

# Ricerca e studio di stati esotici *charmonium-like* in



## Attività di ricerca del II anno di Dottorato in Fisica XXIX ciclo

**Dottorando**

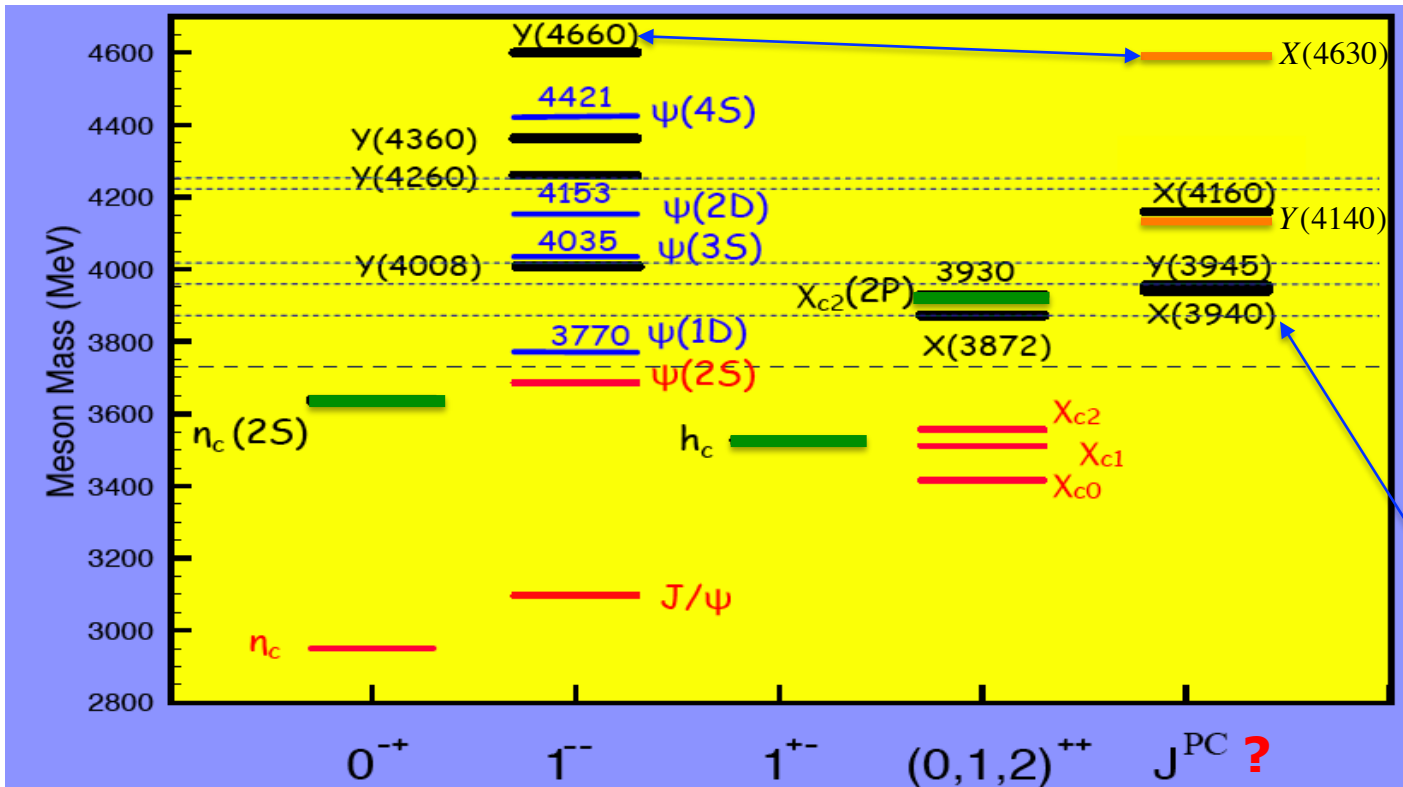
Leonardo Cristella

**Tutore**

Dott. Alexis Pompili

# Exotic charmonium

- ▶ In the last 10 years ~20 new states have been observed (known as **X, Y, Z states**) above this threshold
- ▶ They are inconsistent **with expected charmonium spectrum** (even if threshold effect might deform the spectrum)
- ▶ **Above/below** the  $D_{(s)}^{(*)}\bar{D}_{(s)}^{(*)}$  threshold these states should be **large/narrow**
- ▶ Quantum numbers still not experimentally established for many of them



$Z(4430)^+$   
 $Z_2(4250)^+$   
 $Z_1(4050)^+$   
 $Z(3900)^+$   
**charged states with hidden charm**

$X(3915)/Y(3915)$

# Motivation of the $Z(4430)^-$ search analysis

➤ The  $Z(4430)^-$  has been observed by Belle experiment in 2008 (but not by BaBar).

The Belle collaboration dedicated 3 PRD papers to the observation with 3 different analyses and increasing refinement:

PRL 100:142001 (2008)  
PRD 80:031104 (2009)  
PRD 88:074026 (2013)

Discovery exclusive decay mode:  $B^{-,0} \rightarrow Z(4430)^- K^{0,+} \rightarrow [\psi(2S)\pi^-] K^{0,+}$

➤ In 2014 Belle found evidence ( $4\sigma$ ) of  $B^0 \rightarrow Z(4430)^- K^+ \rightarrow [J/\psi\pi^-] K^+$

➤ LHCb recently confirmed  $Z(4430)^-$  ( $m = 4475\text{MeV}$ ,  $\sigma = 172\text{MeV}$ ) applying exactly Belle's method<sup>[1]</sup>.

➤ Both experiments showed evidence of **further states**:

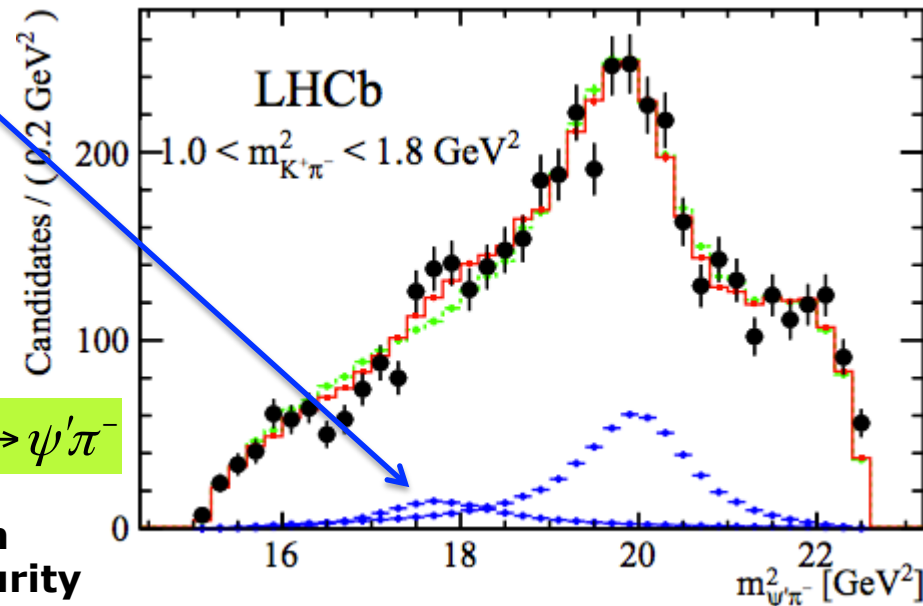
[1] PRL 112, 222002 (2014)

- $Z_c(4240)$  in the  $\psi(2S)\pi$  system (LHCb)
- $Z_c(4200)$  in the  $J/\psi\pi$  system (Belle).

➤ In CMS we can perform two complementary searches :

➤ **Inclusive search:**  $pp \rightarrow Z(4430)^- X, Z^- \rightarrow \psi'\pi^-$

➤ **Exclusive search** like Belle (starting from the  $B^0$  3-body decay) [it requires high purity sample to perform an Amplitude Analysis]



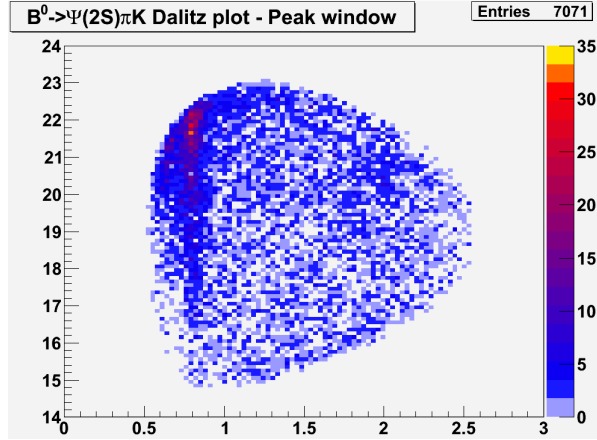
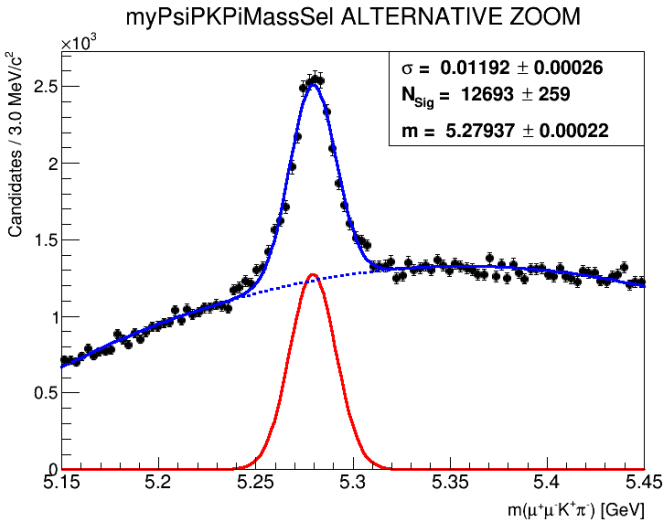
# Exclusive search

➤ By considering an additional track w.r.t the inclusive search, we reconstructed the

$B^0 \rightarrow \psi(2S)K^+\pi^-$

decay channel:

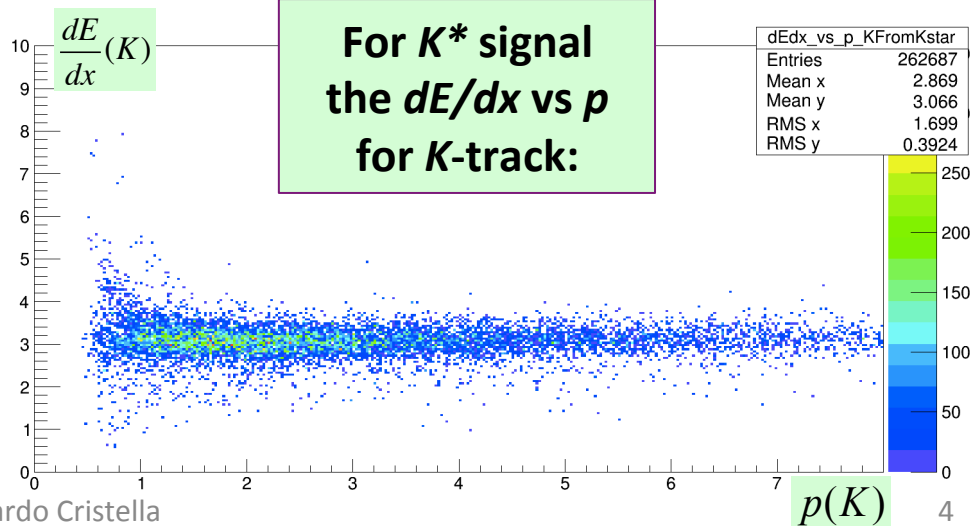
➤ In order to identify and separate kaons from pions, we explored the possibility of using the  $dE/dx$  information of the tracks, measured by the CMS silicon tracker.



$B^0 \rightarrow \psi(2S)K^{*0}[\rightarrow K\pi] : dE/dx \text{ for the "kaon"-track}$

➤ We assign the Kaon mass hypothesis to the  $B^0$  daughter with lower momentum.

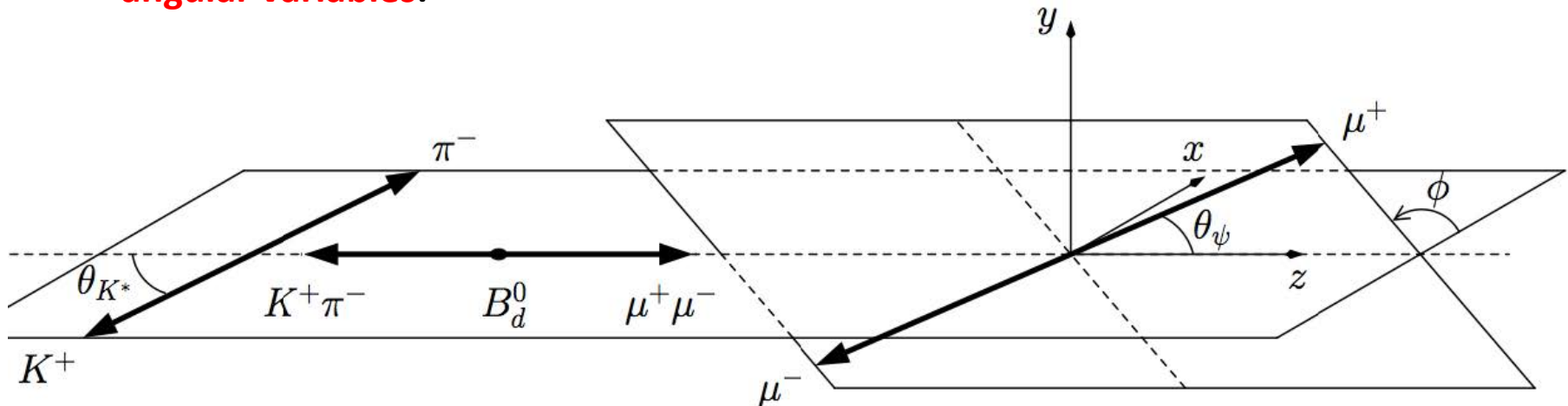
This is not optimal but we checked a-posteriori that this is the most likely choice.



# MC studies

Several Monte Carlo samples (up to 12M events) have been generated in order to:

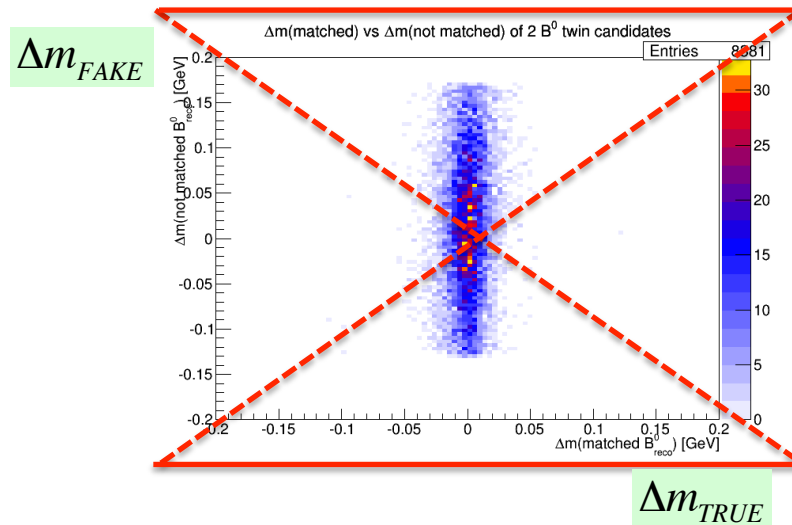
1. establish selection criteria to apply in case of events with **more than one  $B^0$  candidate**
2. determine the **reconstructed interaction vertex** which better represents the generated one
3. evaluate the effects of eventual **reflections from other decay channels**
4. evaluate the **reconstruction efficiency** both on the **Dalitz Plot** and on the **angular variables**:



## 2 $B^0$ candidates events

Taking into account events in which both tracks' mass assignments ( $K_1\pi_2$  and  $K_2\pi_1$ ) generate a  $B^0$  candidate which satisfies the selection criteria, we performed a MC truth matching of the two  $B^0$  candidates w.r.t. the generated  $B^0$  meson

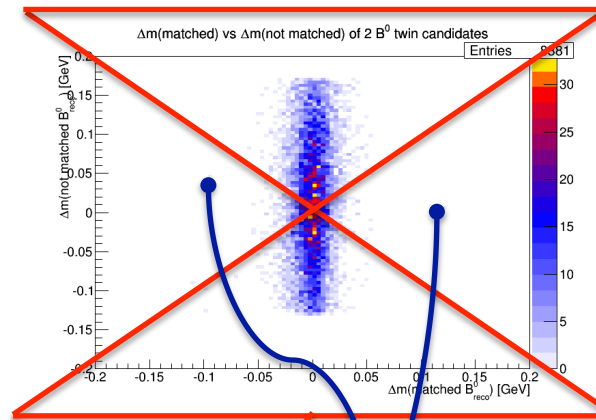
➤ The great majority of the couples have one true and one false candidate, thus we plot  $\Delta m_{TRUE}$  vs  $\Delta m_{FAKE}$  as in the following scatter plot:



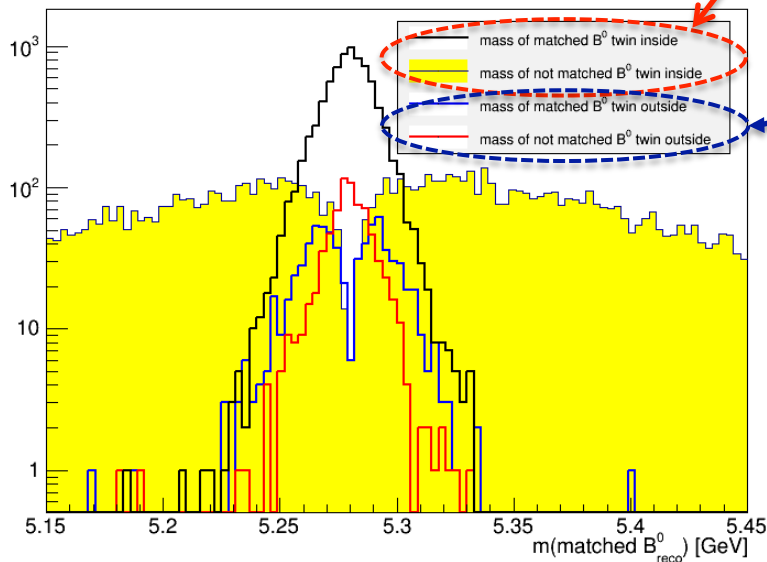
➤ Behavior is as expected: a vertical band, narrow in  $\Delta m_{TRUE}$  (about  $\pm 30 \text{ MeV} \cong \pm 3\sigma$ , as the signal region) and wide in  $\Delta m_{FAKE}$  (spanning the whole sidebands).

➤ All the entries INSIDE the **hourglass region** are characterized by:  $\Delta m_{TRUE} < \Delta m_{FAKE}$ . This means that by using a method that chooses the candidate closest to the  $B^0$  nominal mass we would select the true candidate and discard the fake one. **However** in the signal region it happens to have twins outside the hourglass...

# Hourglass regions



mass of matched  $B^0$  twin inside



By applying - in the data - the method to choose that candidate (between the twins) having the mass *closest* to the nominal  $B^0$  mass we would ...

- loose a bit of **signal** due to **true  $B^0$  cand**s
- reject some **contamination** due to **fake  $B^0$  cand**s
- admit **fakes (yellow)** in the signal region at a level equal (or even lower) to the level of the sidebands

# Comparison between Generated PV & Reconstructed PVs

➤ In each event several Primary Vertex (PV) can be defined.

➤ We consider **6 different reconstructed PVs** :

1) "standard": PV from *OfflinePrimaryVertices list* with highest  $\Sigma_{\text{tracks}}(p_T)^2$

2) the "B<sup>0</sup>-less" PV obtained as follows:

remove the daughters of the B<sup>0</sup> (vertexed at the secondary vertex) from the track collection, derive a new *OfflinePrimaryVertices list* collection and take the PV with highest  $\Sigma_{\text{tracks}}(p_T)^2$

{3,4}) the "best  $\cos(\alpha_{\{2D,3D\}})$ " PV chosen the from the list used in (1) that minimizes the pointing angle {in the transverse plane, in 3D}

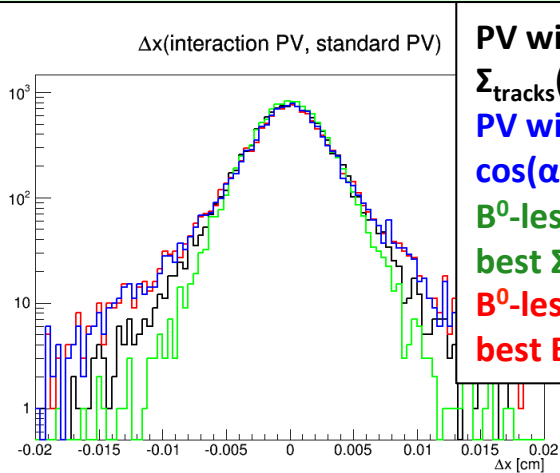
{5,6}) the "best  $\cos(\alpha_{2D(3D)})$ " PV chosen the from the list used in (2) that minimizes the pointing angle {in the transverse plane, in 3D}

➤ We finally compare  **$\Delta x$ ,  $\Delta y$ ,  $\Delta z$  distributions** for each of these 6 PVs w.r.t. the interaction vertex (namely the generated PV)!

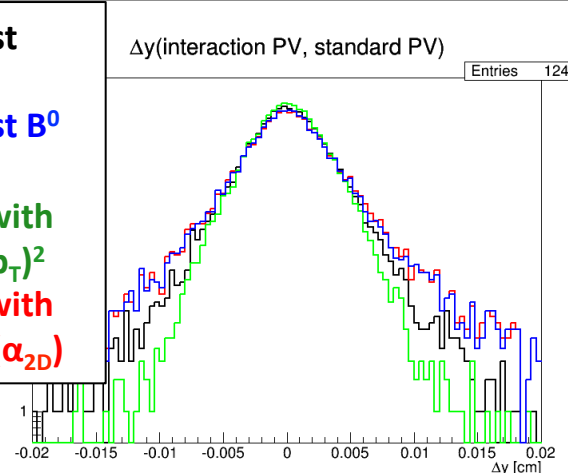


# $\Delta x, \Delta y, \Delta z$ distributions

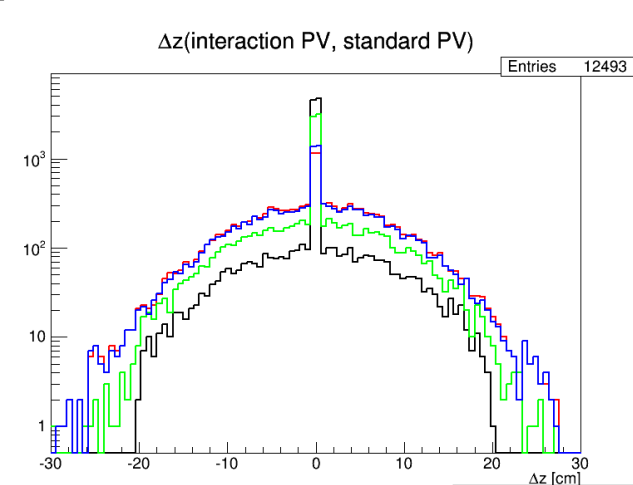
$\Delta x$  (interaction PV, reco PV)



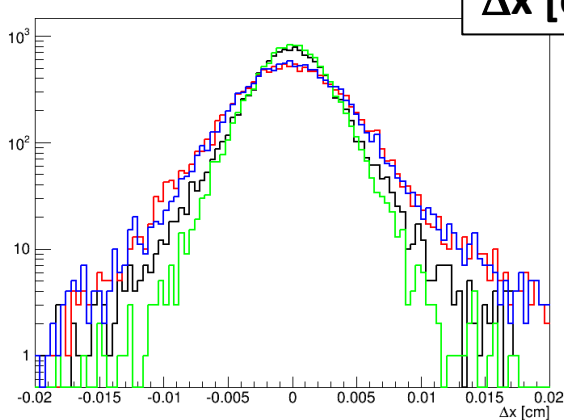
$\Delta y$  (interaction PV, reco PV)



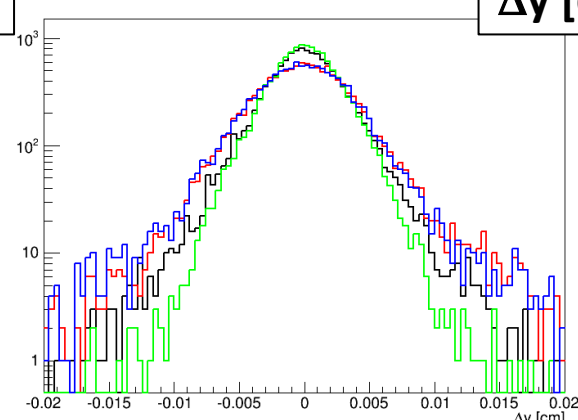
$\Delta z$  (interaction PV, reco PV)



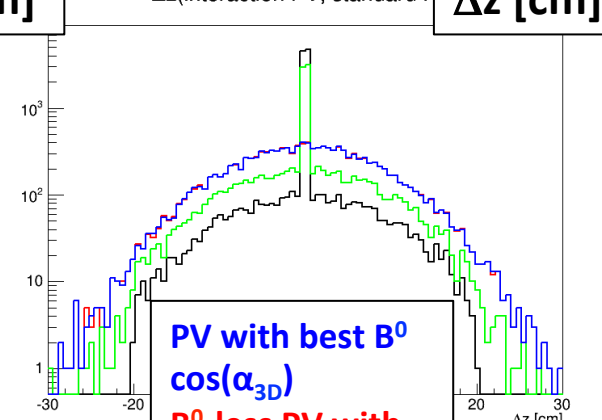
Δx(interaction PV, standard PV)



Δy(interaction PV, standard PV)



Δz(interaction PV, standard PV)

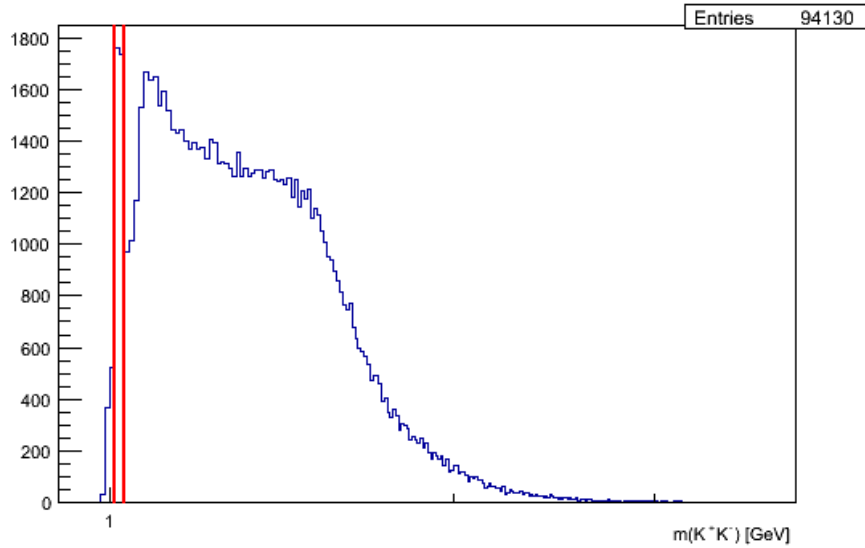


➤ The  $B^0$  less PV performs better than the standard PV for the x and y coordinates.

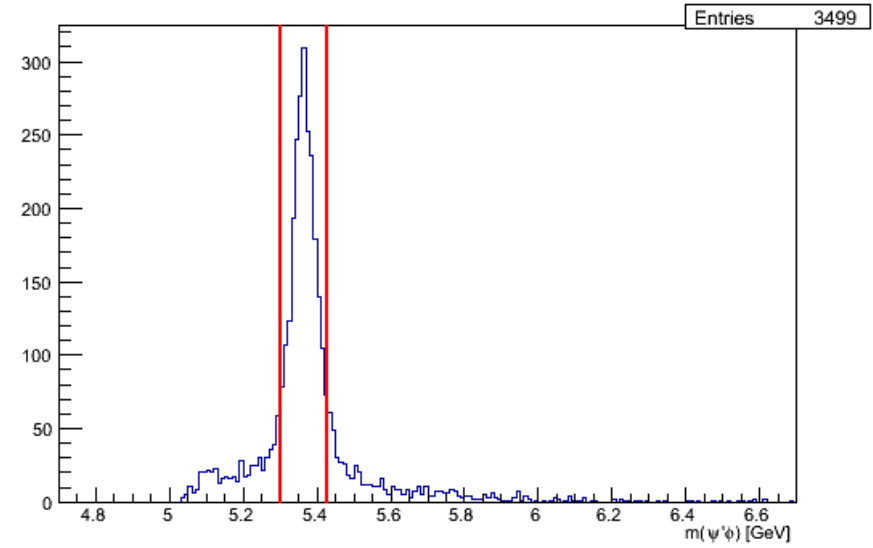
➤ We have added the PV with best 3D pointing angle but it seems that it performs worse than the 2D one, especially for the z coordinate.

# $B_s$ reflection in $\psi' \pi^- K^+$

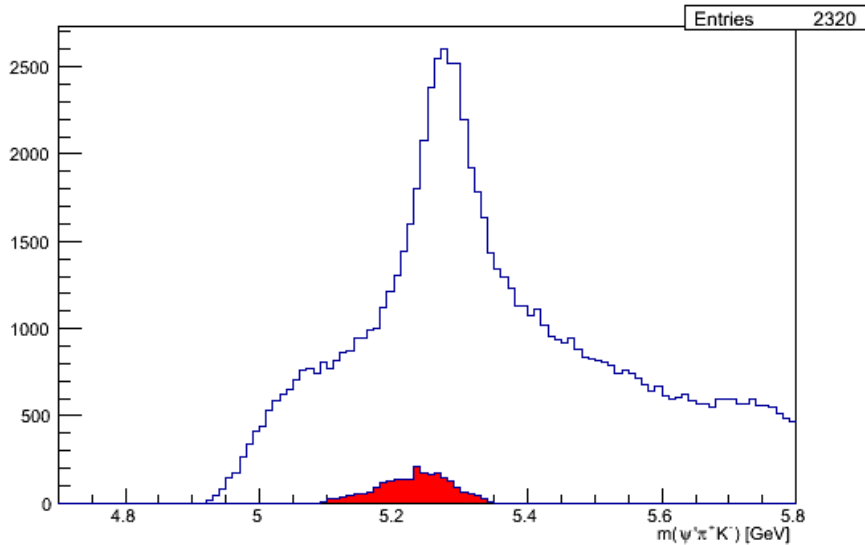
KK mass



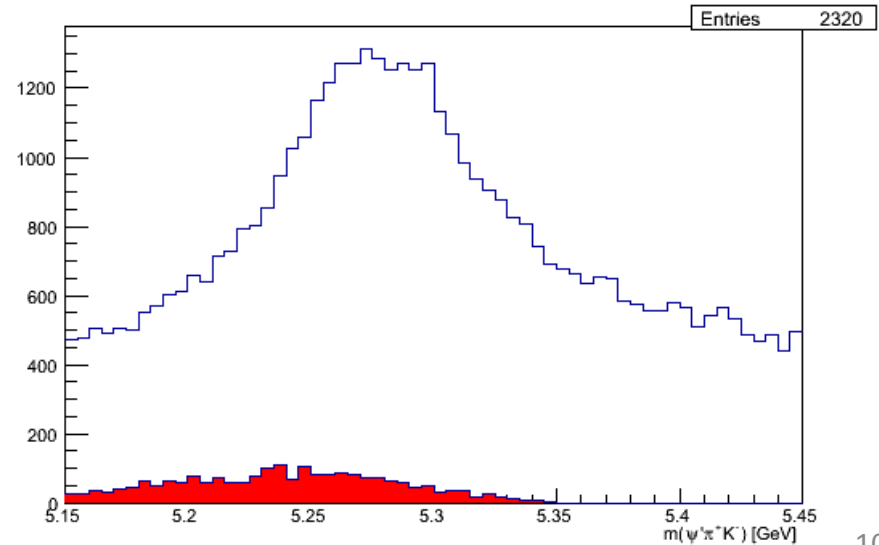
PsiPPhi mass



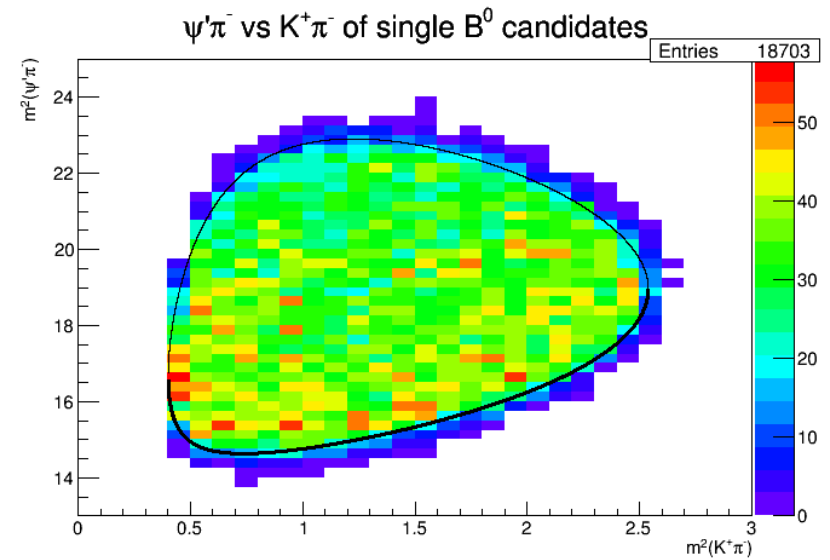
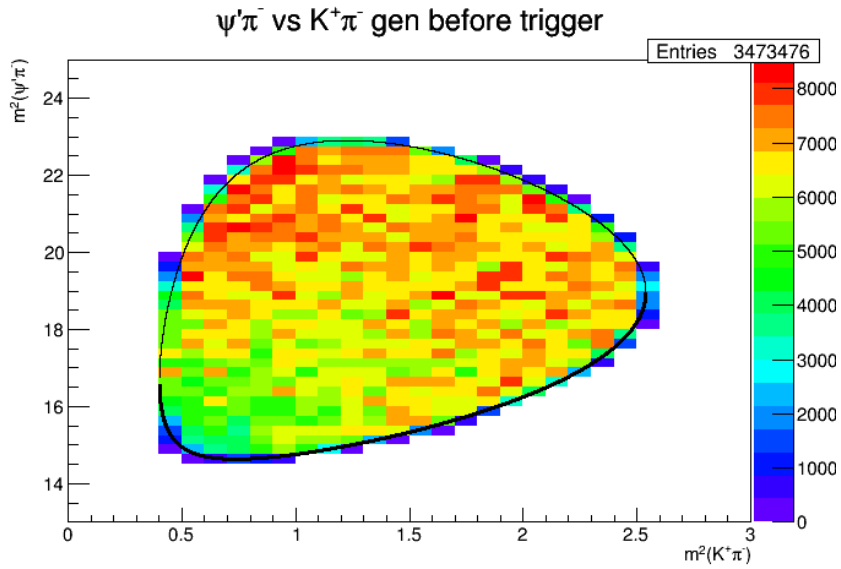
PsiPPiK mass



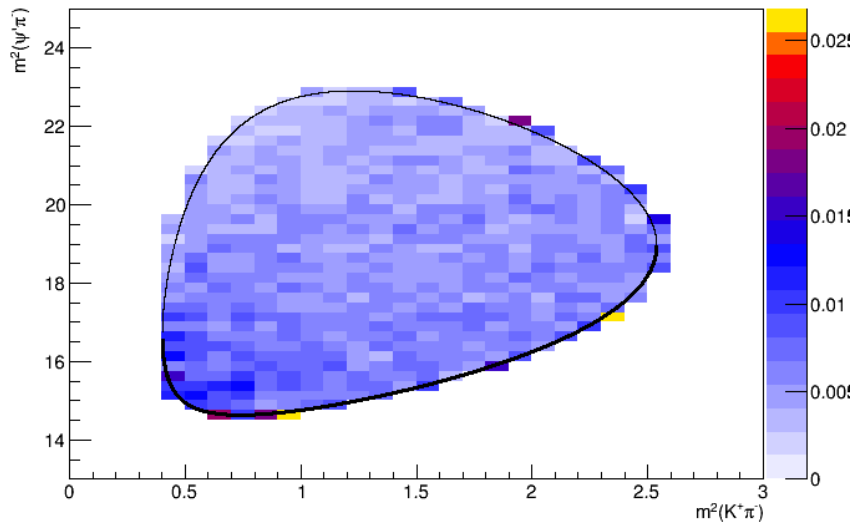
PsiPPiK mass



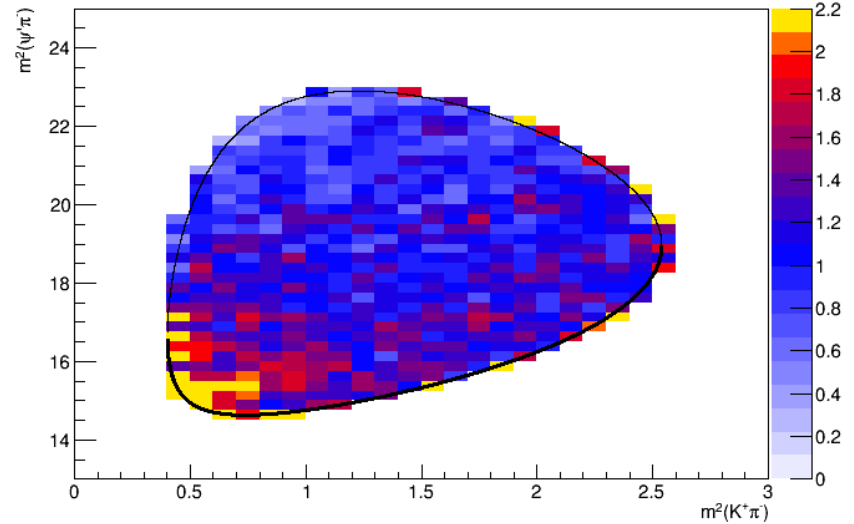
# Ingredients to obtain relative reconstruction efficiency over the Dalitz Plot



# Absolute and relative reconstruction efficiency over the Dalitz Plot



**Absolute efficiency**

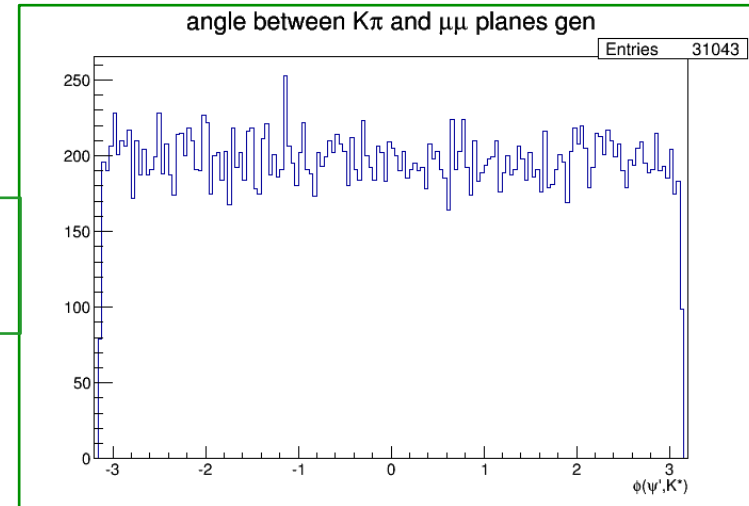
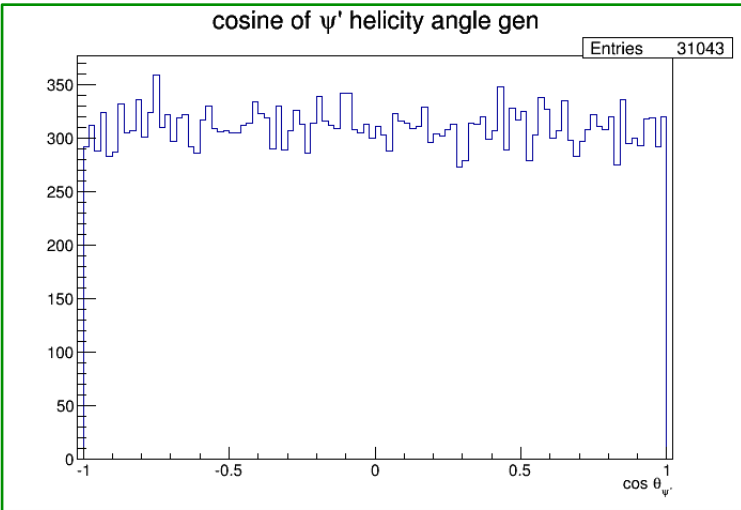


**Relative efficiency**

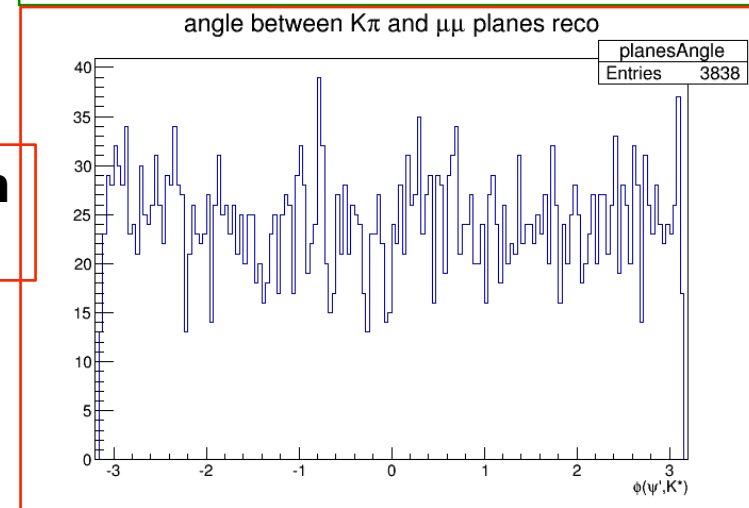
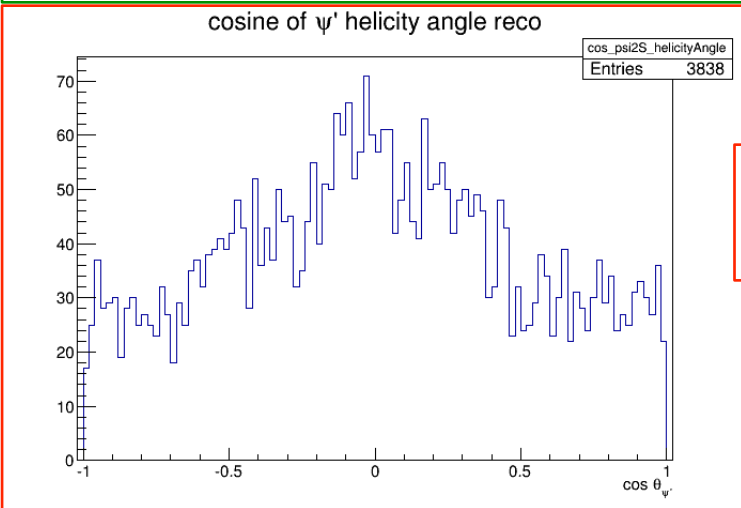
# Gen/Reco angles

➤  $\psi(2S)$  helicity angle

➤ angle between  $\psi(2S)$  decay plane and  $K^*$  decay plane



**Generation level**

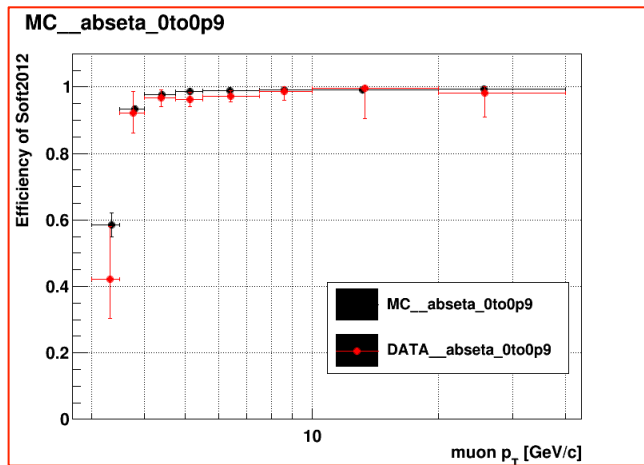
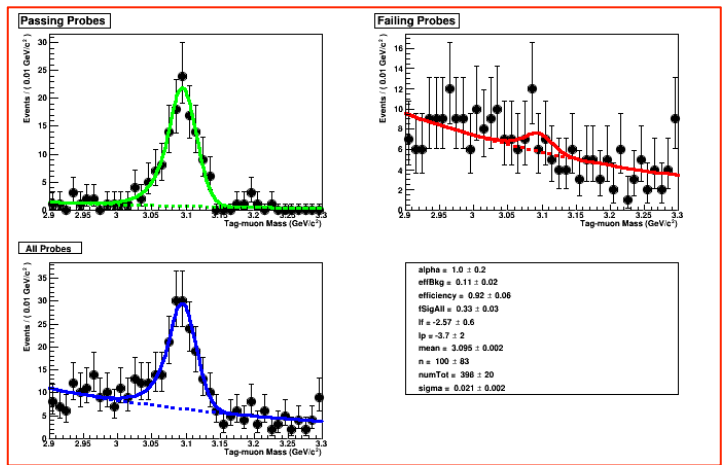


**Reconstruction level**

# Tag & Probe

In support to the research activity carried on within the CMS B-Physics working group I worked on the extraction of the single muon reconstruction efficiency through the “Tag & Probe” (T&P) method.

➤ The T&P method allows to measure the single reconstructed object efficiency making use of resonances, such as Z or J/ψ, which decay into two similar objects (μ<sup>+</sup>μ<sup>-</sup>, e<sup>+</sup>e<sup>-</sup>).



This study represents a fundamental piece in the analyses of the Run-II data collected by CMS, in particular for the cross section measurements of charmonium, bottomonium and B mesons:

$$\frac{d\sigma(pp \rightarrow B^+ X)}{dp_T^B} = \frac{\text{Factor of 2 for charge conjugation} \cdot \text{Signal yield} \cdot \text{Bin width}}{\text{overall eff.} \cdot \text{Branching fractions from PDG} \cdot \text{Luminosity}}$$

$$\frac{d\sigma(pp \rightarrow B^+ X)}{dp_T^B} = \frac{2 \cdot n_{\text{sig}}(p_T^B) \cdot \mathcal{L} \cdot \Delta p_T^B}{2 \cdot \epsilon(p_T^B) \cdot \mathcal{B}(B^+ \rightarrow J/\psi K^+ \rightarrow \mu^+ \mu^- K^+) \cdot \mathcal{L} \cdot \Delta p_T^B}$$

# Conferenze e scuole

## Conferenze con presentazione orale a nome della collaborazione CMS:

- LHCP 2015 (San Pietroburgo, 1-5 Settembre 2015):  
“Heavy flavour spectroscopy and exotic states in CMS”
- Lake Louise Winter Institute (Lake Louise, 15-21 Febbraio 2015):  
“Recent results of flavour physics in CMS”

## Conferenze con presentazione di poster:

- IFAE 2015 (Roma, 8-10 Aprile), vincendo il premio per il miglior poster dal titolo  
“Strutture esotiche in decadimenti di mesoni  $B$  in CMS”

## Workshop:

- Data Science @ LHC (CERN, 9-13 November 2015)
- CMS week (CERN, 19-23 Ottobre 2015)
- CMS week (CERN, 9-13 Febbraio 2015)

## Scuole frequentate:

- Summer school on Machine Learning in High Energy Physics (San Pietroburgo, 27-30 Agosto 2015)
- XXVII Seminario Nazionale di Fisica Nucleare e Subnucleare “Francesco Romano” (Otranto, 4-11 Giugno 2015)
- INFN School of Statistics (Ischia, 25-29 Maggio 2015)
- CMS Data Analysis School (Università di Bari, 19-23 Gennaio 2015), contribuendovi anche in qualità di facilitatore per i “pre-exercises” degli studenti

**Backup**

# Charmonio convenzionale

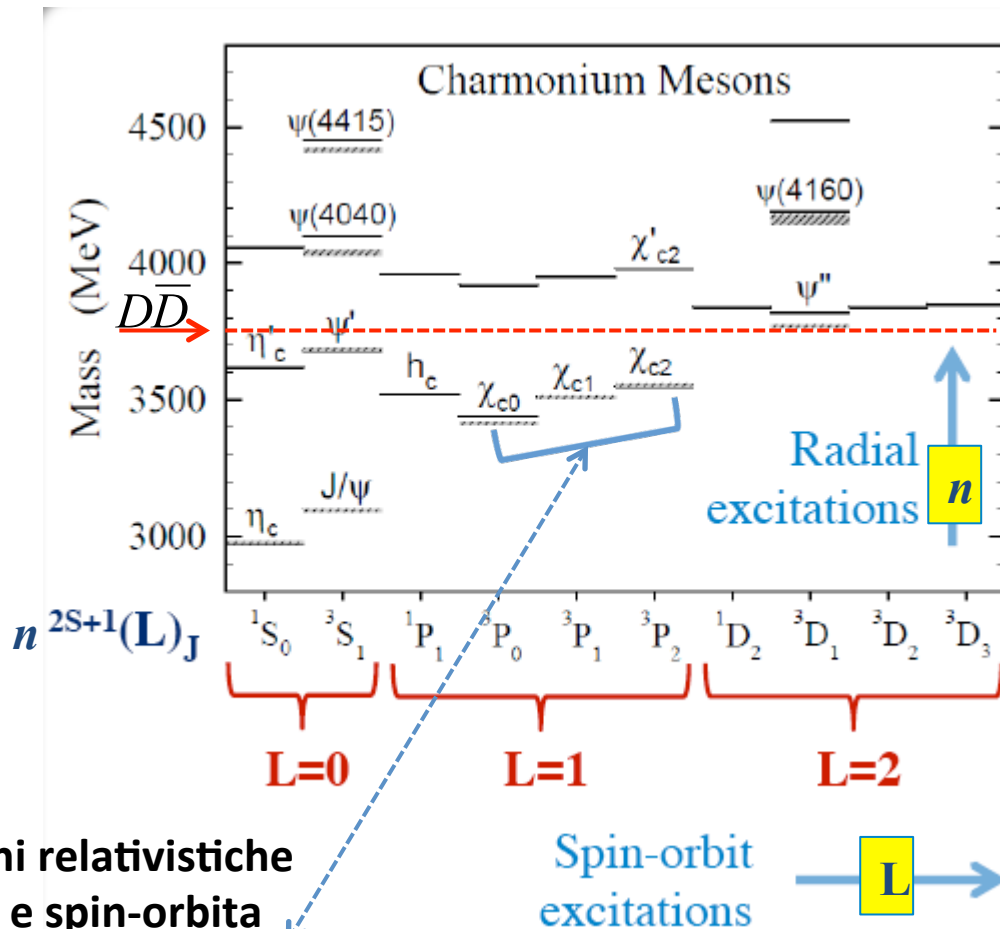
- ▶ Tutti gli stati dello spettro del Charmonio ( $c\bar{c}$ ) sotto la **soglia open-charm**  $D\bar{D}$  ( $\sim 3.8$  GeV) previsti da modelli a potenziale sono stati identificati sperimentalmente (in ottimo accordo)

- ▶ Modello a potenziale :

$$V(r) \approx -\frac{4\alpha_s}{3r} + kr$$

Potenziale di legame fenomenologico non relativistico a piccoli  $r$   
[Cornell Model]

Confinamento dei quark a grandi  $r$   
[Colored flux tube Model]




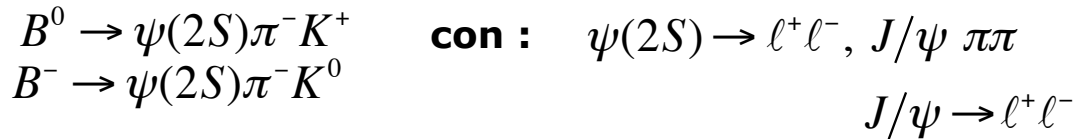
- ▶ Questo modello può includere correzioni relativistiche corrispondenti alle interazioni spin-spin e spin-orbita (effetto dell'interazione di spin  $\rightarrow$  **splitting in multipletti**)
- ▶ spin-parità naturali del quarkonio:  $0^{-+}, 1^{-}, 1^{+}, 0^{++}, 1^{++}, 2^{++}, \dots$  sono proibite:  $0^{-}, 1^{-+}, 2^{+-}, \dots$



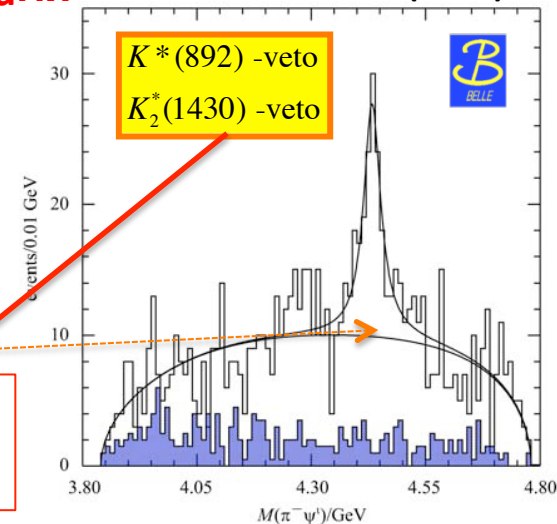
# Z(4430)<sup>-</sup> - Osservazione

- ▶ Questo stato *hidden-charm* ha suscitato forte interesse poichè deve avere un contenuto minimo in quark pari a  $c\bar{c}d\bar{u}$  e quindi rappresenterebbe un'inequivocabile manifestazione di uno stato di mesone a 4 quark!

- ▶  (2008)<sup>[1]</sup> osserva (signif. > 6σ) una stretta struttura nello spettro di massa invariante  $\psi(2S)\pi$  del decadimento a 3 corpi:

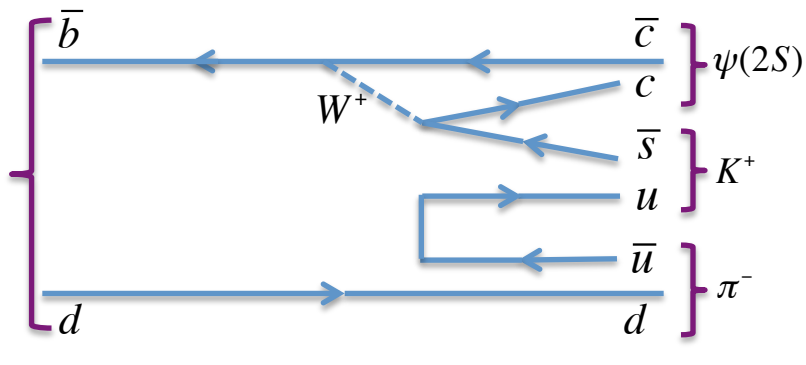


[1] PRL 100:142001 (2008)

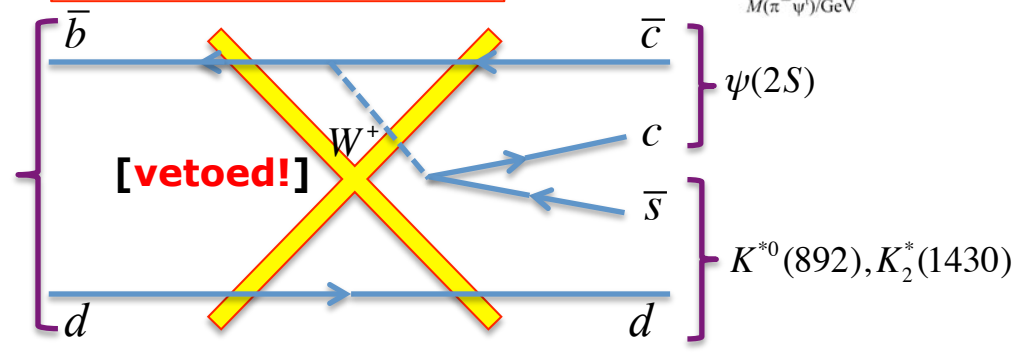


Diagrammi a quark con transizioni deboli effettive:

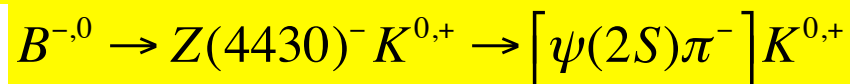
Incoerente a 3 corpi




Quasi 2-body con eccitazioni dei kaoni

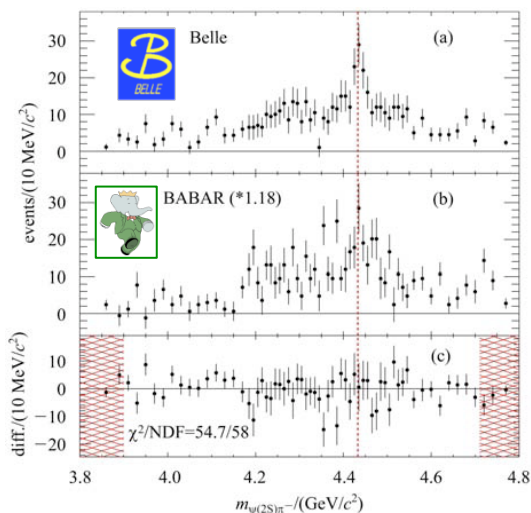


Questa struttura implicherebbe un decadimento *quasi-two-body* in cui la Z carica è uno stato intermedio:



# Z(4430)<sup>-</sup> - BaBar

- 
**(2009)<sup>[2]</sup> sostiene che la dinamica del sistema  $K\pi^-$  può riflettere strutture nella massa invariante  $\psi'\pi^-$ .**



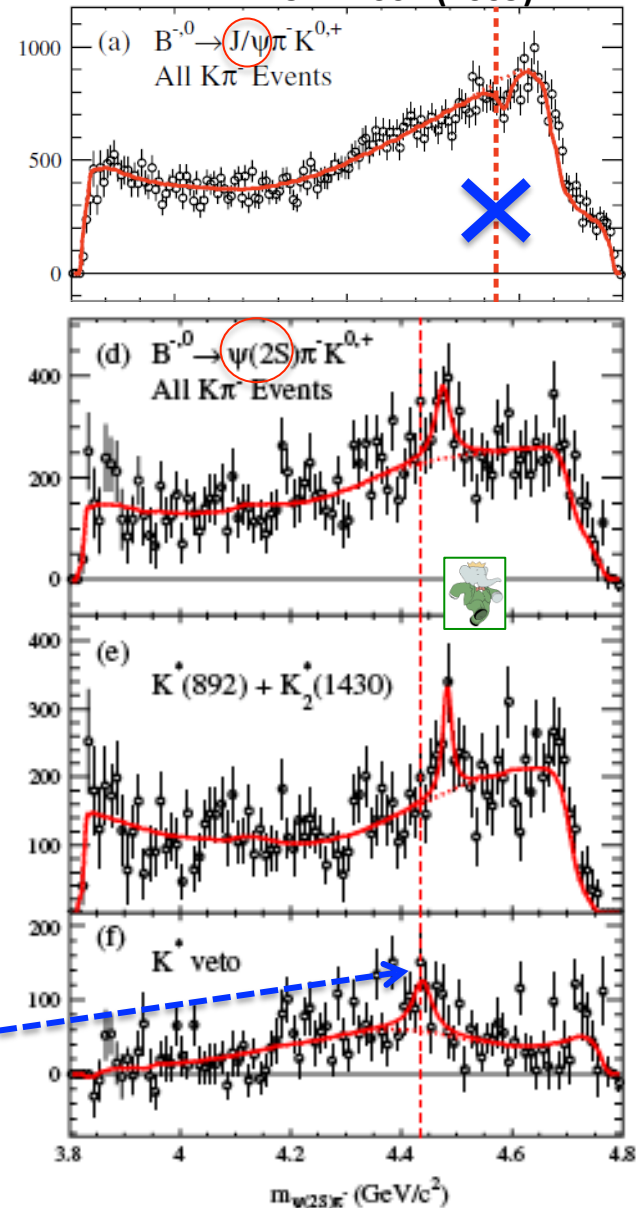
- Confrontando le distribuzioni fondo-sottratte normalizzate dei 2 esperimenti: il plot differenza indica che i 2 samples sono statisticamente equivalenti.**

- Studiando in dettaglio la massa invariante  $K\pi^-$  e le distribuzioni angolari per ricavare la riflessione del sistema  $K\pi^-$  nella massa invariante  $\psi'\pi^-$  (utilizzata come fondo per una BW che riproduce un eventuale segnale associato alla Z):**

**le riflessioni  $K\pi^-$  riproducono bene la distribuzione di massa invariante  $\psi'\pi^-$ .**

**signif.  $\sim 1.9\sigma$   
 @ shifted mass  
 ( $\sim 3.1\sigma$  forcing parameters)**

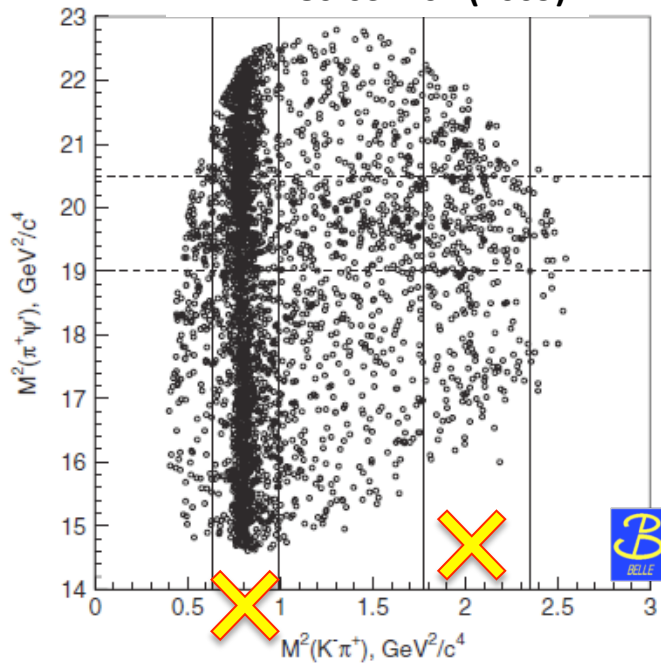
[2] PRD 79:112001 (2009)



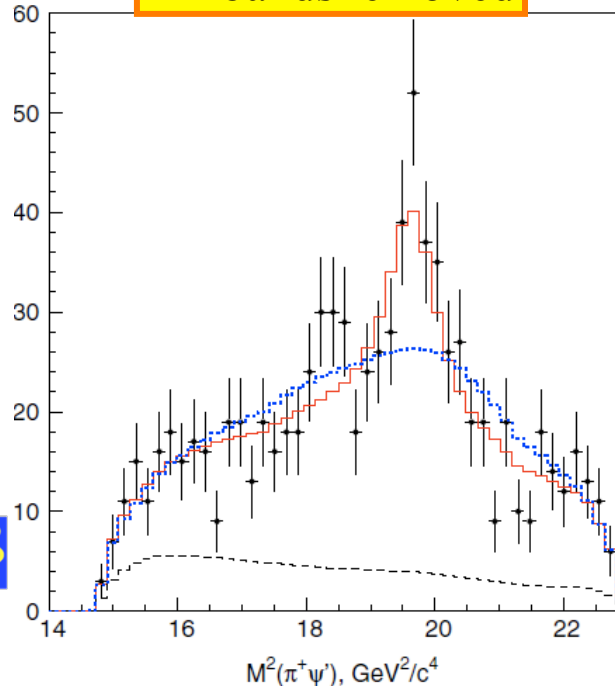
# Z(4430)<sup>-</sup> - Dalitz-plot fit

- Ciò ha indotto una re-analisi di  (2009)<sup>[3]</sup> basata su un Dalitz-plot fit che include una BW relativistica per le risonanze  $K\pi^-$  (onde S, P, D):

[3] PRD 80:031104 (2009)





K \* bands removed



segnale Z ancora visibile con:

- signif. =  $6.4\sigma$
- $\Gamma$  raddoppiata (entro gli err. sist.)



Un'utile cross-check di  sarebbe ripetere l'analisi nel canale  $J/\psi$  in cui  non ha trovato nessun segnale.

- Vi è una differenza metodologica tra Belle e BaBar!

L'obiezione di BaBar è la seguente:

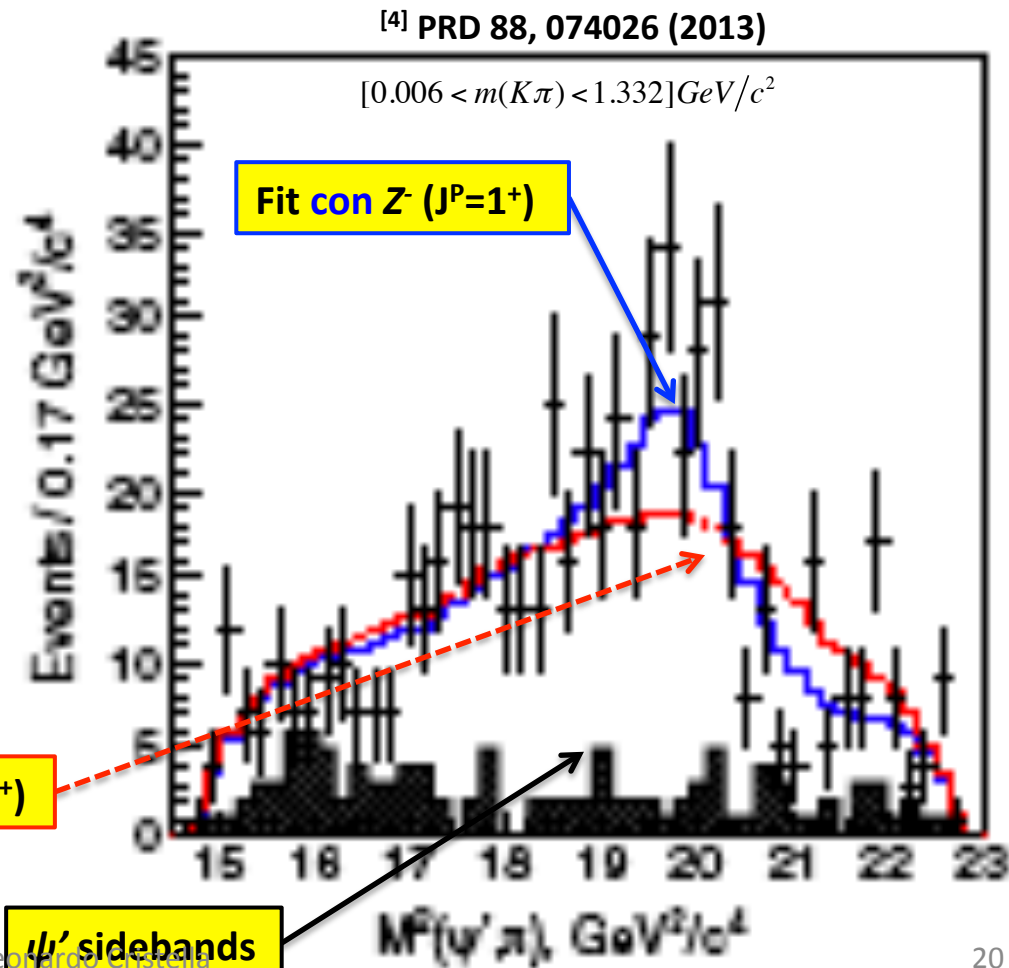
lo stato finale contiene 1 vettore e 2 pseudoscalari → la struttura complessiva in ampiezza richiede di considerare la correlazione fra il decadimento della  $\psi'$  e la dipendenza dalla massa e dall'angolo di produzione del sistema  $K\pi^-$  (cioè una vera e propria decomposizione in ampiezze).

# Z(4430)<sup>-</sup> - Conferma

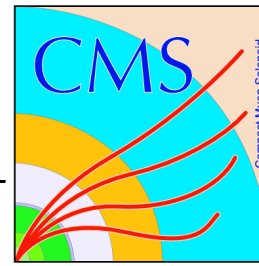
- ▶ L'analisi Dalitz di  è semplificata perchè integra sulla distribuzione angolare del decadimento della  $\psi'$ , ignorando così le correlazioni. Se ci fossero strutture nel sistema  $\psi'\pi^-$  ... ci sarebbe bisogno di includere onde parziali di grado più elevato nel sistema  $K\pi^-$  poichè tali strutture sarebbero costituite dai contributi di queste "extra"  $K\pi^-$  ampiezze.
- ▶ Questa controversia ha indotto una ulteriore analisi di  (2013)<sup>[4]</sup> basata su una *amplitude analysis* (4D: 2 masse inv. + 2 variabili angolari) includendo tutte le risonanze  $K\pi^-$  conosciute sotto il limite cinematico.

Z(4430)<sup>-</sup> è ora confermata  
e  $J^P=1^+$  è l'ipotesi favorita

Fit *senza* Z<sup>-</sup> ( $J^P=1^+$ )



# Prospettive in CMS



- ▶ Per stabilire definitivamente l'esistenza della  $Z(4430)^-$  è necessaria una conferma da altri esperimenti.
- ▶ CMS può eseguire una ricerca sia **inclusiva** che **esclusiva**:
  - la sezione d'urto di produzione *prompt* della  $Z$  in collisioni  $pp$  è sconosciuta. È comunque utile esaminare gli spettri di massa di charmonio+traccia:
    - $\psi'\pi$  con  $\psi' \rightarrow \mu^+\mu^-$  ( $\psi'$  triggers inclusivi)
    - $\psi\pi$  con  $\psi \rightarrow \mu^+\mu^-$  ( $J/\psi$  triggers inclusivi)
  - ricerche esclusive con decadimenti del  $B$ :
    - $B^0 \rightarrow \psi'\pi K^+$  con  $\psi' \rightarrow \mu^+\mu^-$
    - $B^0 \rightarrow J/\psi\pi K^+$  con  $J/\psi \rightarrow \mu^+\mu^-$  fungerebbe da canale di controllo
- ▶ Nella ricerca esclusiva dovrebbe essere estratto un campione con alta purezza & statistica poichè sarà necessaria una **full amplitude analysis (AA)** del decadimento a 4 corpi per considerare la correlazione fra il decadimento della  $\psi'$  (e la sua polarizzazione) e la dipendenza dalla massa e dall'angolo di produzione del sistema  $K\pi$ .
- ▶ Lo strumento dell'**AA** sarà sviluppato e condiviso insieme all'analisi  $B^+ \rightarrow J/\psi\Phi K^+$ , decadimento già studiato da CMS confermando lo stato esotico  $Y(4140)$  di CDF . Tale analisi aiuterà anche a studiare il candidato esotico  $Y(4274)$ .

# $\psi(2S)\pi^\pm$ candidates reconstruction : baseline cuts

## $\psi(2S)$ CUTS

- $\mu^\pm$  : MuonID
- $|y(\mu^\pm)| < 2.4$  &  $|y(\psi')| < 2.4$
- $P_{\chi^2}(\mu\mu\text{-VTX}) > 0.005 \equiv 0.5\%$
- $p_T(\psi') > 5(7) \text{ GeV}$  for data 2012(2011)
- Take events with only 1 candidate

## $\pi$ CUTS

- #PixelHits  $\geq 2$  & #StripHits  $\geq 8$
- $|y(\pi^\pm)| < 2.4$
- $p_T(\pi^\pm) > 0.7 \text{ GeV}$

## $Z^\pm \equiv \psi(2S)\pi^\pm$ CUTS

- $\psi'$  candidates from variable mass window:  
 $|m_{\mu\mu} - m_{\mu\mu}^{\text{fit-peak}}(j)| < 2 \cdot \sigma(j)$ ,  $j = 1, \dots, 22$  (see backup slides) [ $\Rightarrow |y(\psi')| < 2.2$ ]
- $P_{\chi^2}(\mu\mu\pi\text{-VTX}) > 0.05 \equiv 5\%$
- $p_T(\psi'\pi) > 8 \text{ GeV}$
- pointing angle :  $|\cos\alpha| > 0.9$  [to be hardened later]
- $\Delta R(\psi', \pi) < 1.0$  [harder criteria will be explored later]

NEW w.r.t.  
previous  
presentation

**Inclusive search:**  $pp \rightarrow Z(4430)^- X, Z^- \rightarrow \psi'\pi^-$  with  $\psi' \rightarrow \mu^+\mu^-$

### $\psi(2S)$ CUTS

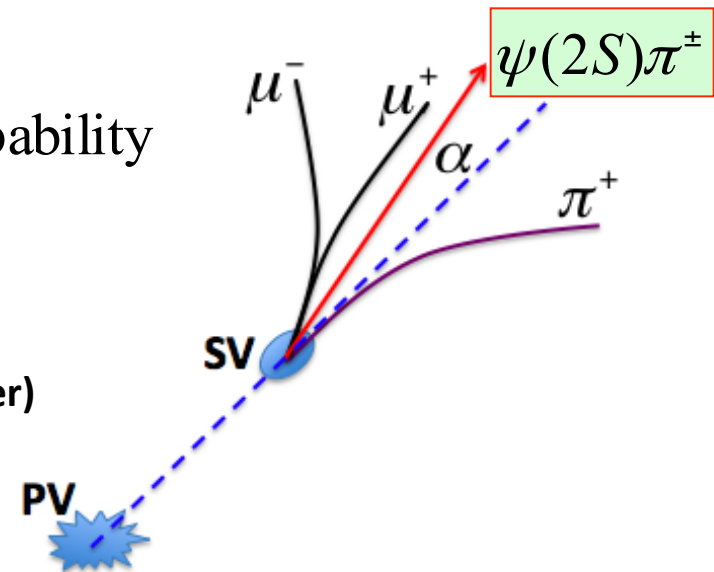
- $\mu^+\mu^-$ : common vertex fit
- $\mu^\pm$ : MuonID requirement
- $\mu^\pm \in$  detector fiducial region
- $\psi'$  candidates from variable mass window  
(mass resolution changes with rapidity)

### $\pi^-$ CUTS

- track quality requirements
- $\pi^- \in$  detector fiducial region

### $Z^- \equiv \psi(2S)\pi^-$ CUTS

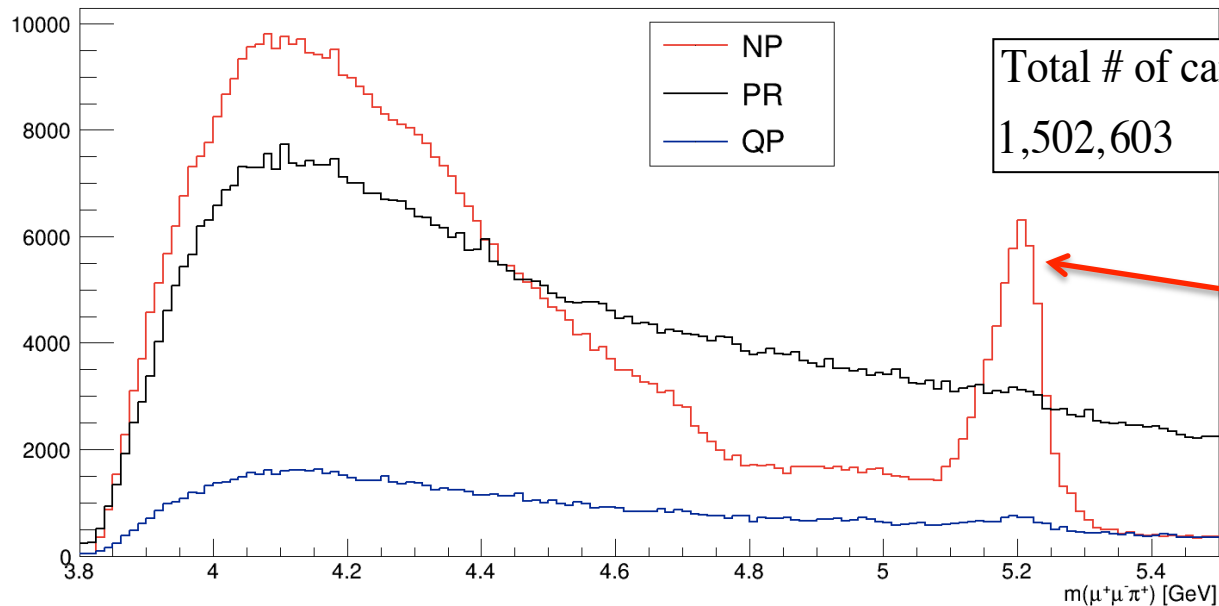
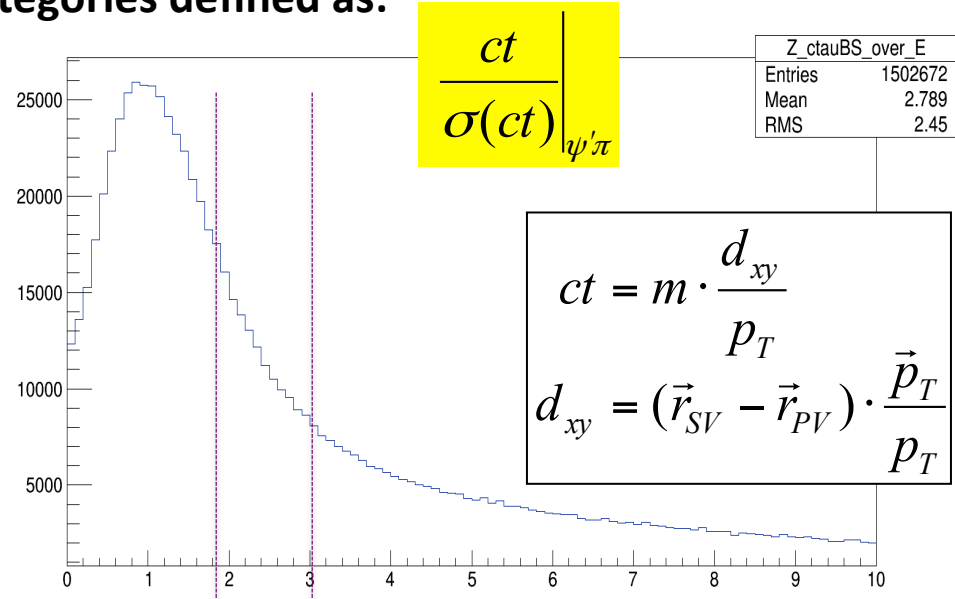
- $\psi'\pi^-$  mass constrained ( $\psi'$ ) vertex fit probability
- pointing angle:  $|\cos \alpha| > 0.9$
- $\Delta R(\psi', \pi) < 1.0$  (harder criteria will be explored later)



# Definition of 3 components w.r.t. $Z$ flight length significance

In the following we will deal with three categories defined as:

- PROMPT [PR]:  $\left. \frac{ct}{\sigma(ct)} \right|_{\psi'\pi} < 1.8$
- QUASI-PROMPT [QP]:  $1.8 < \left. \frac{ct}{\sigma(ct)} \right|_{\psi'\pi} < 3.0$
- NON-PROMPT [NP]:  $\left. \frac{ct}{\sigma(ct)} \right|_{\psi'\pi} > 3.0$



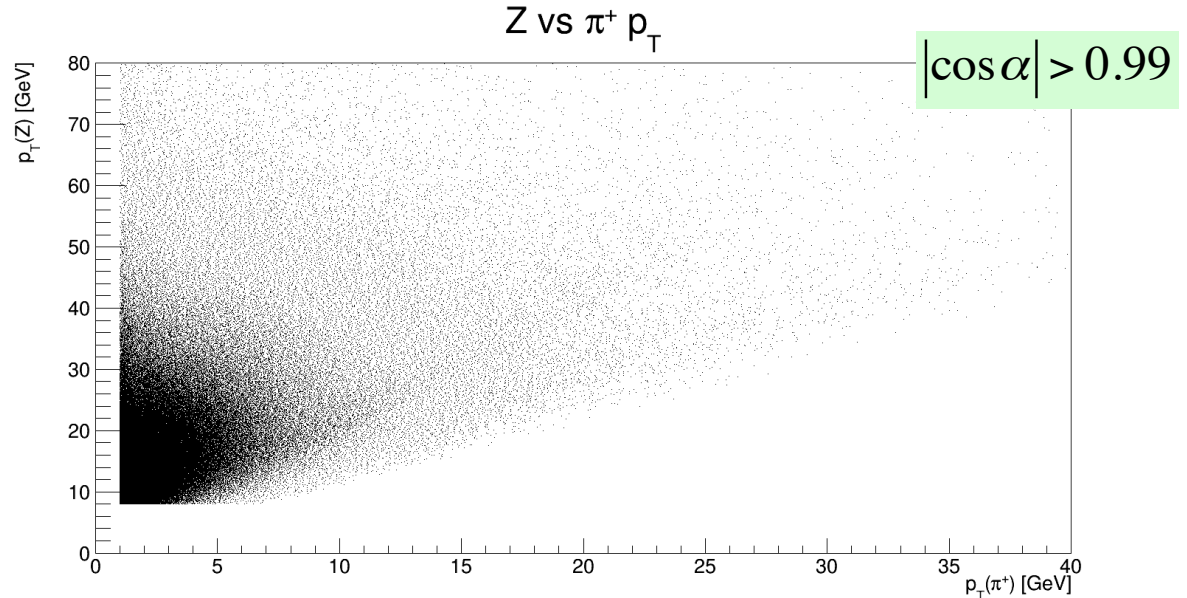
$B^+ \rightarrow \psi' K^+$   
 mass-shift due to  $\pi$  assignment



# Search-by-scan approach

We followed this approach: **apply reasonable cuts ...**  
**... and scan kinematic space to find an eventual hint of a signal.**

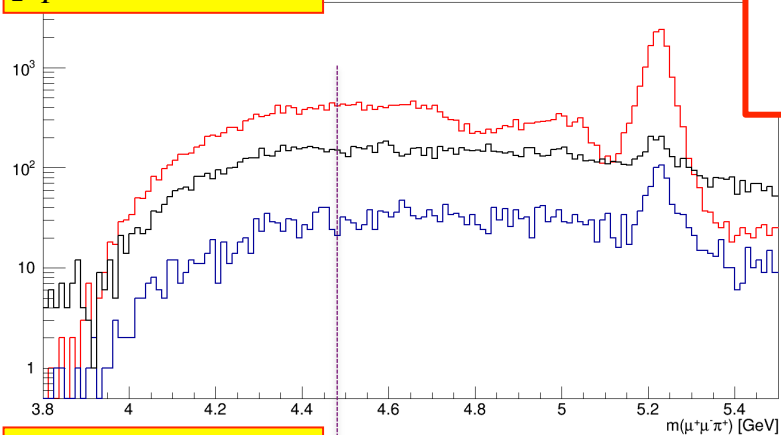
All three components  
together:



- Scanned regions:**
- $p_T(\pi^\pm) > 2\text{GeV}, 3\text{GeV}, 4\text{GeV}, 5\text{GeV}, 7\text{GeV}$
  - $p_T(Z^\pm) > 10\text{GeV}, 12\text{GeV}, 14\text{GeV}, 17\text{GeV}, 20\text{GeV}, 28\text{GeV}, 40\text{GeV}$
  - $p_T(\pi^\pm, Z^\pm) > (1,15)\text{GeV}, (2,20)\text{GeV}, (4,25)\text{GeV}, (7,30)\text{GeV}$

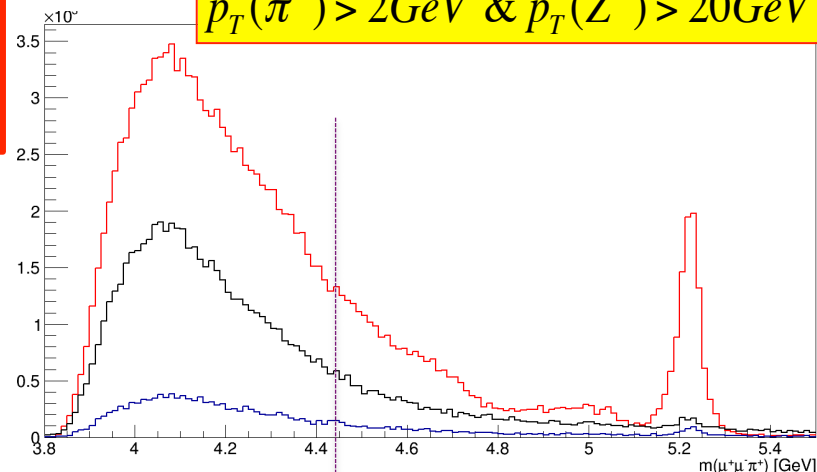
**We have looked at these distributions cutting progressively on  $\Delta R$  as well ( $<0.8, <0.6, <0.4, <0.2$ ).**

$p_T(\pi^\pm) > 7\text{GeV}$

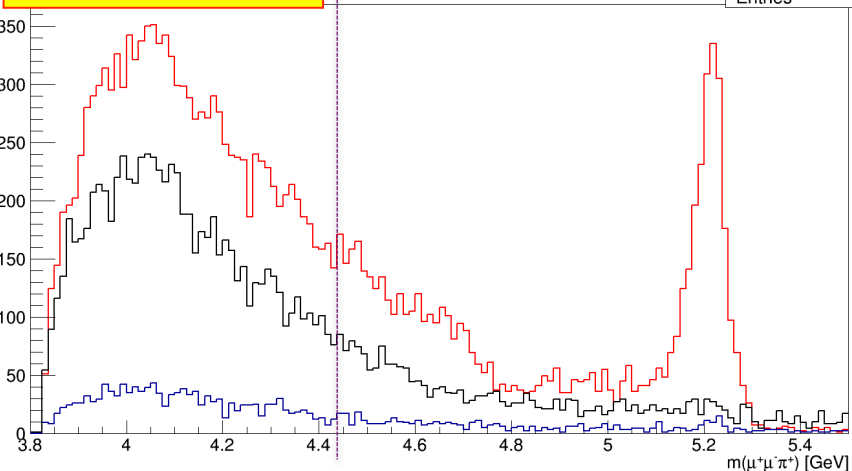


Search  
by scan

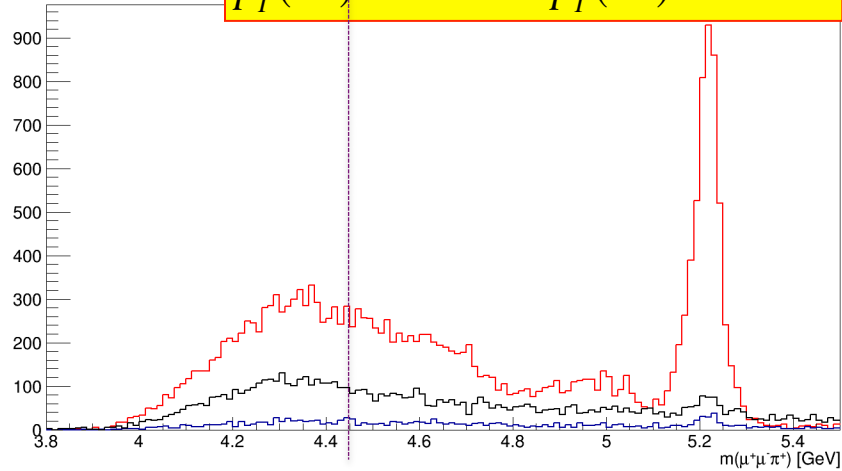
$p_T(\pi^\pm) > 2\text{GeV} \ \& \ p_T(Z^\pm) > 20\text{GeV}$



$p_T(Z^\pm) > 40\text{GeV}$



$p_T(\pi^\pm) > 7\text{GeV} \ \& \ p_T(Z^\pm) > 30\text{GeV}$



With the followed scanning approach **we haven't found any hint of a signal** that could be associated to the  $Z(4430)^-$  in the whole 2011+2012 dataset (Run-I).



Anyway it is difficult to draw a conclusion since the cross section for the inclusive production is unknown, the background level is rather high and  $Z(4430)$  should be large (width  $\sim 150\text{-}200\text{MeV}$ ).

# Exclusive search

➤ By considering an additional track w.r.t the inclusive search, we reconstructed the

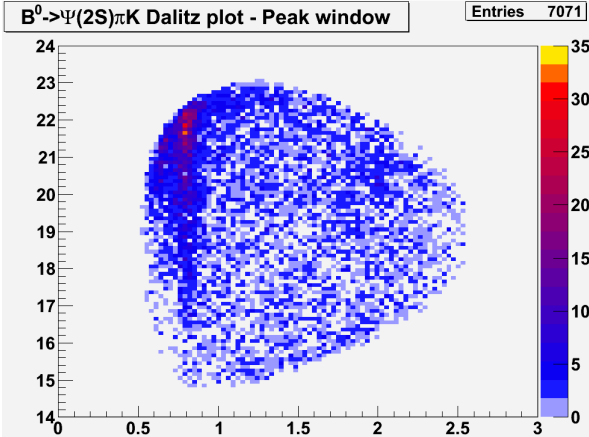
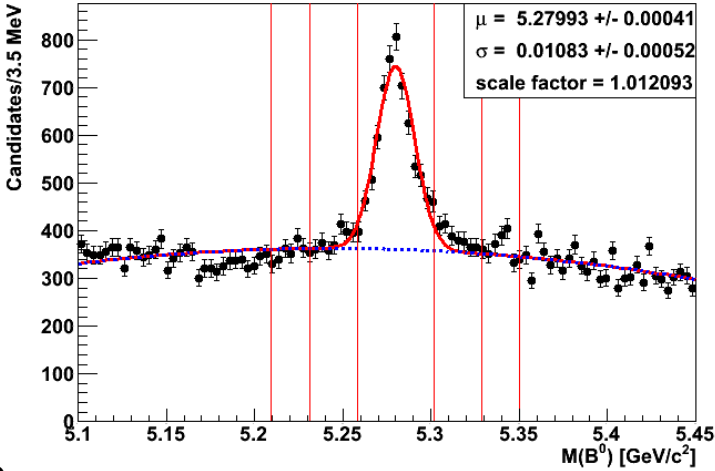
$B^0 \rightarrow \psi(2S)K^+\pi^-$

decay channel:

➤ In order to identify and separate kaons from pions, we explored the possibility of using the  $dE/dx$  information of the tracks, measured by the CMS silicon tracker, in the following **2 cases**.

**1<sup>st</sup> case)  $dE/dx$  for an inclusive tracks' sample**

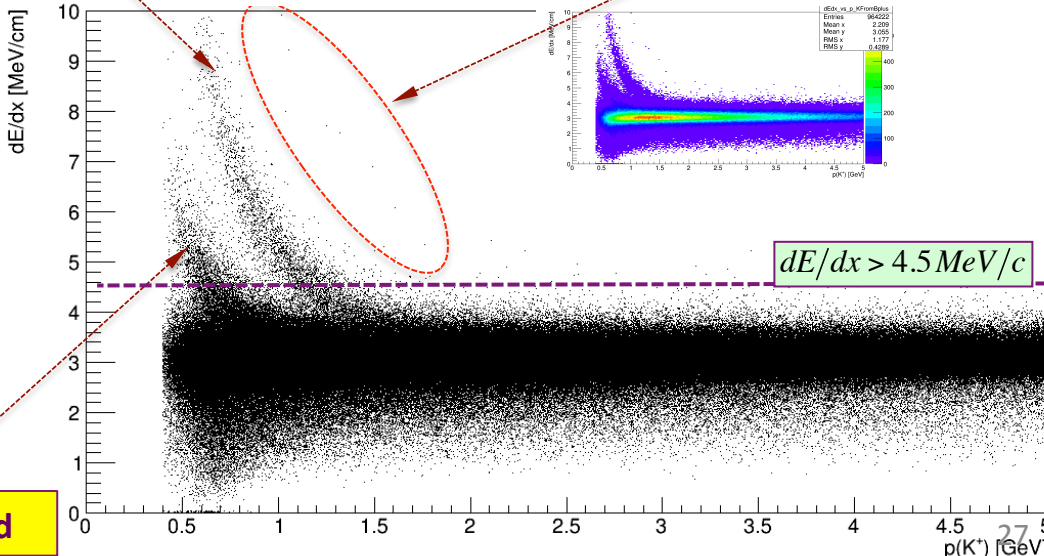
➤ After applying the selection in order to extract a  $B^+$  signal in our **full inclusive  $\psi(2S)+1$  track invariant mass window [3.8-6.4]GeV**:



protons' band

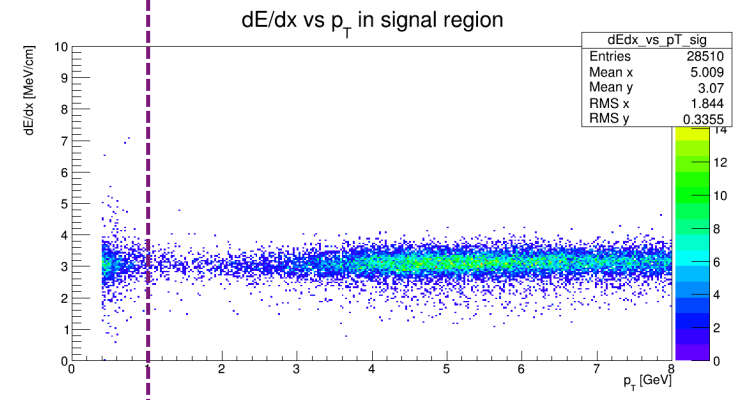
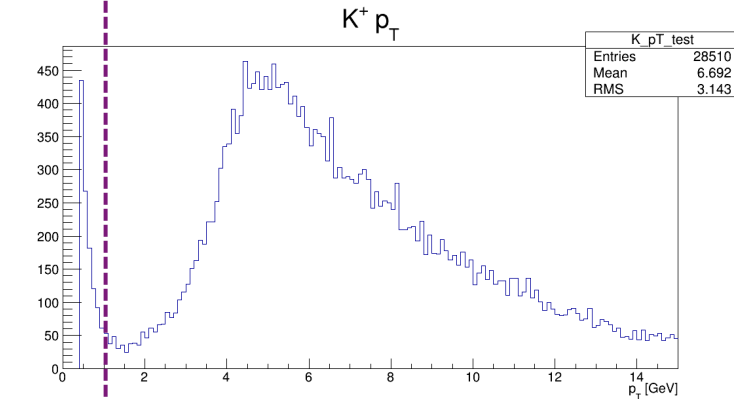
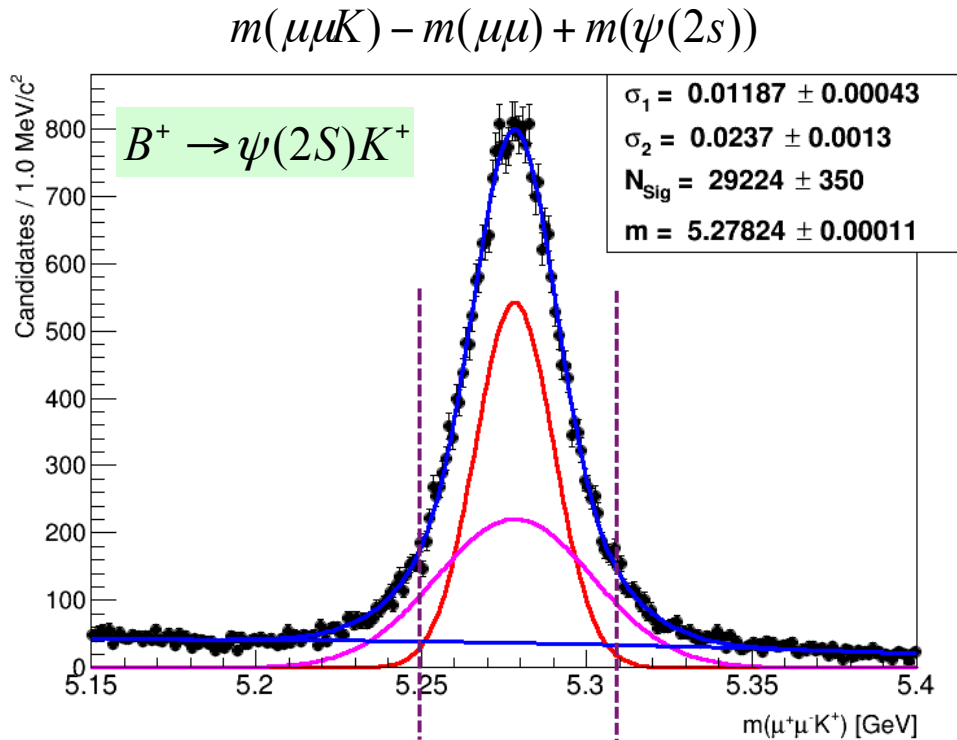
a few deuterons

for any track enough close to charmonium



Kaons' band

$B^+ \rightarrow \psi(2S)K^+$ :  $dE/dx$  for the track



➤ Tracks with  $p_T < 1\text{GeV}$  are clearly background!

➤ With  $p_T > 1\text{GeV}$  signal purity reaches 97.5% but it is useless for  $dE/dx$  studies

➤ At least another  $B$  daughter is needed: consider 3-body decays (charmonium + 2 tracks)

# Attività di servizio - Particle Flow

- ▶ La “ricostruzione *Particle-Flow*” (PF) consiste nell’identificazione e nella ricostruzione offline di ogni singola particella in un evento, tramite un’ottimale combinazione delle misure fornite da tutti i sottorivelatori in CMS.
- ▶ La conoscenza del contenuto di un evento in termini di particelle è alla base di tanti aspetti dell’analisi dati, come:
  - la definizione dell’isolamento
  - l’identificazione del pile-up
  - l’assegnazione del sapore ad un jet
  - l’interpretazione dell’energia mancante.
- ▶ La capacità di formare oggetti ricostruiti il più possibile fedeli al reale contenuto in particelle di un evento riduce le correzioni a posteriori, semplificando il lavoro nelle analisi.
- ▶ Il primo obiettivo del progetto consiste nello sviluppo e nella validazione dell’algoritmo di PF, da integrare all’interno del framework di Data Quality Monitoring (DQM), nonché da utilizzare nel processo standard di ricostruzione in relazione alle rielaborazioni offline al Tier0, alle produzioni Monte Carlo e alle validazioni delle versioni aggiornate del software.
- ▶ La tempistica del progetto prevede che tutta l’infrastruttura funzioni entro la ripresa della raccolta dati (Marzo-Aprile 2015) dopo il primo long-shutdown del collisionatore LHC.