Observation of $B^{\pm} \rightarrow \psi(2S)\Phi K^{\pm}$ at $\sqrt{s}$=8 TeV in CMS

Reddy Pratap Gandrajula (The University of Iowa)

On behalf of CMS collaboration

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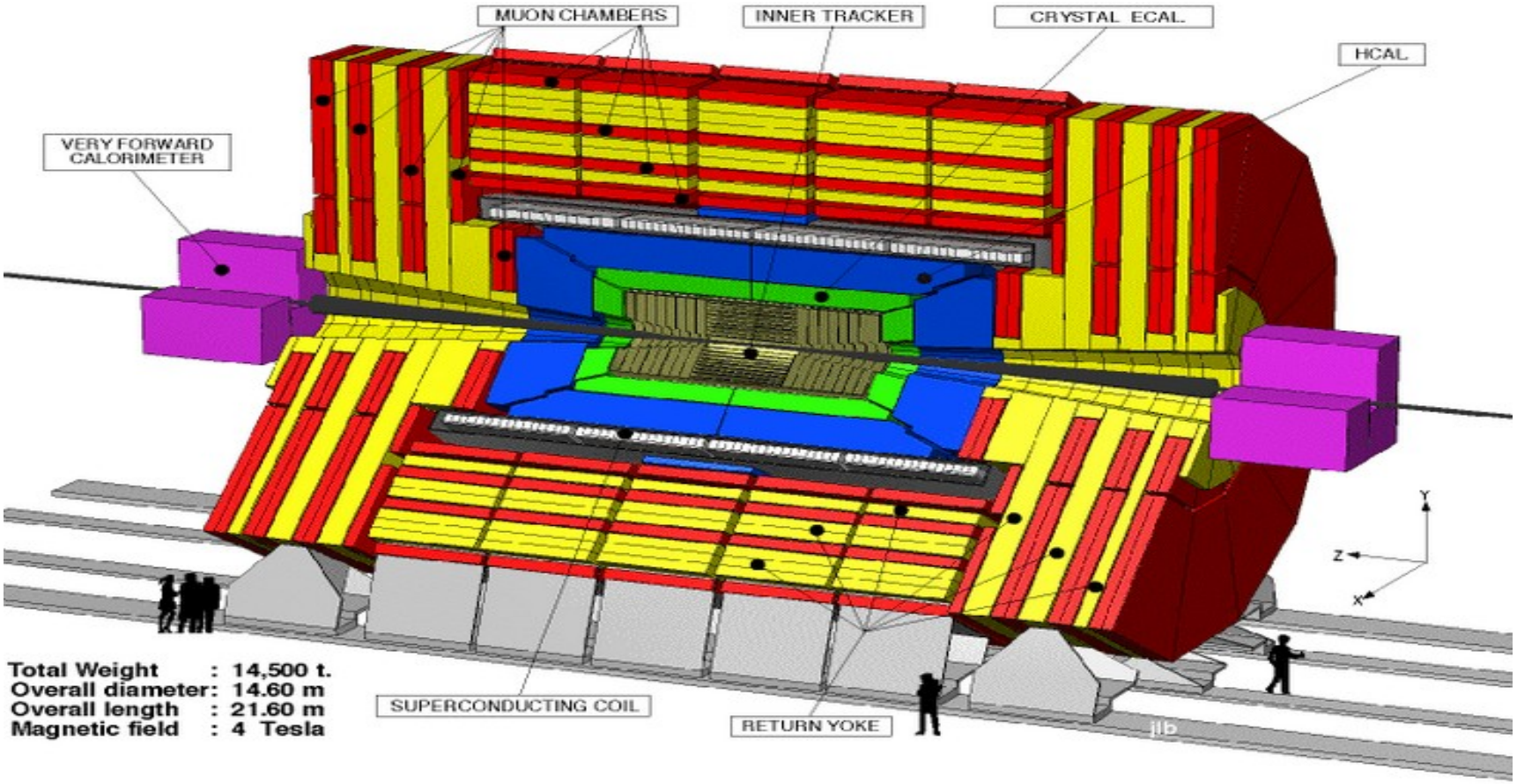
Outline

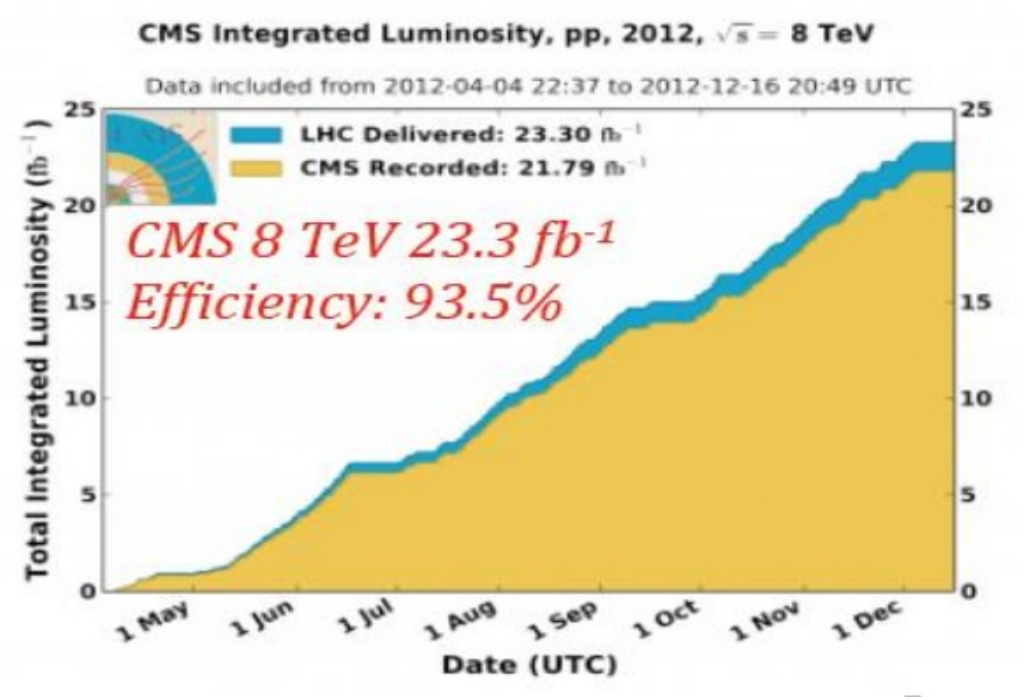
- Introduction: LHC & CMS detector
- Exotic structures introduction
- Search structures in $B^+ \to J/\psi \Phi K^+$
- triggers and Data set
- Monte Carlo
- Event selection
- $B^+ \to \psi(2S) \Phi K^+$ observation
- Branching fraction measurement (In approval stage)
- Summary and conclusion

Introduction: LHC & CMS detector

Compact Muon Solenoid (CMS) identifies and measures e, μ, γ, charged/neutral particles, Jets, MET etc.



Introduction: LHC & CMS detector

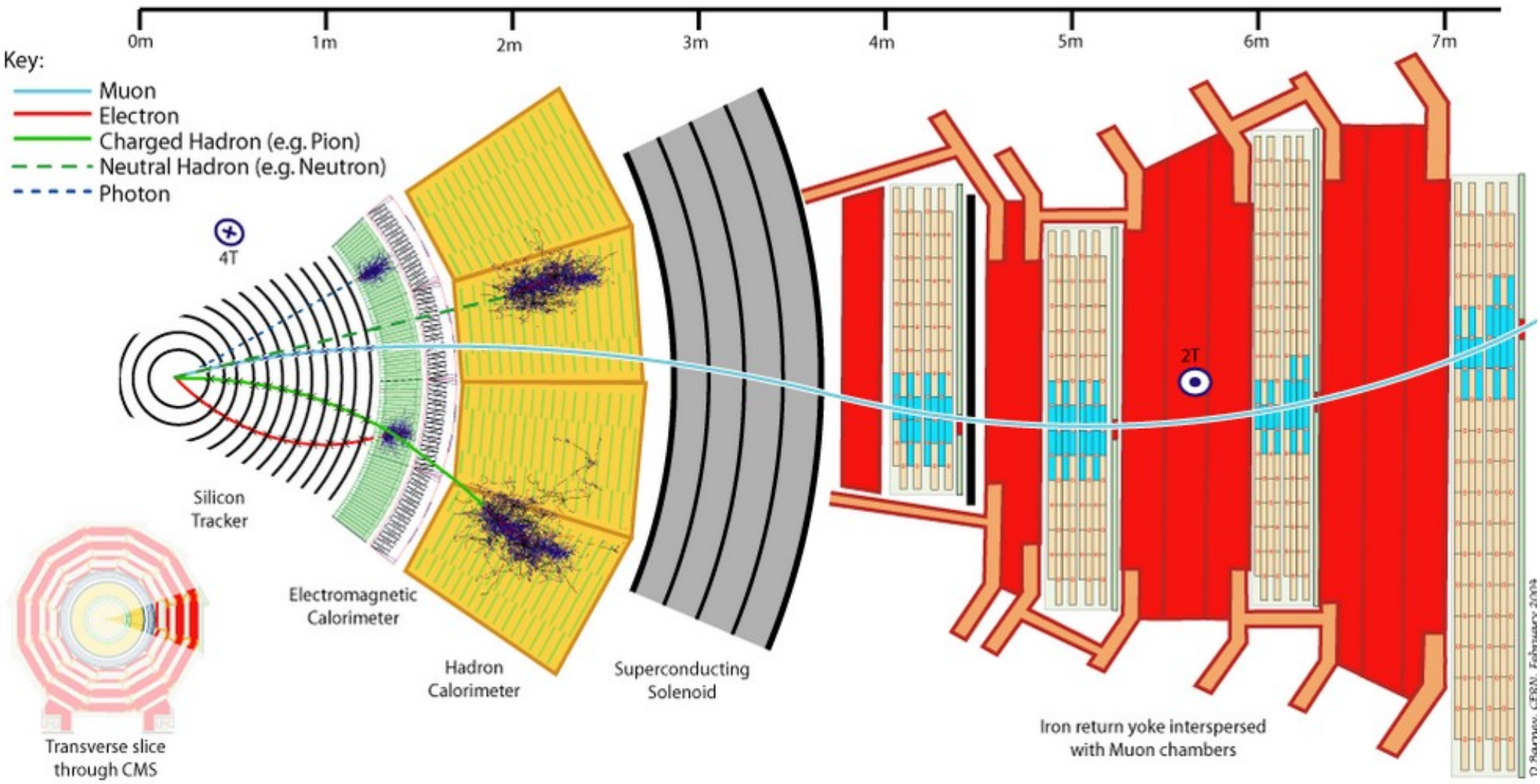


- CMS collects data very efficiently.
- CMS yields large amounts of data at the world's highest energy

--CMS/ATLAS just discovered the Higgs, confirms & completes the SM

--Enormous opportunities to search for new phenomena

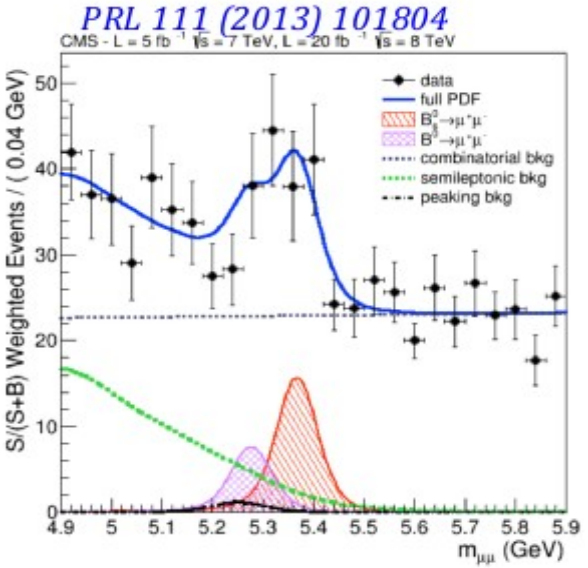
Introduction: Relevant sub-detectors



CMS detector performance

Excellent muon/silicon detectors for quarkonium:

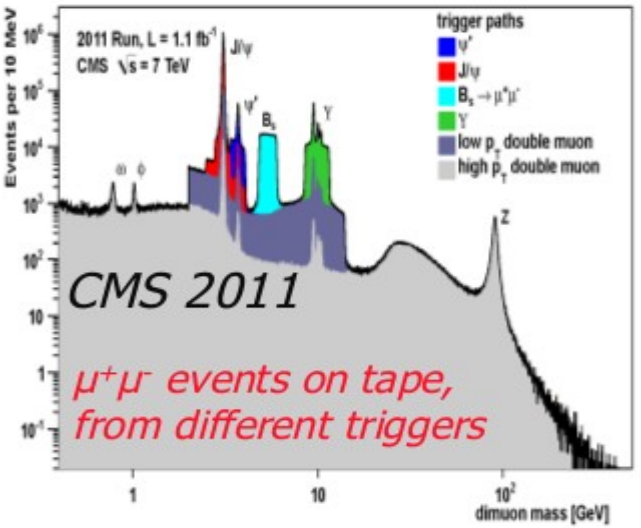
- Muon system
  - High purity muon identification
  - Good dimuon mass resolution($\Delta m/m \sim 0.6\%$ for J/ψ)
- Silicon Tracking detector
  - excellent track momentum resolution($\Delta pT/pT \sim 1\%$)
  - excellent vertex reconstruction
- Observation of Bs($\mu^+\mu^-$)(>4σ) shows an excellent combined performance of the all-silicon tracker and muon detector
  - identifying and measuring muons with high resolution
  - strong background rejection capabilities.



LHC luminosity and CMS trigger:

- Collect data at increasing instantaneous luminosity.
- Triggers are essential ingredients
  - Special trigger for different analysis

For this analysis: displaced dimuon vertex & minimum (di)muon transverse momentum

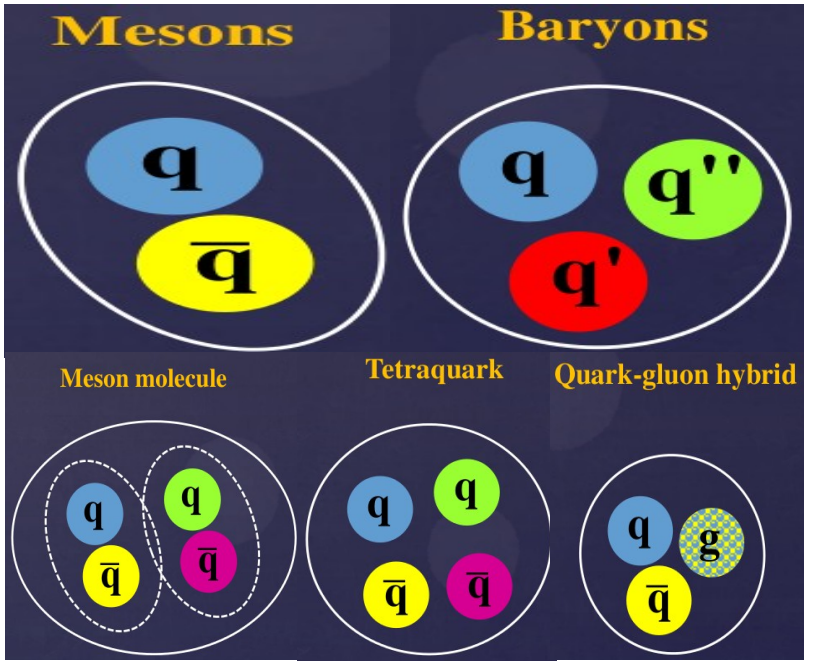


Search for exotic structures

- With the availability of large CMS dataset, there are enormous opportunities to search for new phenomena.
- 1964: Gell-Mann & Zweig postulated Constituent Quark Model (CQM)

  ⇒Quarks form two types of bound states:Mesons and Baryons. Only colorless combinations are allowed.
- What about other combinations in bound states?

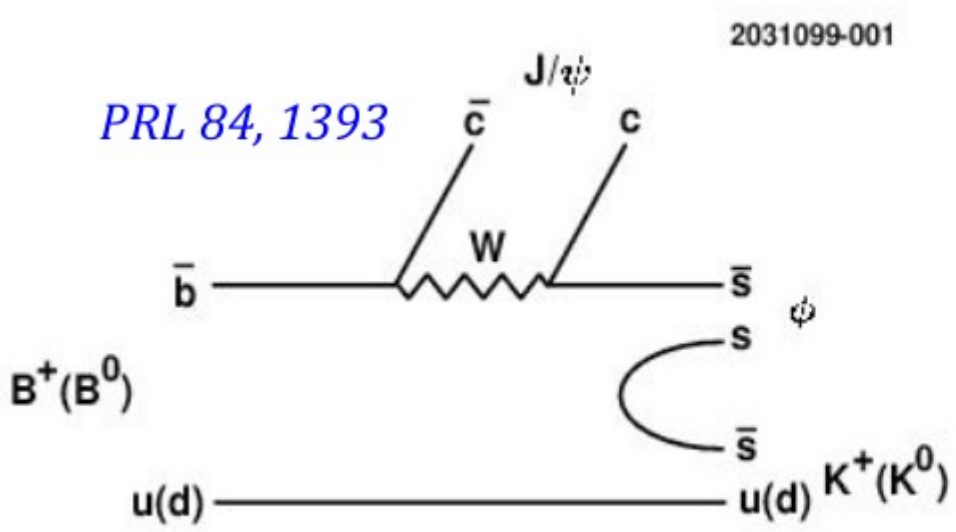
  No theoretical reason to exclude other types of (colorless) bound quark states, For example: Meson molecule, Tetraquark, or Quark-gluon hybrid states.



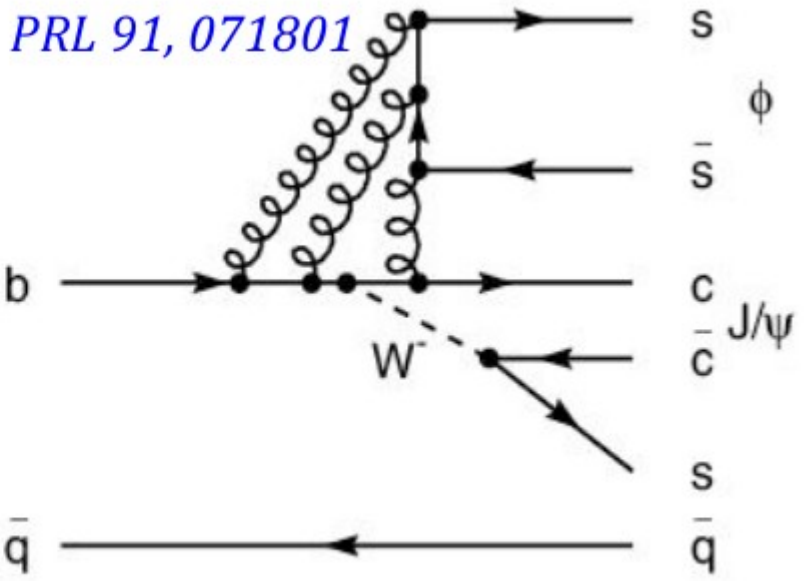
- Recent studies at several experiments (CDF, CMS, and D0) observed such a possible exotic state Y(4140) in J/ψϕ spectrum.

Search structures → J/ψΦ via B decays

- Experimentally attractive to search through clean $B^+ \to J/\psi \Phi K^+$ channel
  --taking advantage of B lifetime and narrow B mass window
  --$B^+ \to J/\psi \Phi K^+$ is OZI suppressed, so, low rate from phase space decays
  --constrained phase space favors forming of two-body structures



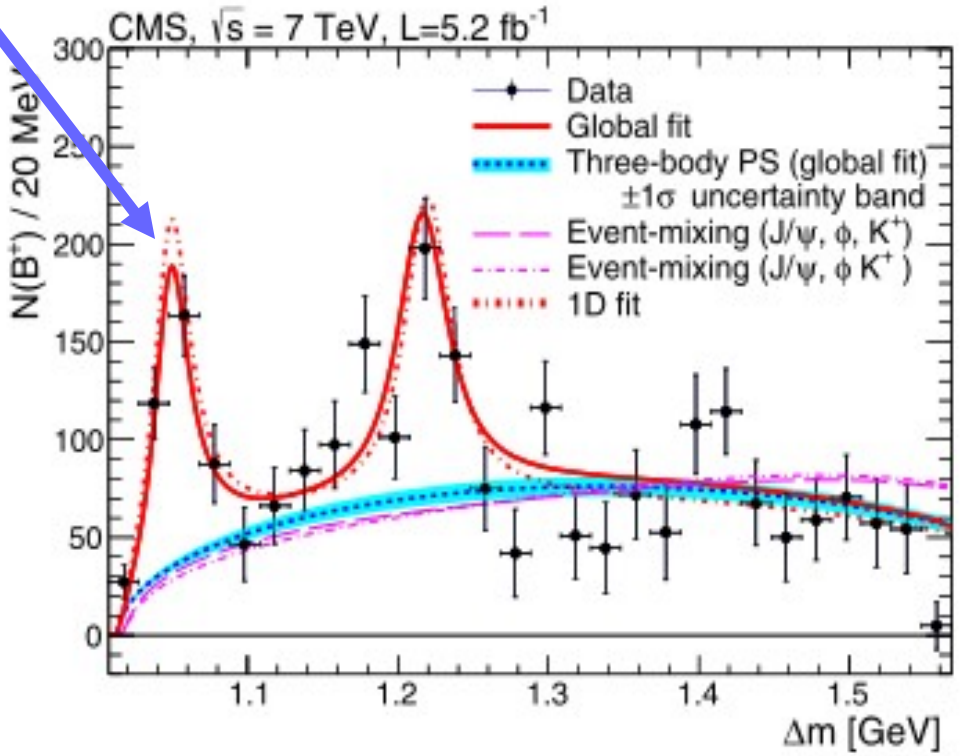
Vacuum polarization



Gluon coupling

Motivation for current analysis

CMS reported already on the presence of substructure Y(4140) in the known decay $B^+ \to J/\psi\phi K^+$, arXiv:1309.6920.



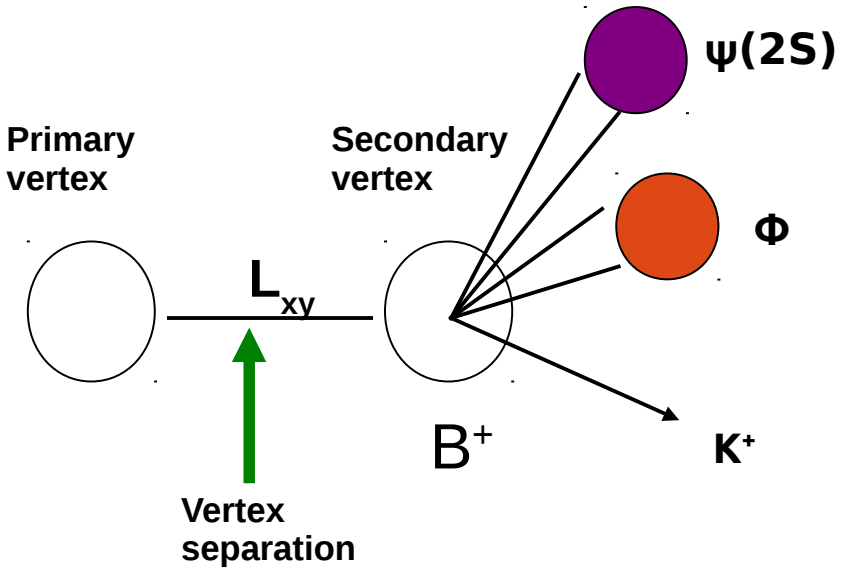
- A natural extension to structure in $J/\psi\phi$ spectrum, is to search for structure in $\psi(2S)\phi$ spectrum via exclusive $B^+ \to \psi(2S)\phi K^+$ decays. As part of that investigation, the final state $B^+ \to \psi(2S)\phi K^+$ was observed.

Event reconstruction

- B signal: Reconstruct B signal from ψ(2S),Φ, and K mesons.

- Reconstruct ψ(2S) from $\mu^+\mu^-$ pair and Φ from K^+K^- pair that has mass closest to the nominal Φ mass.

- We chose **$B^+ \rightarrow \psi(2S)K^+$ as** normalization channel for branching fraction measurement.



B^+ life time ~1.64 ps

$B^+ \rightarrow \psi(2S)\Phi K^+$,
$\psi(2S) \rightarrow \mu^+\mu^-$, $\Phi \rightarrow K^+K^-$

Triggers & Data set

- Software: CMSSW_5_3_7_patch5.
- Jason file:Cert_190456-208686_8TeV_22Jan2013ReReco_Collisions12_JSON_MuonPhys.txt.
- Triggers: HLT_Dimuon5_Psiprime
- Dataset:

Dataset [Run range]	Luminosity	Dimuon trigger effective Luminosity
/DoubleMuParked/Run2012A-22Jan2013-v1/AOD [190456, 193621]	0.9373 fb^{-1}	0.413 fb^{-1}
/MuOniaParked/Run2012B-22Jan2013-v1/AOD [193833, 196531]	4.829 fb^{-1}	4.257fb^{-1}
/MuOniaParked/Run2012C-22Jan2013-v1/AOD [198022, 203746]	7.3079 fb^{-1}	7.3079 fb^{-1}
/MuOniaParked/Run2012D-22Jan2013-v1/AOD [203768, 208686]	7.576 fb^{-1}	7.576 fb^{-1}
Sum	20.65 fb^{-1}	19.55 fb^{-1}

Monte Carlo samples

- Monte Carlo (MC) simulated data were created using PYTHIA 6 for the particle production, EVTGEN for the particle decays, and GEANT4 for tracing the particles through a detailed model of the detector

- **Signal $B^+ \rightarrow \psi(2S)\Phi K^+$ samples**
- Official MC events: using phase space distributions,ψ(2S) decay to $\mu^+\mu^-$ is $V \rightarrow LL$ and Φ decay to K^+K^- is $V \rightarrow SS$.
- 10 million requested.
- 9538259 available in CMS DBS.

- **Normalization channel $B^+ \rightarrow \psi(2S)K^+$ samples**
- Official MC events: SVS model distributions, ψ(2S) decay to $\mu^+\mu^-$ is $V \rightarrow LL$.
- 0.5 million requested.
- 504823 available in CMS DBS

MC Signal DBS Path:/BuToPsiPhiK_BFilter_TuneZ2star_8TeV-pythia6-evtgen/Summer12_DR53X-PU_RD2_START53_V19F-v2/AODSIM

MC Normalization DBS path:/BuToPsiK_BFilter_TuneZ2star_SVS_8TeV-pythia6-evtgen/Summer12_DR53X-PU_RD2_START53_V19F-v2/AODSIM

- These samples were created with the appropriate conditions for the data analyzed, including the effects of alignment, efficiency, and number of simultaneous pp collisions.

Event selection for Signal channel

- We use $\frac{\sqrt{S}}{(5/2+\sqrt{B})}$ as the Figure Of Merit(FOM) for optimization. Where S is the N(B+) candidates from the official signal MC, and B is the number of background candidates within 5σ of the B^+ mass peak.

- Pointing Angle:defined as the cosine of the angle between the B meson pseudo-momentum direction and the direction obtained by the secondary and the primary vertices. The primary vertex is chosen to be the one that minimizes this angle for a given secondary vertex. Cos(θ*)>0.99

- Transverse impact parameter significance $\frac{L_{xy}}{\sigma_{xy}}(B^+)$ >4.0

- B vertex probability>0.1

- Dimuon pT > 7 GeV/c.

- Φ mass window<8 MeV

Note: Event Pre-Selection cuts are in backup slides

Normalization channel

- We use exactly the same requirements for $B^+ \to \psi(2S)K^+$ as in the $B^+ \to \psi(2S)\Phi K^+$ channel except **the requirement of Φ** to cancel systematics.

Explicit list of requirements:

- All kaon tracks to have $|\eta| \leq 2.4$ and muon tracks to have $|\eta| \leq 2.0$.
- All kaon tracks to have pT > 1 GeV.
- All muon tracks to have at least 1 pixel hit and at least 5 silicon hits.
- The fit probability for B vertex > 0.1.
- The detachment significance $\frac{L_{xy}}{\sigma_{xy}}(B^+) > 4.0$
- Dimuon p_T > 7 GeV and ψ(2S) candidate should pass HLT Dimuon 5 PsiPrime trigger

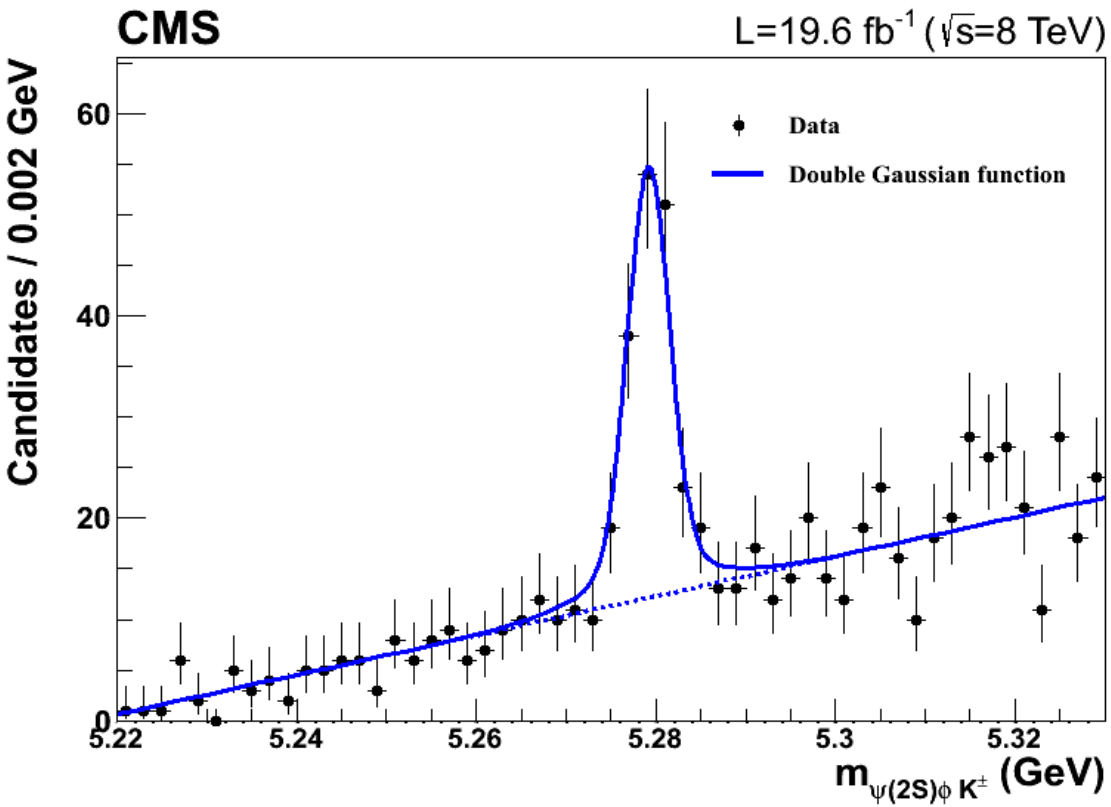
- We require $\mu^+\mu^-$ mass should be within 5σ of ψ(2S) PDG mass at its pseudorapidity.

$B^+ \rightarrow \psi(2S)\Phi K^+$ un binned fit

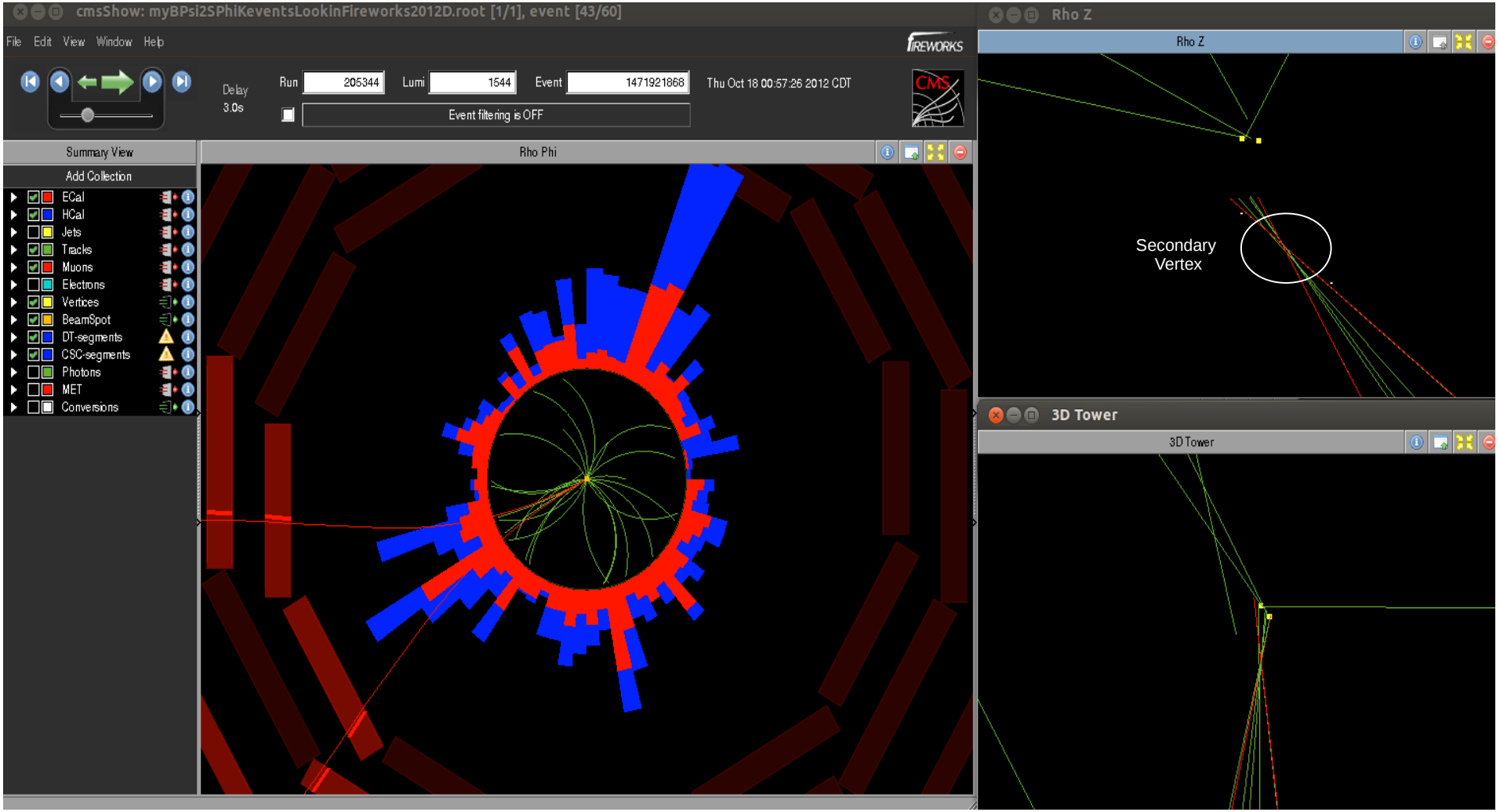
- Signal fitted to a double Gaussian function with fixed mean to PDG value and widths from MC fit parameters and background to a 1st order Chebyshev polynomial.

- Goodness of the fit

$$\frac{\chi^2}{d.o.f} = 0.96$$



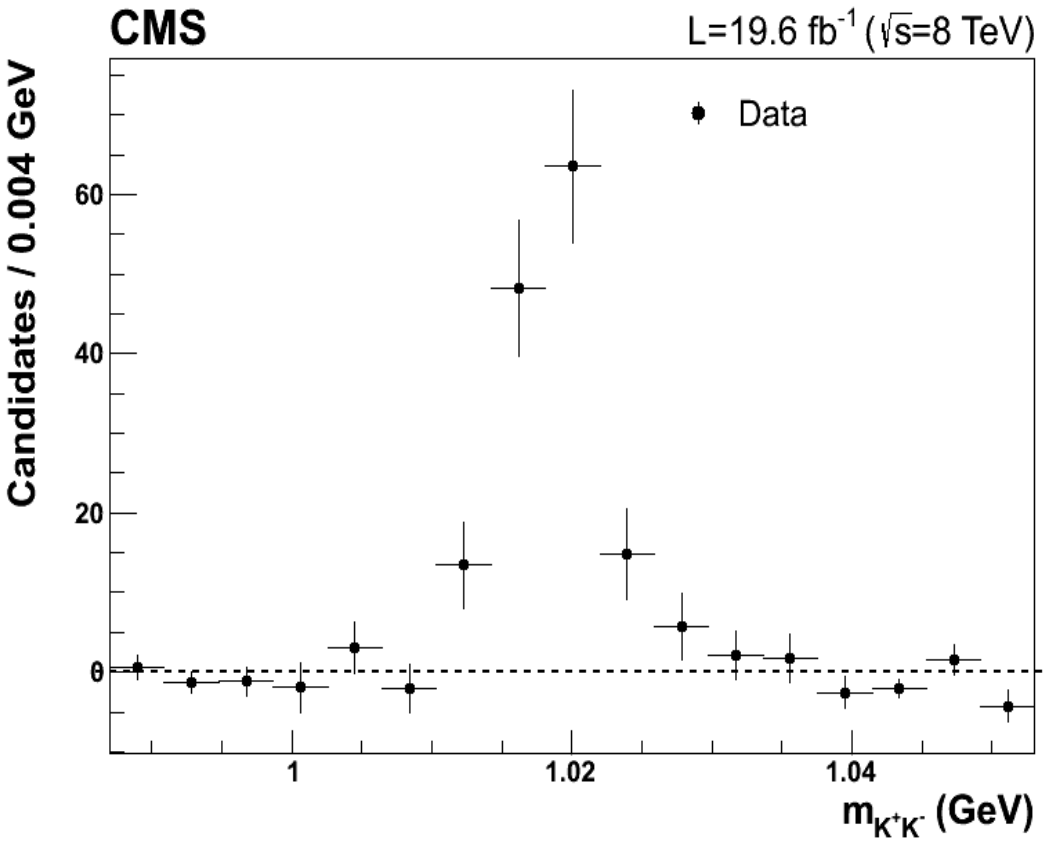
Event display in CMS fireworks



B^+ sideband subtracted Φ signal

- The Φ signal mass window [0.986,1.058] GeV is divided into 18 bins

- In each bin width, extract the B^+ yield by fitting data to a double Gaussian signal function + a 1st order Chebyschev polynomial background function.



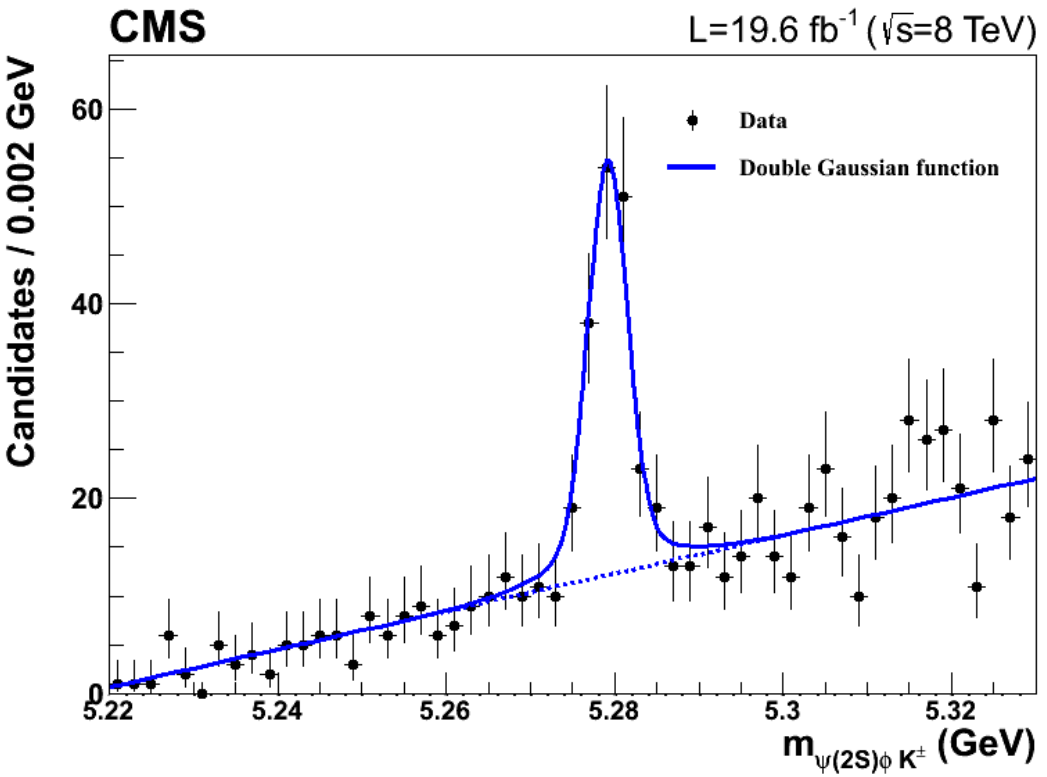
$B^+ \to \psi(2S)\Phi K^+$ significance

- We performed two hypothesis tests to the data:

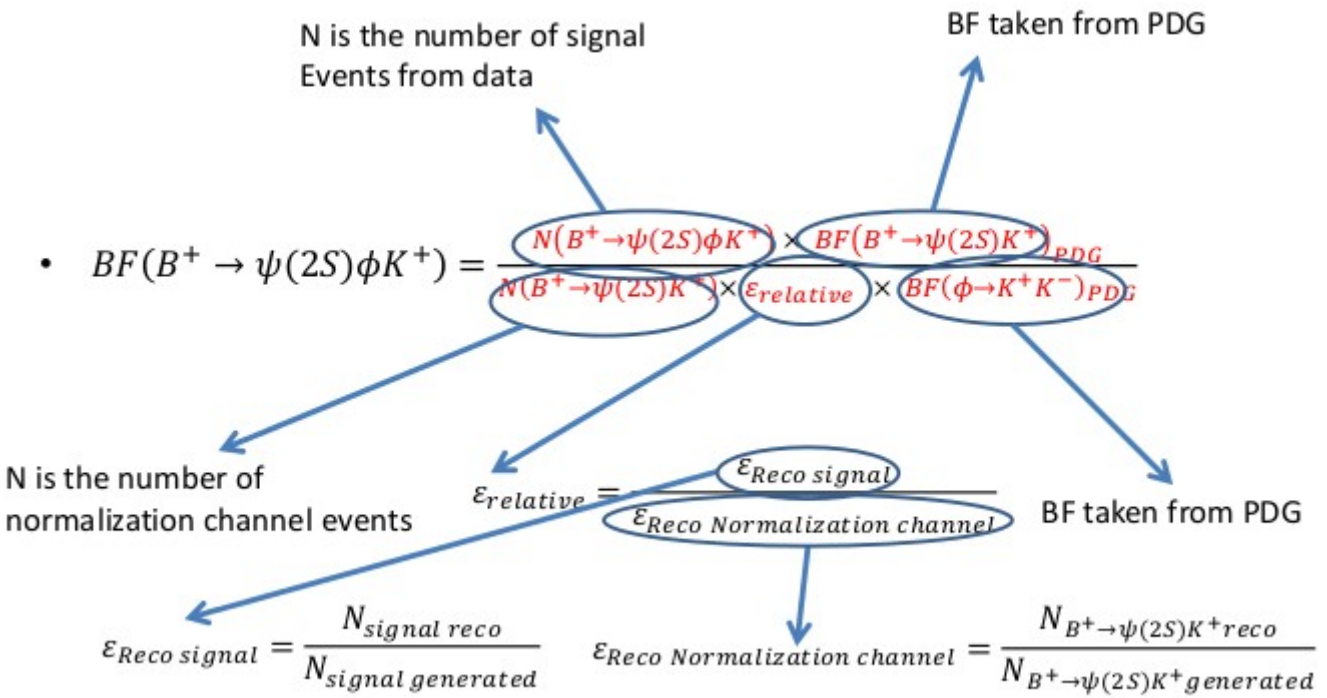
(1) A null hypothesis is tested by fitting the data using a background only model, and

(2) a signal hypothesis is tested by fitting the data to a background model and a signal model together while floating the signal amplitude.

- Likelihood returned from the null- or signal-hypothesis fit is denoted by L_0 or L_s, respectively.
- Local significance= $\sqrt{-2\ln\left(L_s/L_0\right)}$ $>5\sigma$



Branching fraction measurement strategy



Summary and Conclusion

- We observed the rare decay $B^+ \to \psi(2S)\Phi K^+$ for the first time

- the expected BR accuracy is of the order of 10% (In approval stage).

- With large data set at higher energy (i.e., LHC Run II data), It is possible to study substructures in $\psi(2S)\Phi$ system.

Thank You.
Any Questions ?

Event pre-selection

- Event pre selection requirements:
- All kaon tracks to have $p_T > 0.5$ GeV.
- All kaon and muon tracks to have $|\eta| \leq 2.4$.
- All muon tracks to have at least 1 pixel hit and at least 5 silicon hits.
- $\mu^+\mu^-$ pair with a valid vertex fit and mass within the range [3.4, 4.0] GeV.
- Three different tracks with assigned kaon mass, total charge= ±1 and mass upon combining with μ^+ μ^- in the range [5.15, 5.45] GeV.
- We have two K^+K^- pairs from three charged kaon tracks. We require the mass of K^+K^- pair with lower mass to be smaller than 1.06 GeV.
- We do a vertex fit to the five tracks and constraint $\mu^+\mu^-$ to nominal ψ(2S) mass and require vertex probability > 10^{-6}.
- We fitted $\mu^+\mu^-$ mass with MC extracted resolution with the varied pseudorapidity. We require $\mu^+\mu^-$ mass should be within 5σ of ψ(2S) PDG mass at its pseudorapidity.