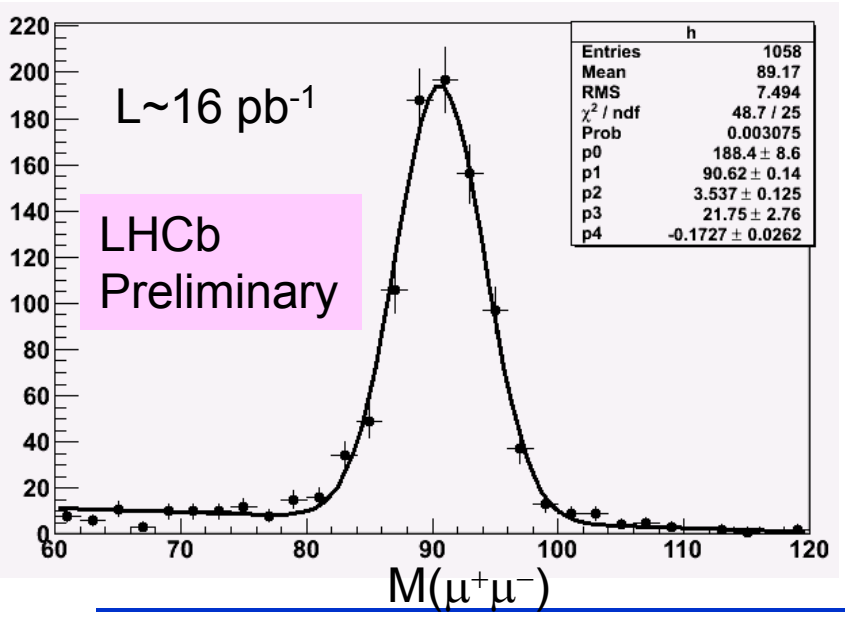
- #ψ(2s)=2991±101
- #X(3872)=433±95

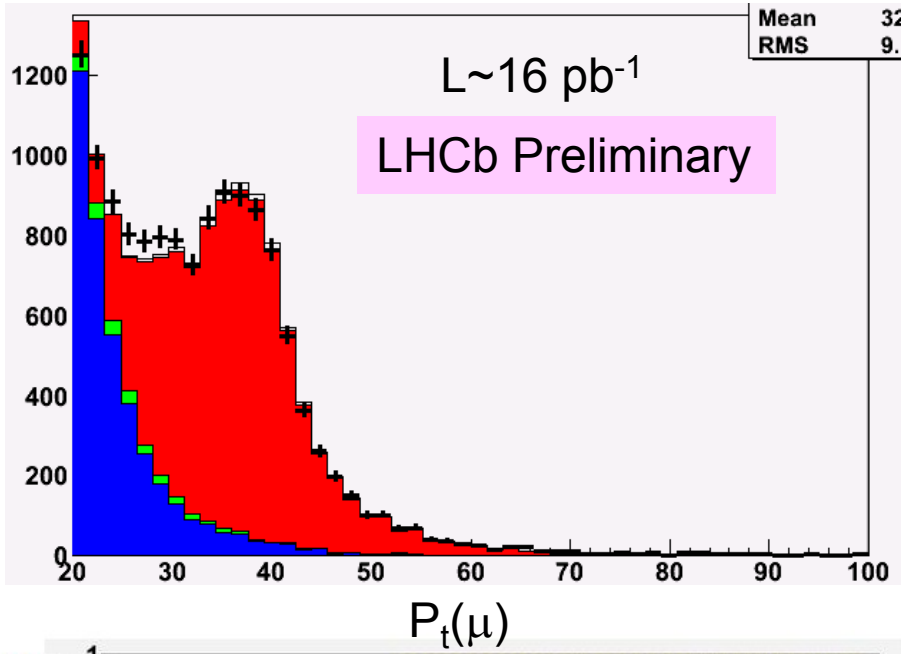
Upsilons too

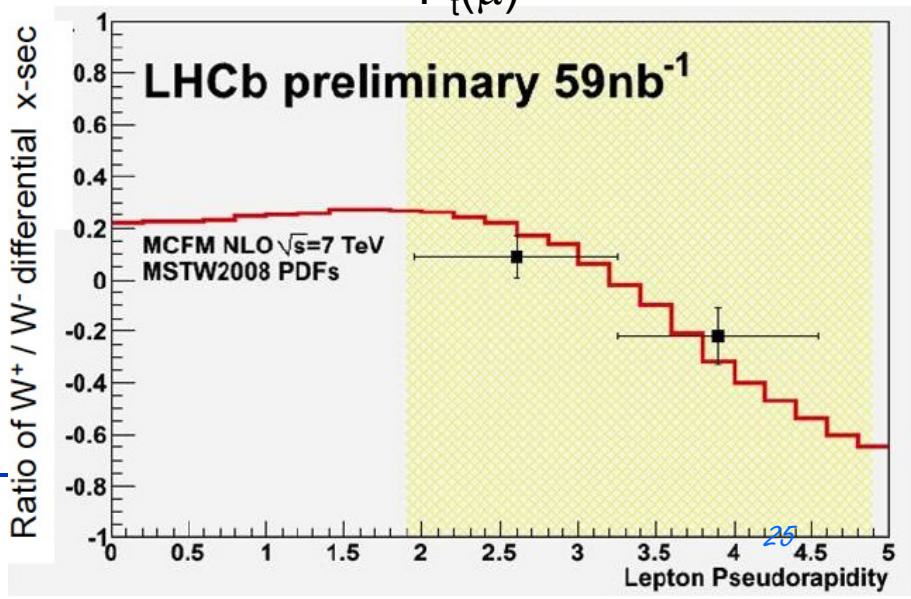


Z^0 & $W^{\pm}$

- Require two $\mu^+\mu^-$, each with p_t>20 GeV
- Require single isolated μ, with p_t>20 GeV & small p_t opposite

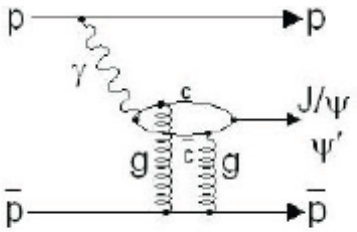


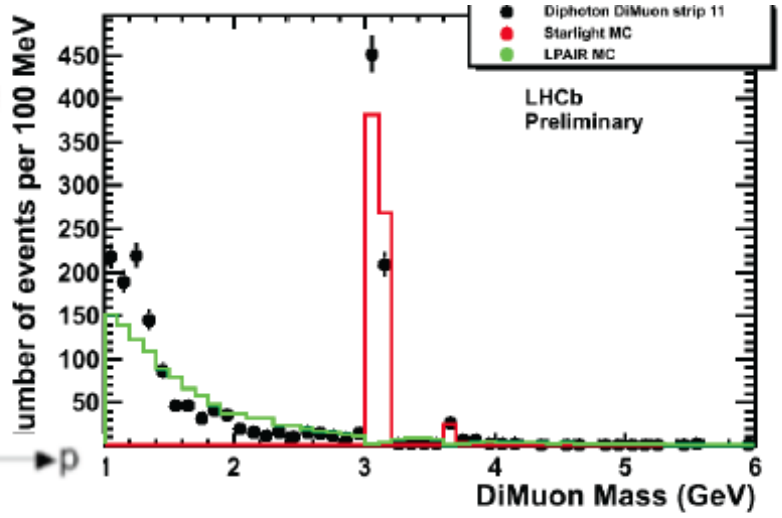


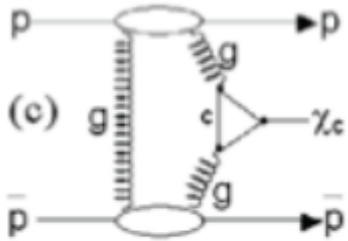


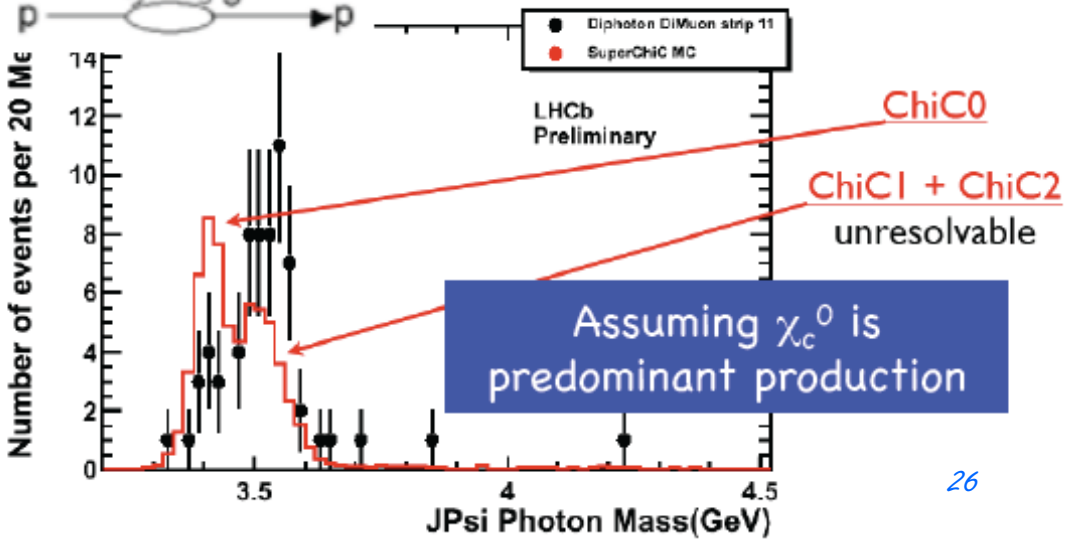
$pp \rightarrow pp J/\psi(\chi_c)$

- We can also do γ's π^o's
- 12 pb^{-1}
- "Standard Candle" QCD processes, arXiv: 1005.0695 [hep=ph]



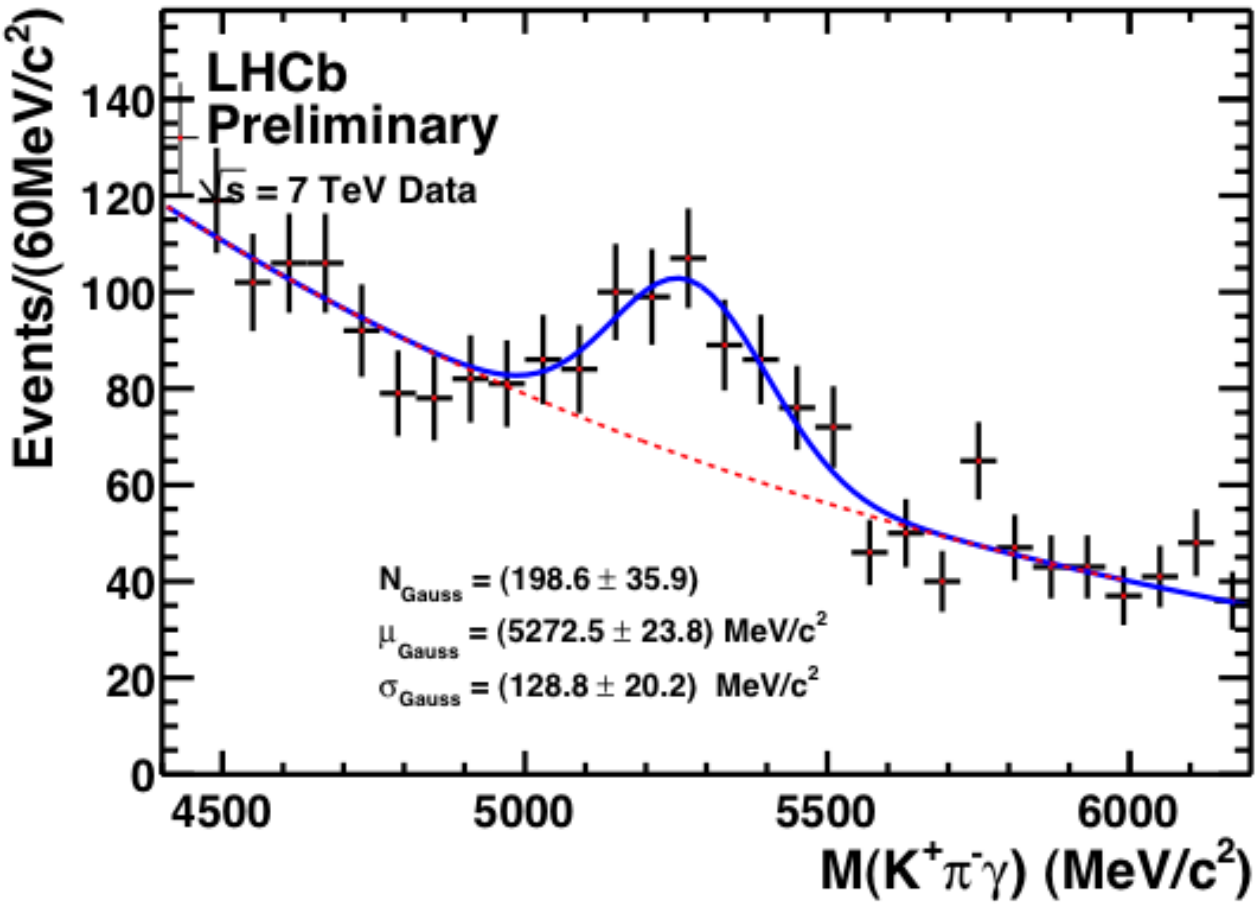






$B^0 \to K^{*0}\gamma$

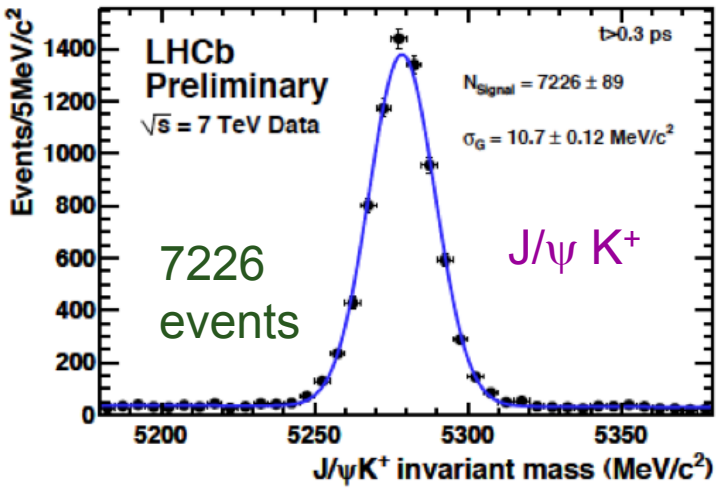
- 37 pb^{-1}
- 199 events

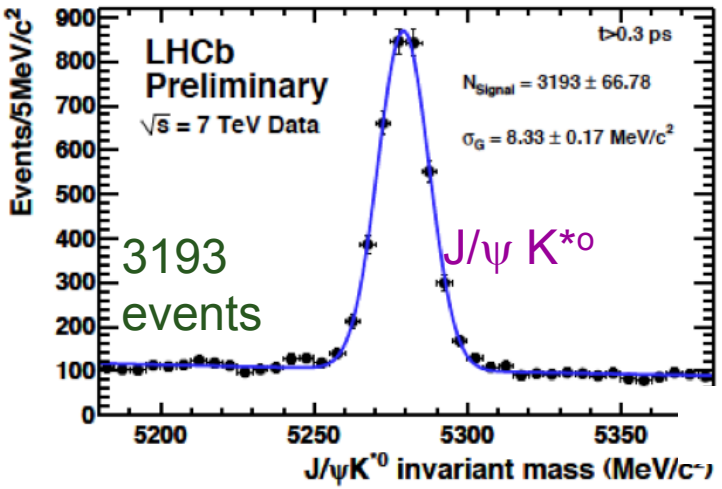


Fully Reconstructed Hadronic Decays

Needed for CP Violation Studies

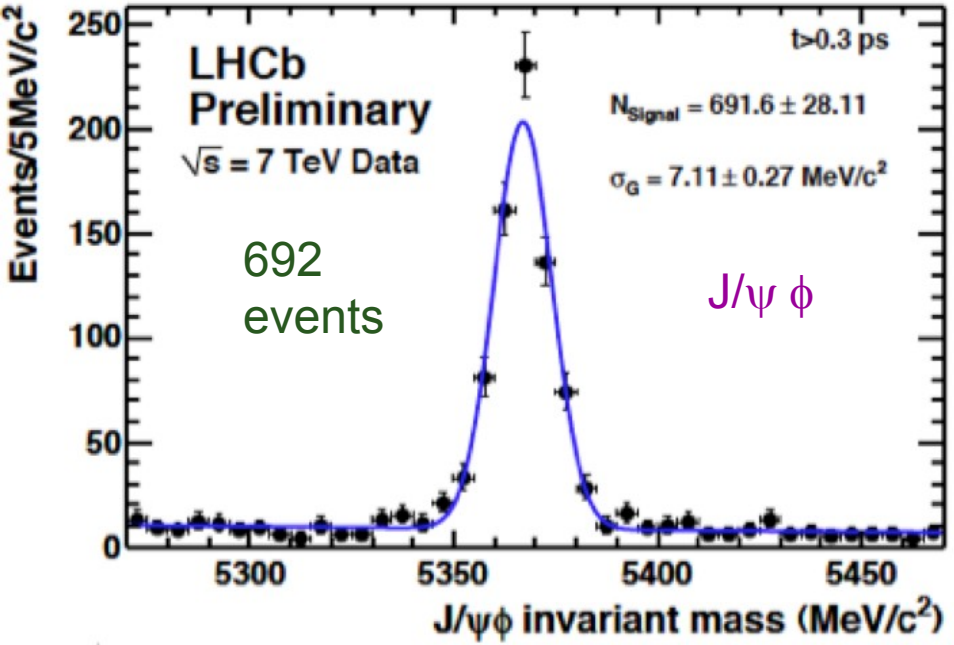
Exclusive B→ J/ψ h

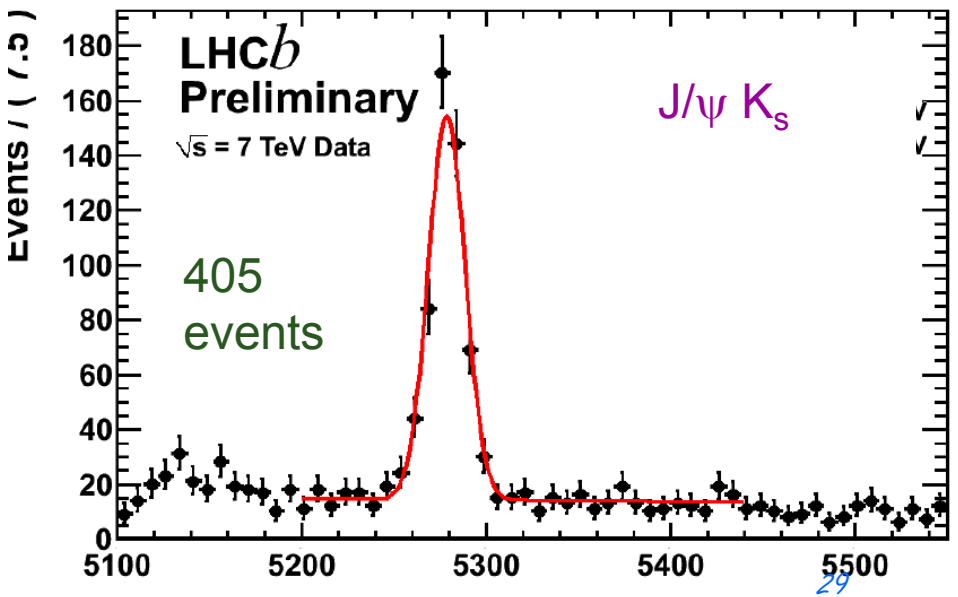




~15 pb^{-1}

$B(B\to J/\psi\, K^+)\bullet B(J/\psi\to\mu^+\mu^-)=6\times10^{-5}$



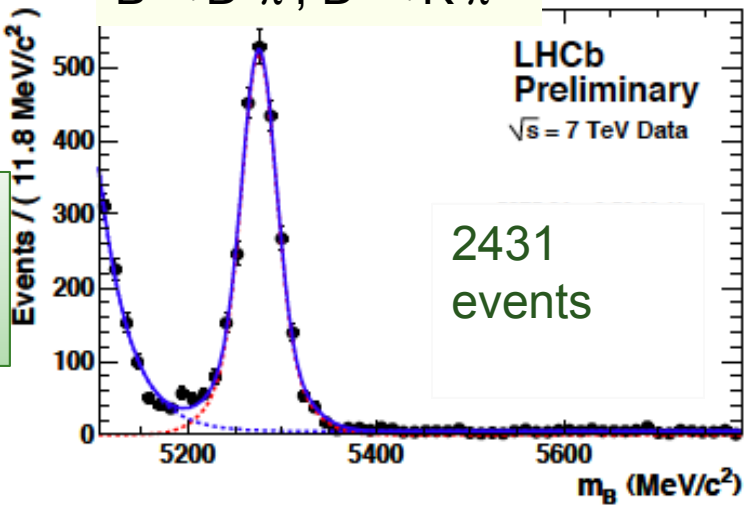


$B^- \to D^o h^-$

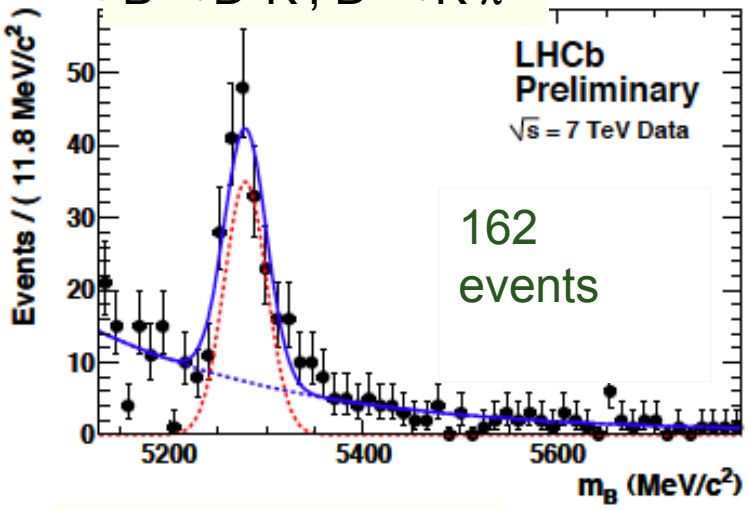
$B(B \to D^o \pi^-) \cdot B(D^o \to \pi^+ K^-) = 1.9 \times 10^{-4}$

~12 pb^{-1}

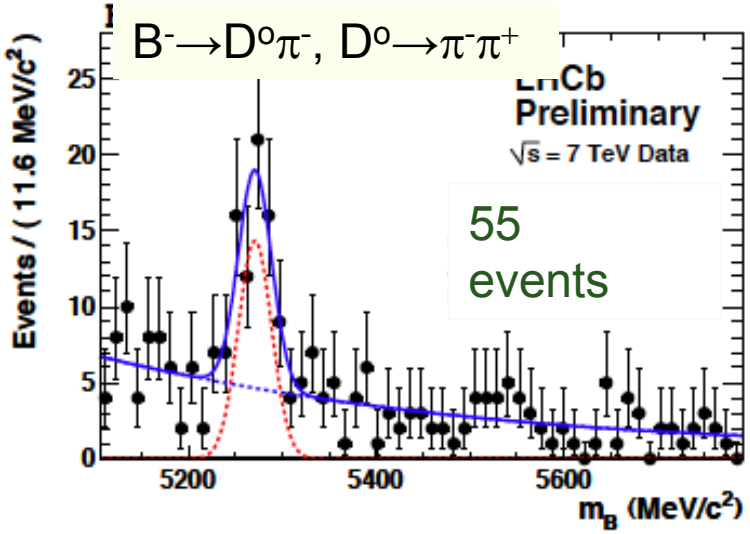
$B^- \to D^o \pi^-$, $D^o \to K^- \pi^+$



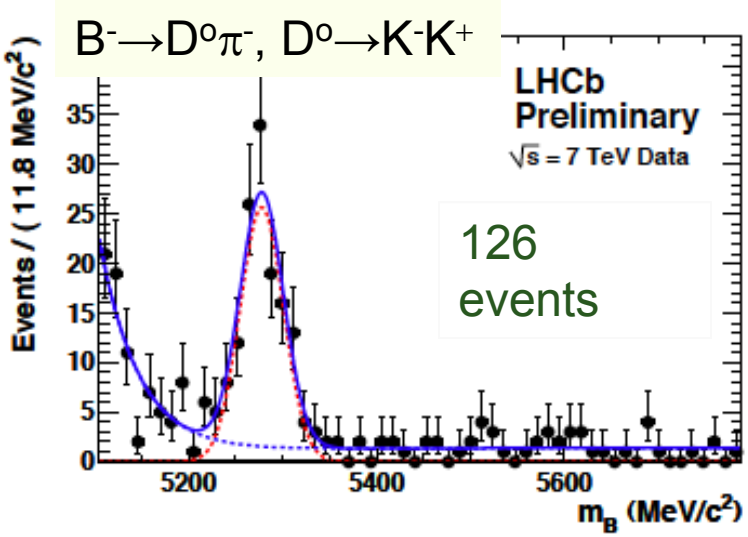
$B^- \to D^o K^-$, $D^o \to K^- \pi^+$



$B^- \to D^o \pi^-$, $D^o \to \pi^- \pi^+$

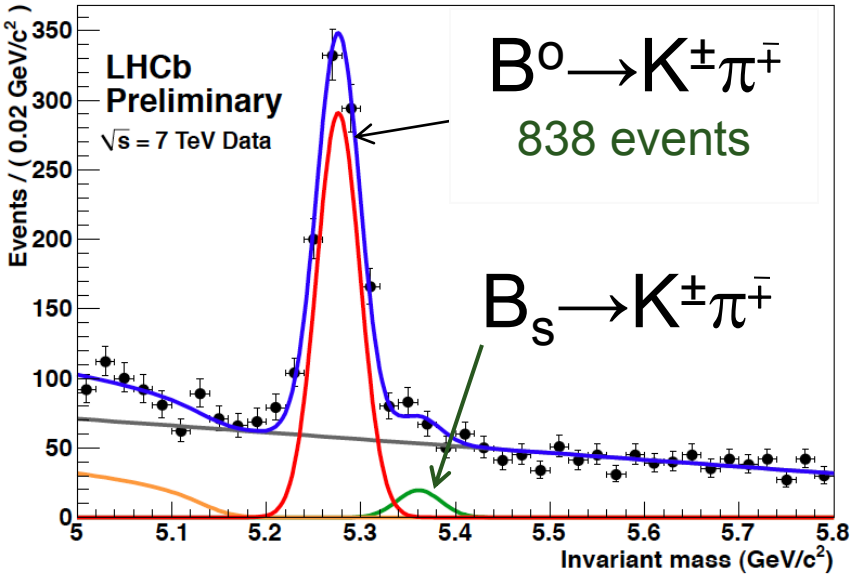


$B^- \to D^o \pi^-$, $D^o \to K^- K^+$

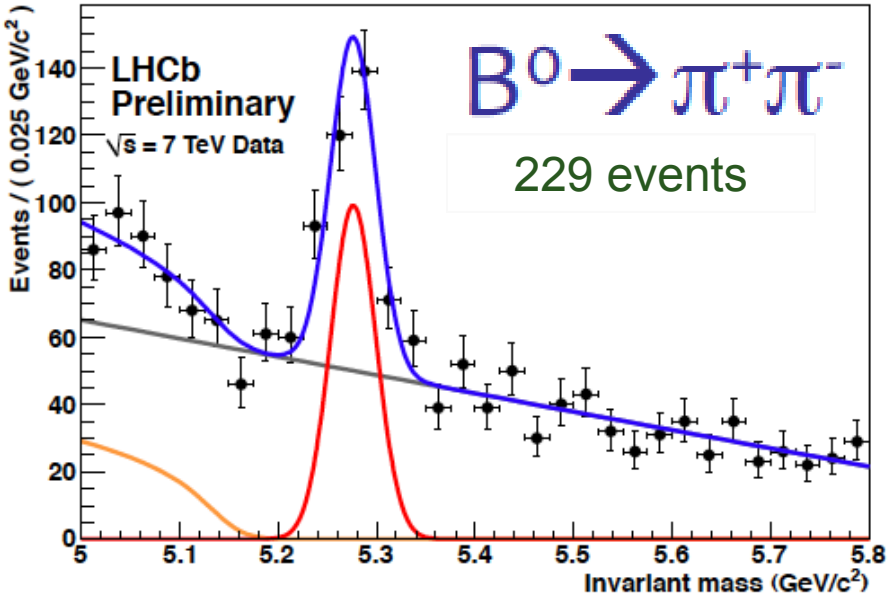


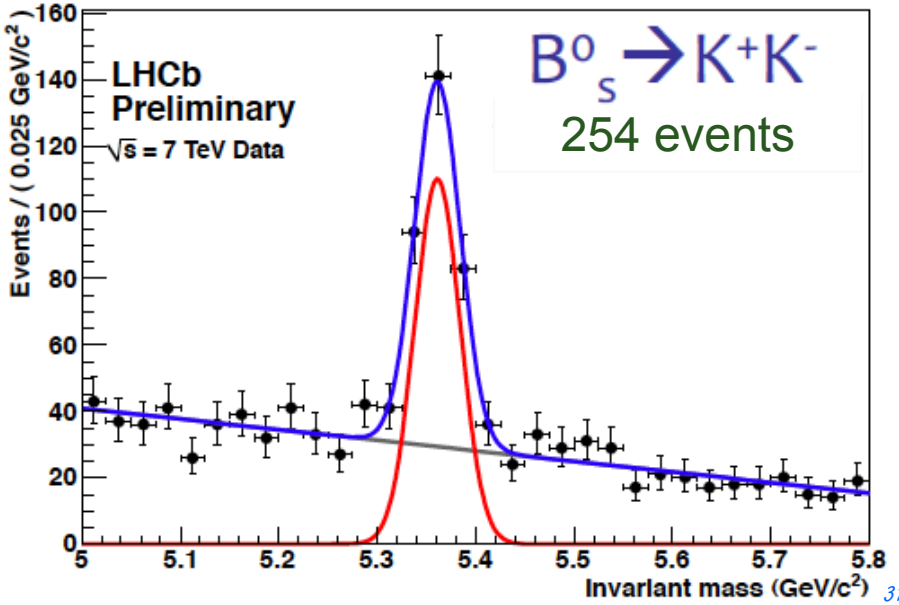
$B \to \pi K, \pi\pi, KK$

- 35 pb^{-1}, "loose cuts"
- We will get as many $K\pi$ in 0.5-0.7 fb^{-1} as Belle in 1000 fb^{-1}

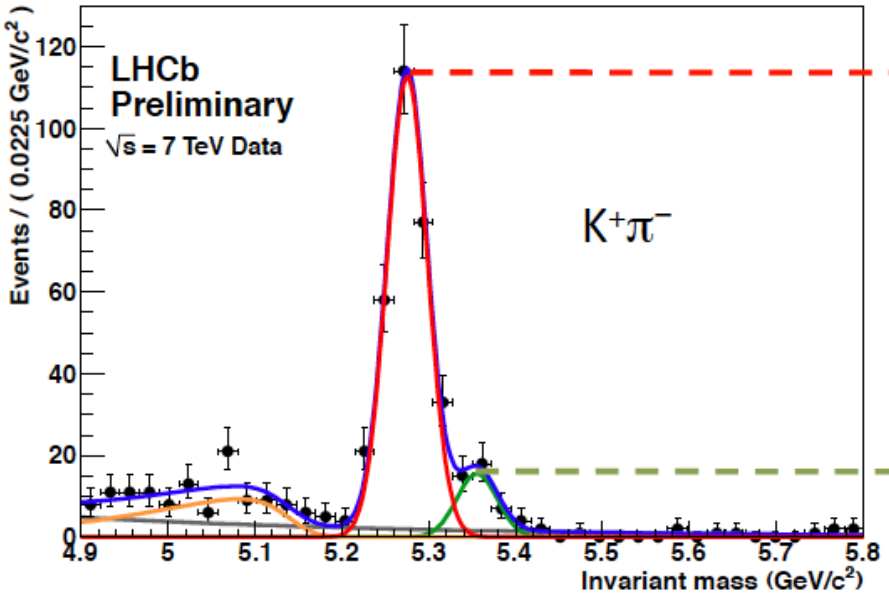


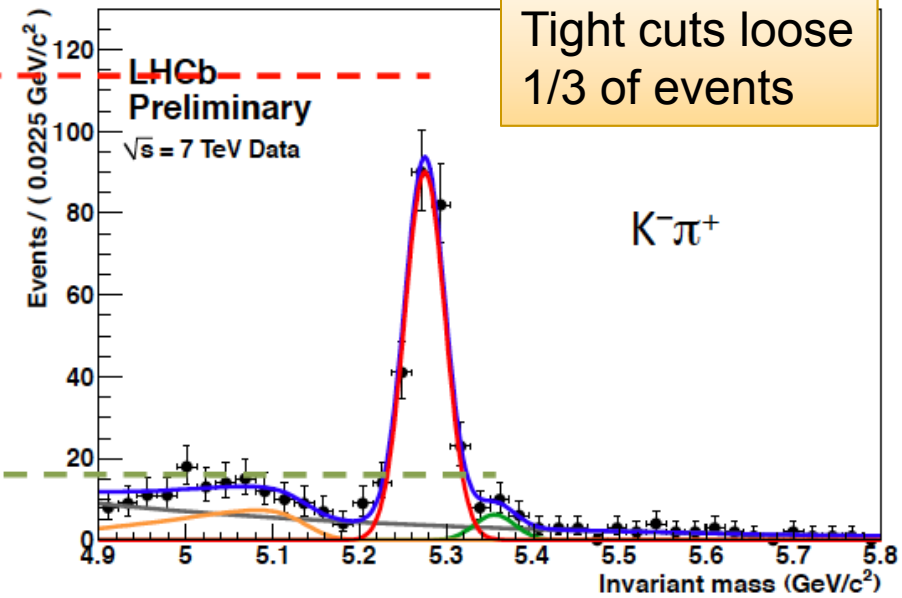
$B(B \to \pi^+\pi^-) = 5 \times 10^{-6}$





B→πK: CPV

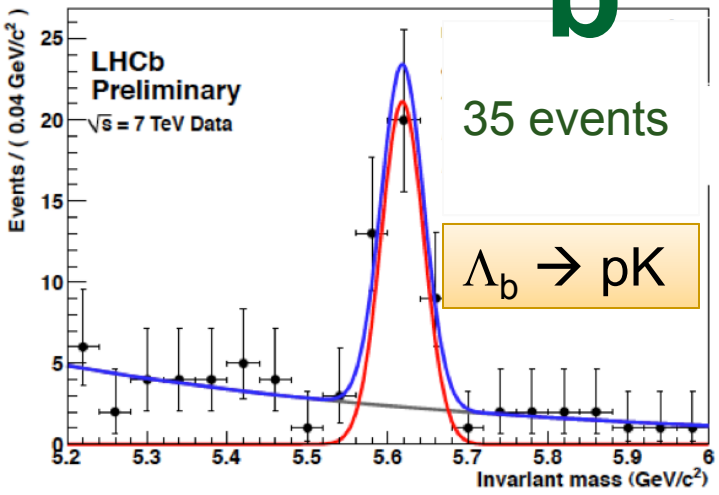




Tight cuts loose 1/3 of events

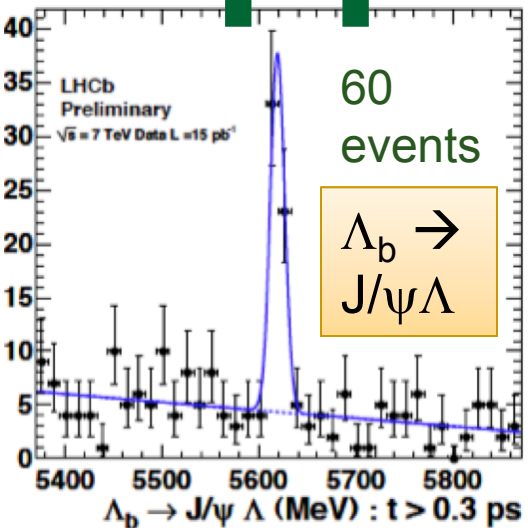
- B_s/B^o yield = (10.7±2.0)%, obvious CPV in both
- Using loose cuts $A_{CP}(B^o)$=-0.134±0.041 stat error only, no corrections (HFAG: -0.098±0.012)
- Using tight cuts $A_{CP}(B_s)$=-0.43±0.17 stat error only, no corrections (CDF: 0.39±0.15±0.08 in 1 fb^{-1})

Λ_b's appearing



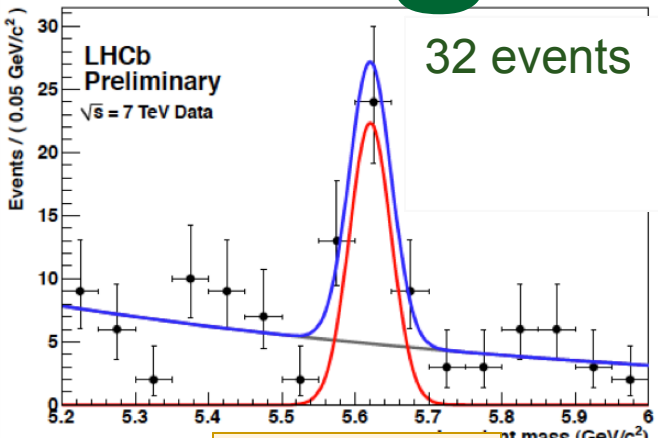
35 events

$\Lambda_b \rightarrow pK$



60 events

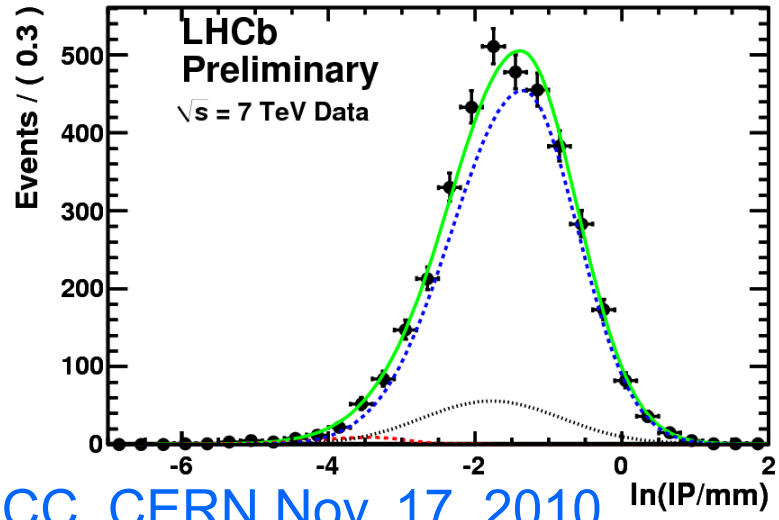
$\Lambda_b \rightarrow J/\psi\Lambda$

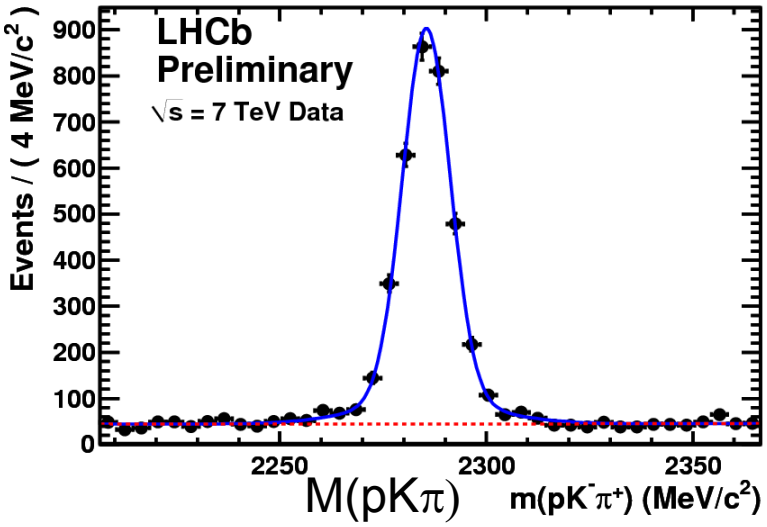


32 events

$\Lambda_b \rightarrow p\pi$

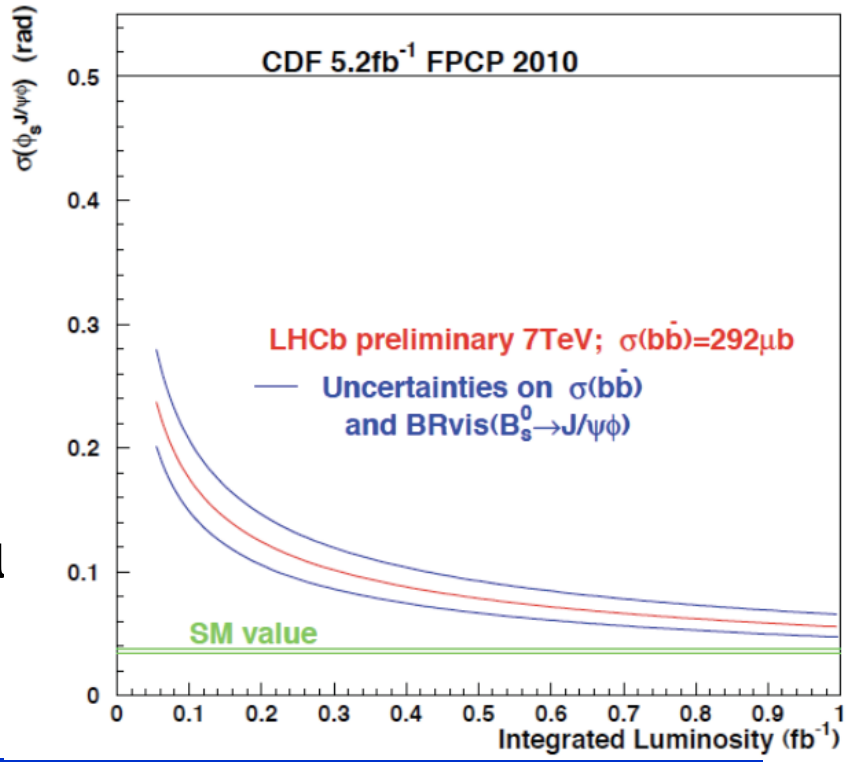
$\Lambda_b \rightarrow \Lambda_c^+ X\mu\nu,\ \Lambda_c^+ \rightarrow pK\pi$ Dfb = 3250±71



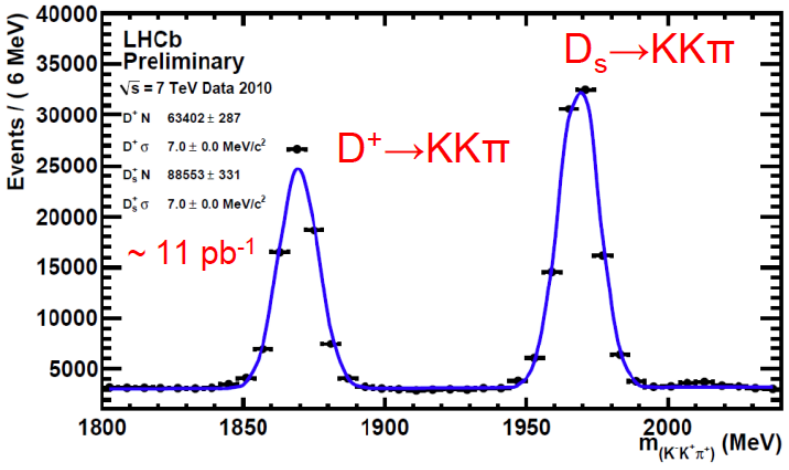


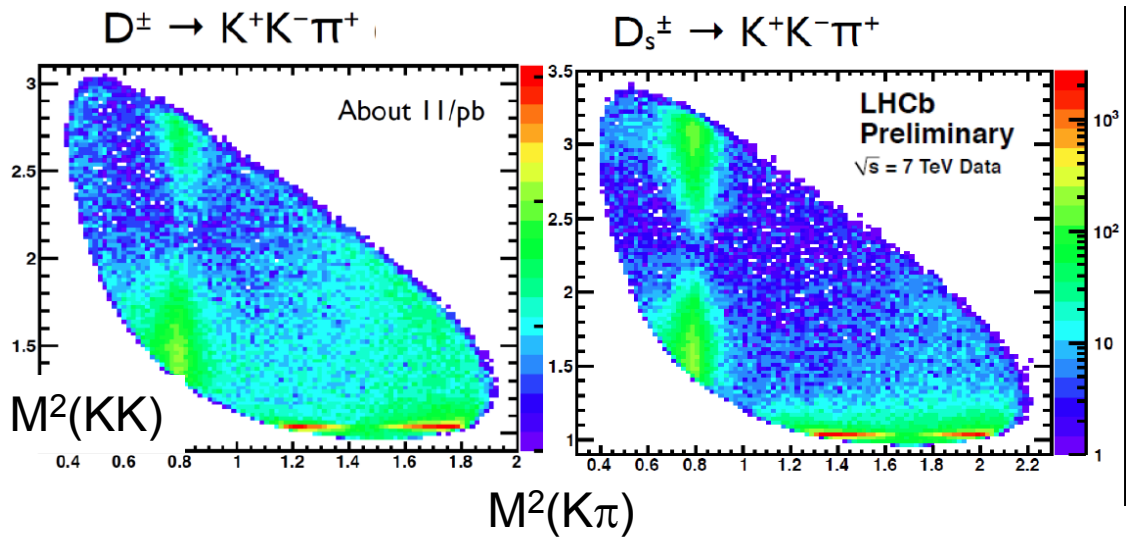
Expectations: Soldiering on

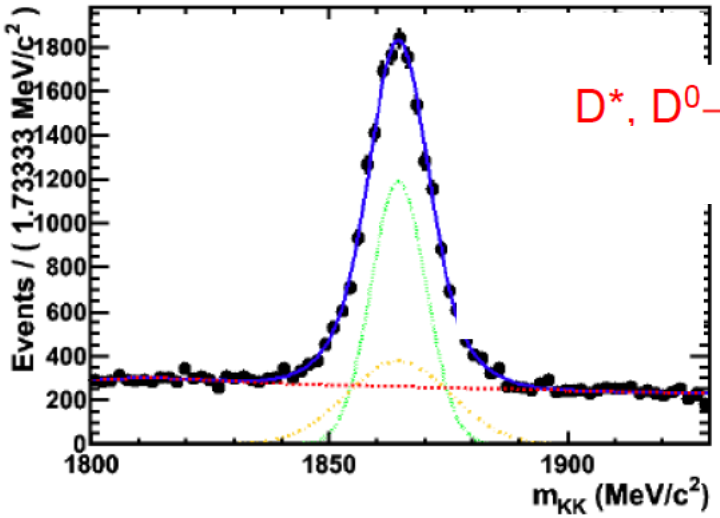
- Next year make world class measurements. With a few hundred pb^{-1} we believe we can begin to make more sensitive measurements than CDF & D0 in many cases. Ex: $B_s \rightarrow J/\psi\ \phi$
- We expect to reach sensitivities which are good enough to see NP in e.g. CPV in $J/\psi\ \phi$ + $J/\psi\ f_0, K^*\mu^+\mu^-$ angular distributions, $B_s \rightarrow \mu^+\mu$ charm CPV….

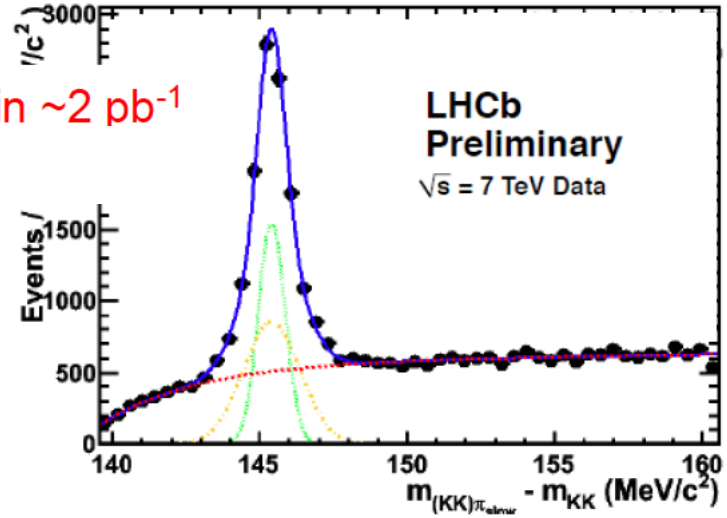


Great Prospects in Charm









Future acts: The LHCb Upgrade

- Run at 10^{33} cm^{-2}/s
- Requires that detector be readout at 40 MHz crossing rate $\Rightarrow$ new front end electronics for most of the detector
- Improve hadron trigger eff.
- Improve tracking, necessary due to large numbers of tracks in multiple interaction xings
- More radiation damage and trigger speed necessitates a new VELO based on pixels

Conclusions

- *"All the world's a stage, and all the men & women merely players; they have their exits and their entrances; & one man in his time plays many parts, his acts being seven ages. At first the infant…"*
- Perhaps we have reached adolescence
- Well known decays have been seen, & we have started to observe new decay modes
- We are ready to make the worlds best measurements next year & hopefully find evidence of something really interesting!
- We would love to get 1-2 fb^{-1} next year!

The End

All the world's a stage

- "All the world's a stage,
And all the men and women merely players;
They have their exits and their entrances;
And one man in his time plays many parts,
His acts being seven ages. At first the infant,
Mewling and puking in the nurse's arms;
And then the whining school-boy, with his satchel
And shining morning face, creeping like snail
Unwillingly to school. And then the lover,
Sighing like furnace, with a woeful ballad
Made to his mistress' eyebrow. Then a soldier,
Full of strange oaths, and bearded like the pard,
Jealous in honour, sudden and quick in quarrel,
Seeking the bubble reputation
Even in the cannon's mouth. And then the justice,
In fair round belly with good capon lin'd,
With eyes severe and beard of formal cut,
Full of wise saws and modern instances;
And so he plays his part. The sixth age shifts
Into the lean and slipper'd pantaloon,
With spectacles on nose and pouch on side;
His youthful hose, well sav'd, a world too wide
For his shrunk shank; and his big manly voice,
Turning again toward childish treble, pipes
And whistles in his sound. Last scene of all,
That ends this strange eventful history,
Is second childishness and mere oblivion;
Sans teeth, sans eyes, sans taste, sans everything." — Jaques (Act II, Scene VII, lines 139-166)