Heavy Quarks as Probes of the Primordial Plasma

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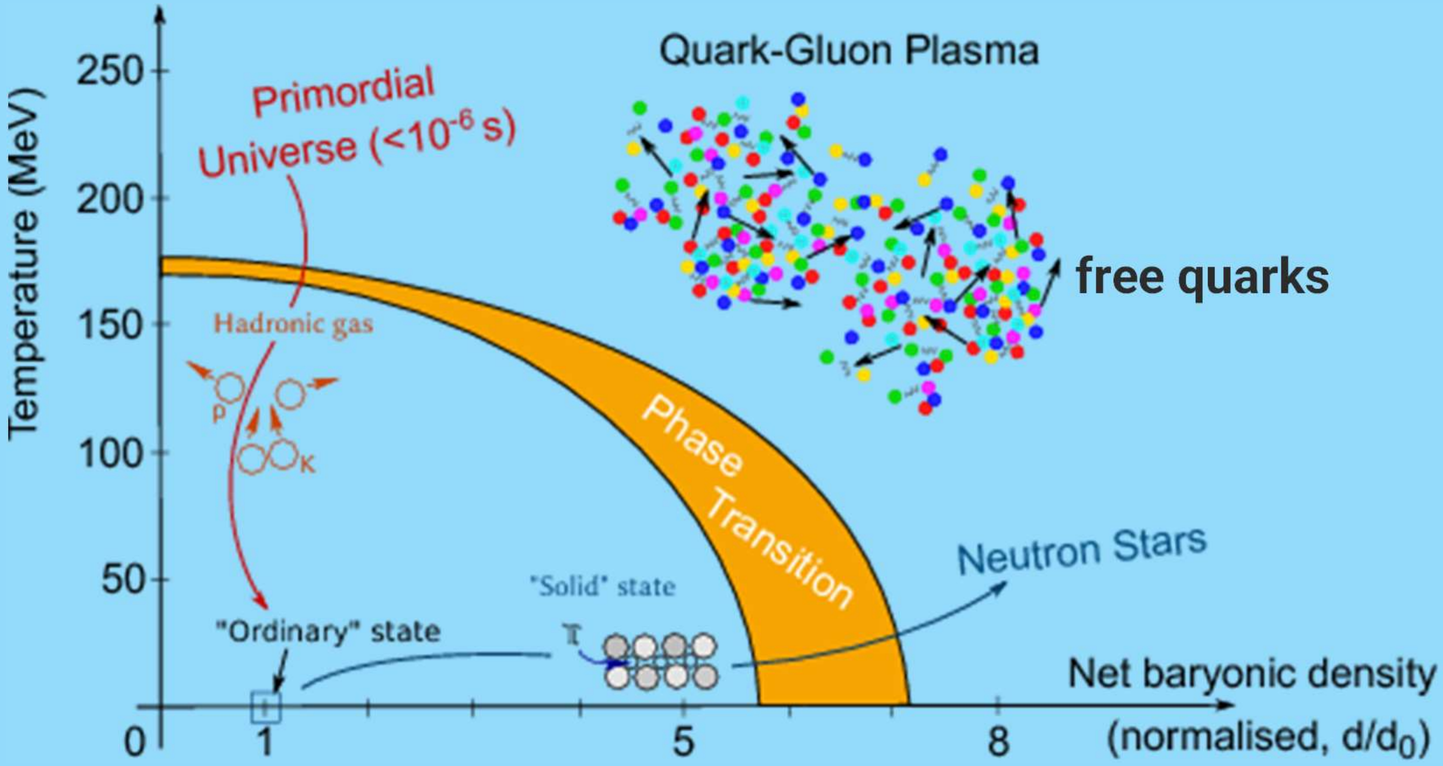
Introduction

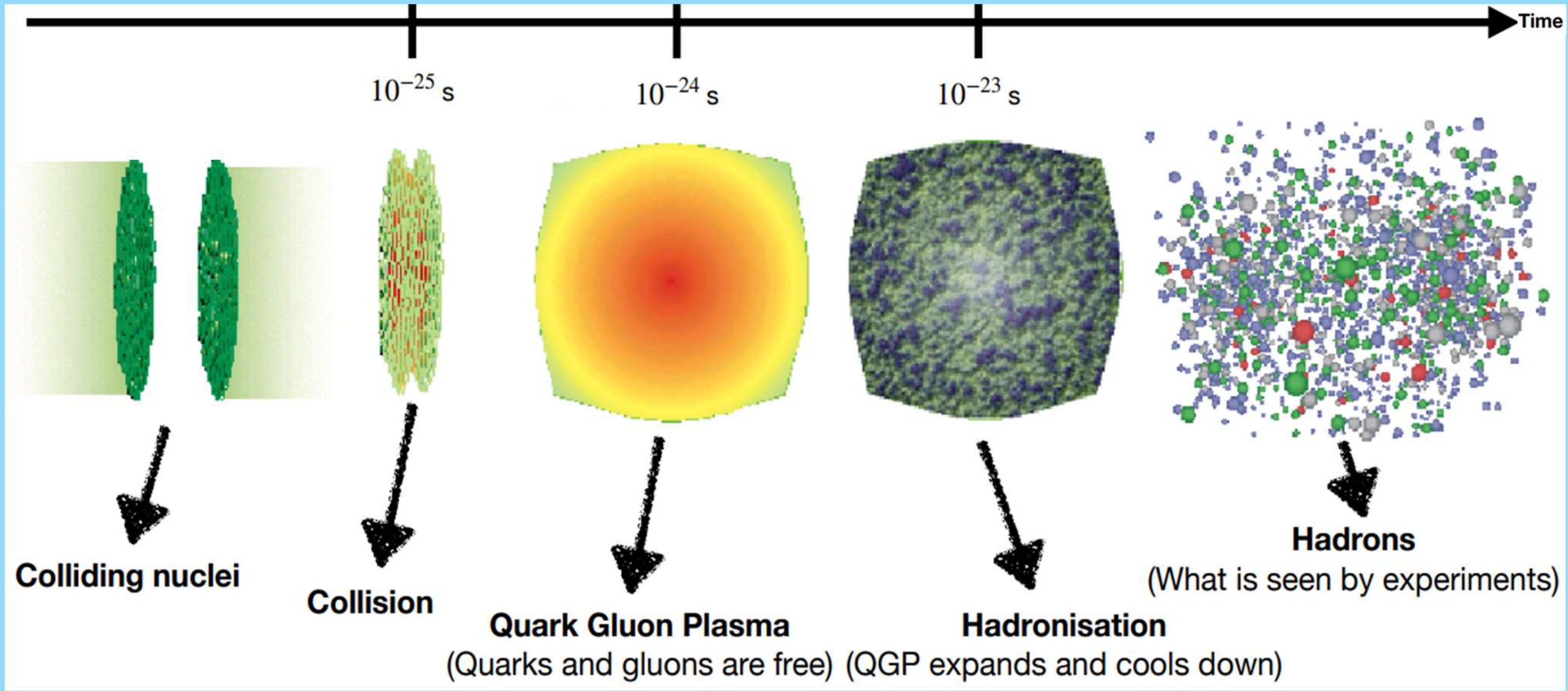
Quark Gluon Plasma (QGP)

State of matter that occurs under **extreme conditions** of **density** and **temperature**



Heavy Ion Collisions

QGP can be **formed** in **high energy particle collisions**, for example, at LHC



What we Want to Study

Study the **hadronization** process **of quarks**

Learn the **effect** of a **quark-gluon plasma** on the **hadronization process**

The Idea

Use **B mesons** that originate in **p-p** and **Pb-Pb** collisions to learn about the QGP

In **p-p** collisions **QGP** does **not form** (or, is negligible)
In **Pb-Pb** collisions, a **big and hot QGP** occurs

⇒ **Measure** the production **Cross Section** of B-mesons in each type of collisions

⇒ Compare them (considering the difference in the number of nucleons involved)

$$R_{AA} \propto \frac{\left(\frac{d\sigma}{dp_T}\right)_{PbPb}}{\left(\frac{d\sigma}{dp_T}\right)_{pp}}$$

Current Work

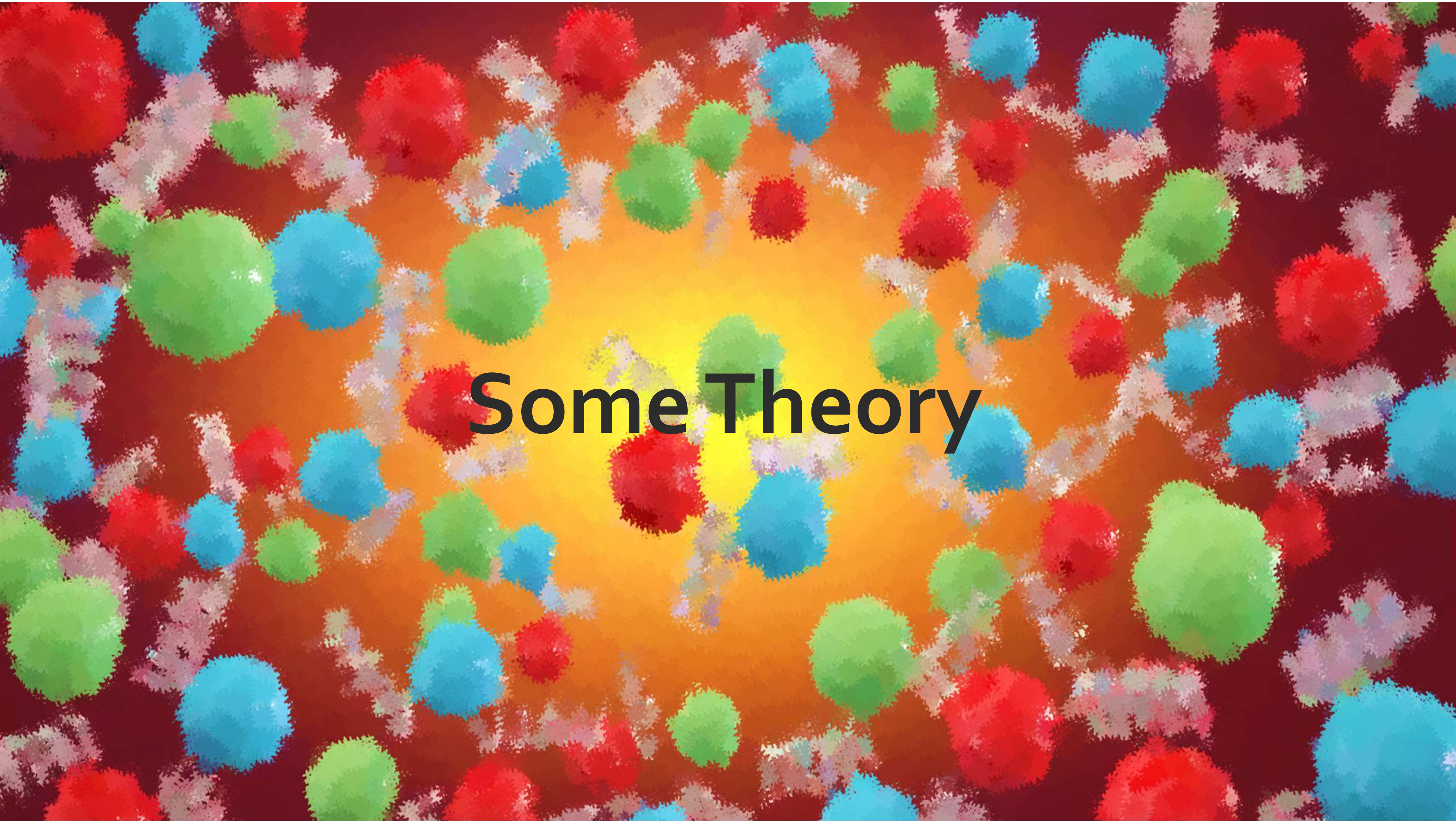
Previously, Pb-Pb Cross Section was studied

Currently we are **working** on the **p-p Cross Section**

⇒ We are using **data** from **p-p collisions** from the **2017 LHC** run:

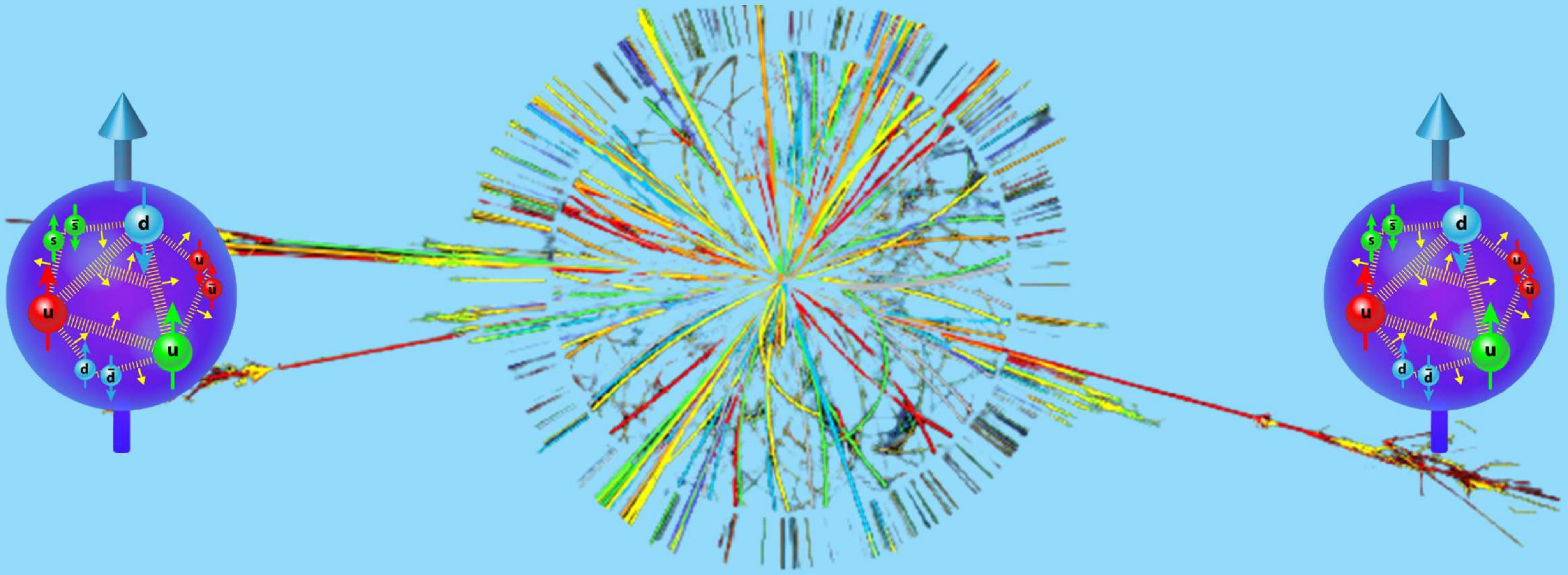
Center of mass energy of $\sqrt{s} = \mathbf{5\ TeV}$

Luminosity of **L= 302.3 pb-1**


Some Theory

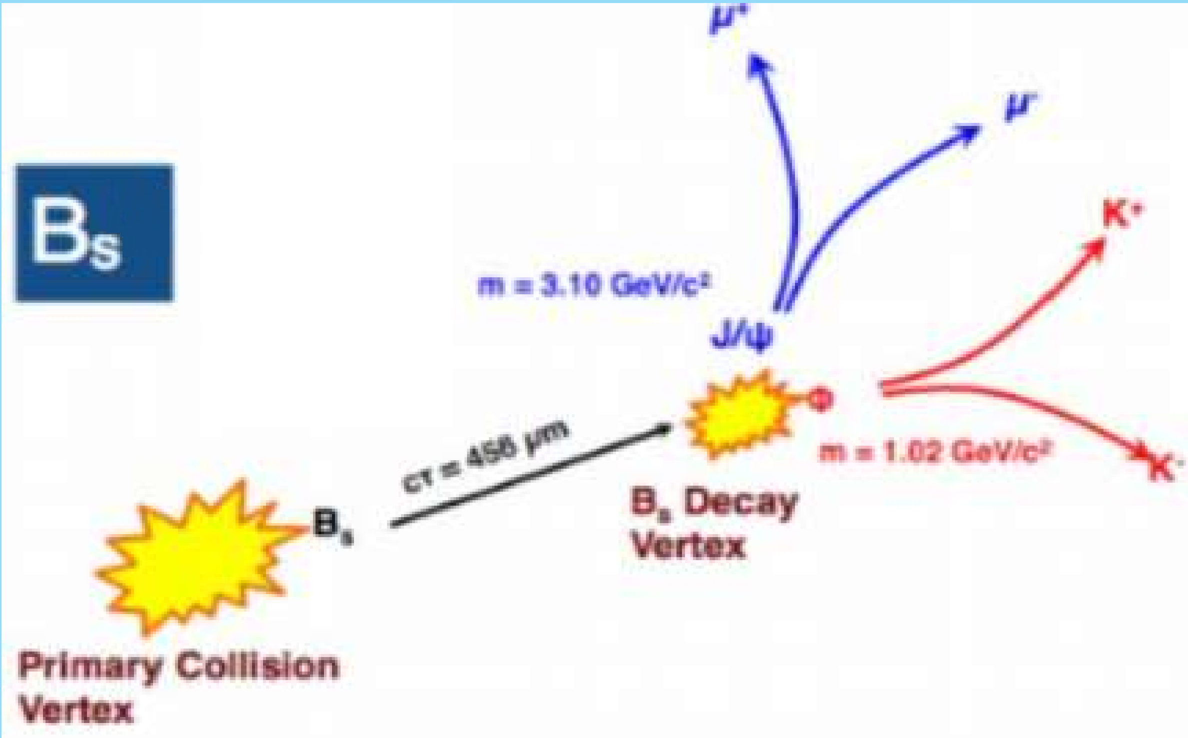
High Energy Particle Collision

In a **nucleon-nucleon** collision many process occur:



Probing the Quark gluon Plasma

Among the new produced particles, **B-mesons** will form due to **hadronization of quarks** and can be used to learn about the **QGP** presence



B-mesons

The following three B-mesons states are good candidates for probing the plasma:

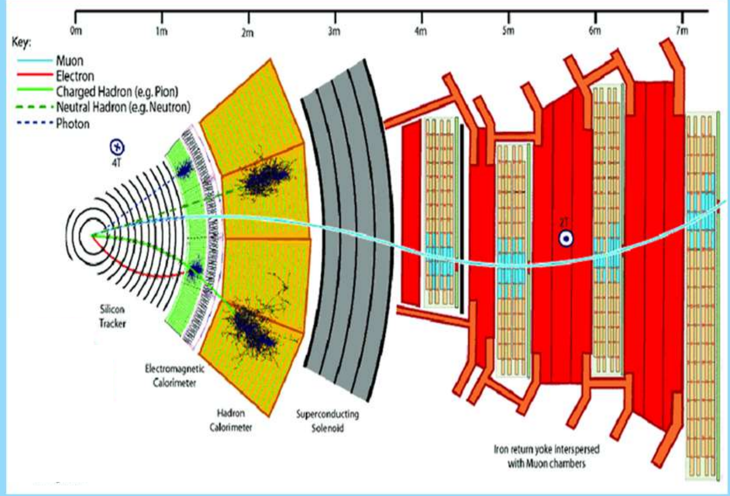
B^+ $(\bar{b}u) \rightarrow$ $J/\psi\ K^+$ $\rightarrow \mu^+\mu^-\ K^+$

B^0_s $(\bar{b}s) \rightarrow$ $J/\psi\ \phi$ $\rightarrow \mu^+\mu^-\ K^+K^-$

B^0 $(\bar{b}d) \rightarrow$ $J/\psi\ K^{*0}$ $\rightarrow \mu^+\mu^-\ K^+\pi^-$

detect and measure these final particles

Use **CMS** (Compact Muon Solenoid) detector



Differential Cross Section

$$R_{AA} \propto \frac{\left(\frac{d\sigma}{dp_T}\right)_{PbPb}}{\left(\frac{d\sigma}{dp_T}\right)_{pp}}$$

$$\frac{d\sigma}{dp_T} = \frac{1}{\epsilon \; L \; B} \frac{dN_S}{dp_T}$$

dN_S: Obtained from a fit to data

ϵ: Obtained from MC simulation

ϵ - Efficiency x Acceptance of the detector

B - Branching fraction (from PDG) of B meson decay

L- Luminosity (L= 302.3 pb^{-1})

N_s – Signal Yield (number of signal events in data)

Extended Unbinned Maximum Likelihood

$$\mathscr{L}(m_i, \vec{\lambda}) = \prod_{i=1}^{N_{obs}} l(m_i) \times \frac{e^{-N} N^{N_{obs}}}{N_{obs}!}$$

N_s is a parameter **multiplying** the **signal peak** chosen function

Model

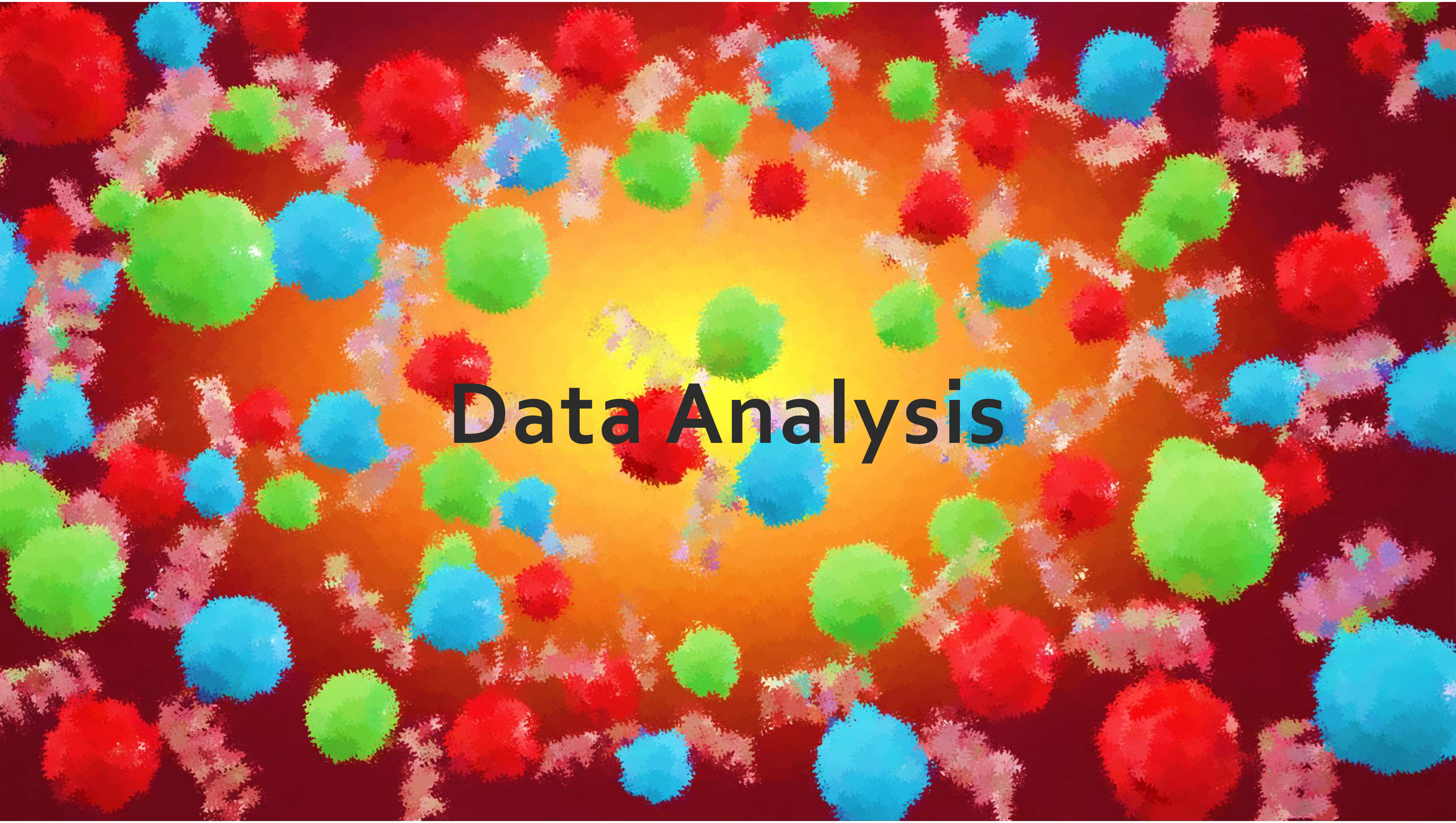
Signal Peak

Background

B^0_s ⇒ **Gaussian** function

B^+ ⇒ **Double Gaussian** function

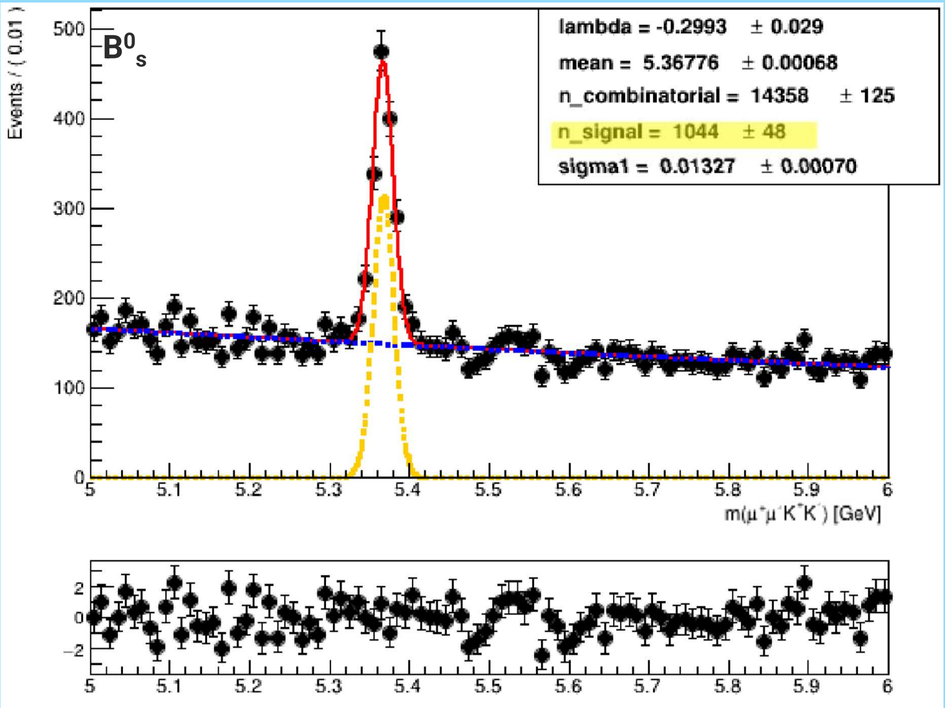
B^0_s and **B^+** ⇒ **Exponential** function


Data Analysis

Data Fitting

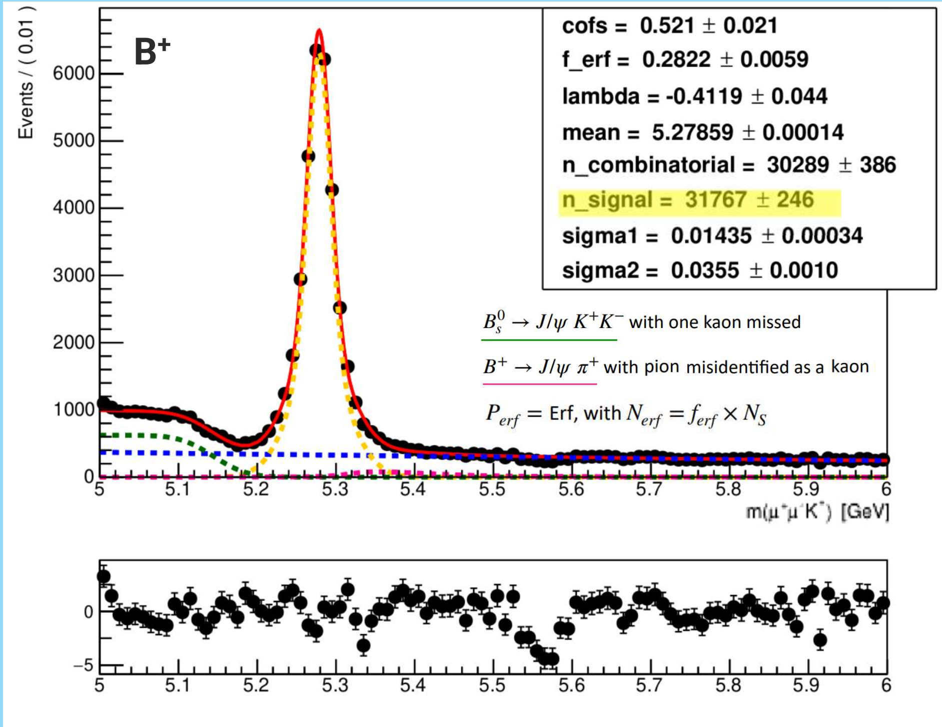
$$l(m_i) = N_S P_S(m_i; \mu, \sigma_1) + N_{CB} P_{CB}(m_i; \lambda)$$

$$P_S = \text{Gauss}(\mu, \sigma_1) \qquad P_{CB} = \text{Exp}(\lambda)$$



$$l(m_i) = N_S P_S(m_i; \mu, \sigma_1, \sigma_2) + N_{CB} P_{CB}(m_i; \lambda) + N_{erf} P_{erf}(m_i) + N_{jpp}(\text{fixed})$$

$$P_S = \alpha \text{ Gauss}(\mu, \sigma_1) + (1-\alpha)\text{Gauss}(\mu, \sigma_2) \qquad P_{CB} = \text{Exp}(\lambda)$$

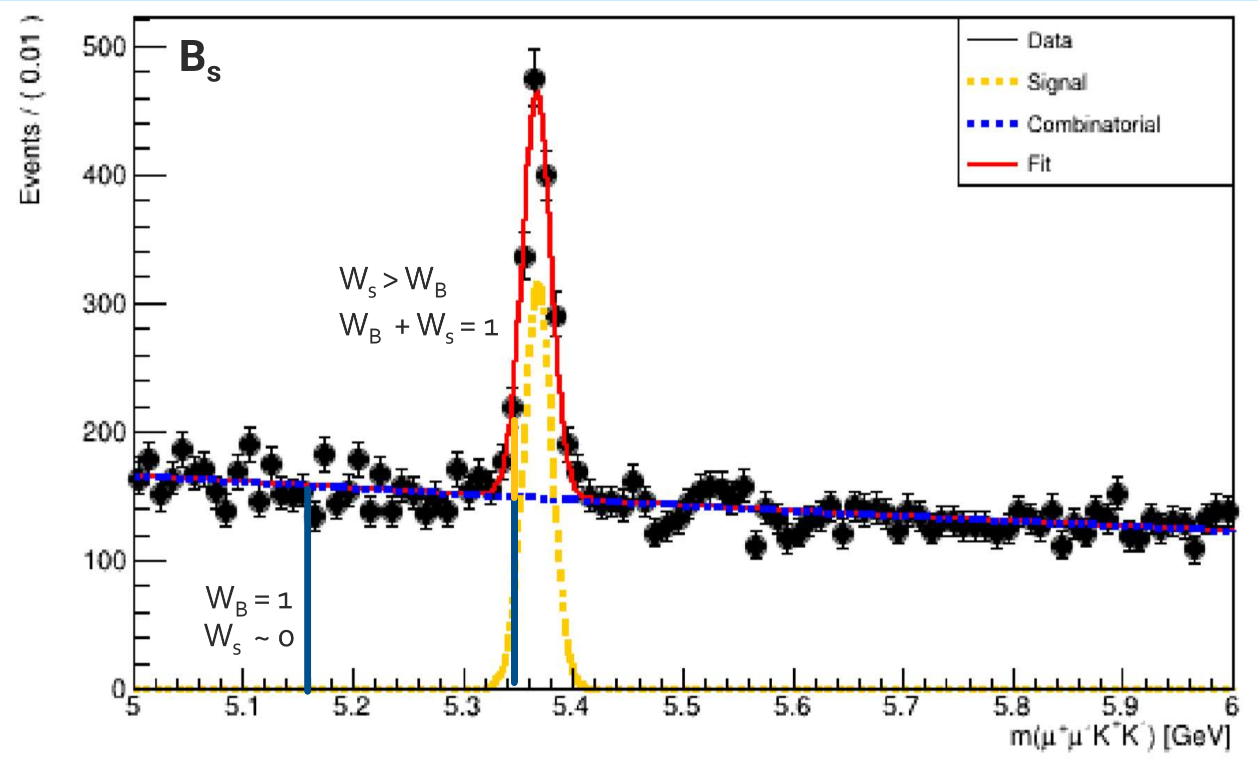


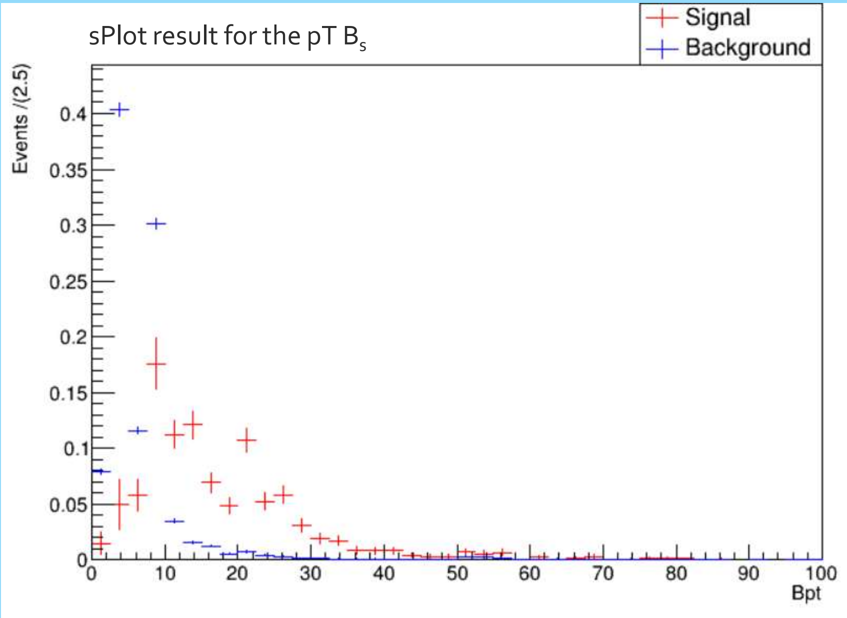
sPlot

Based on the likelihood fit to the B-meson mass and in the following statistical weights:

W_s : Probability of being signal

W_B : Probability of being background

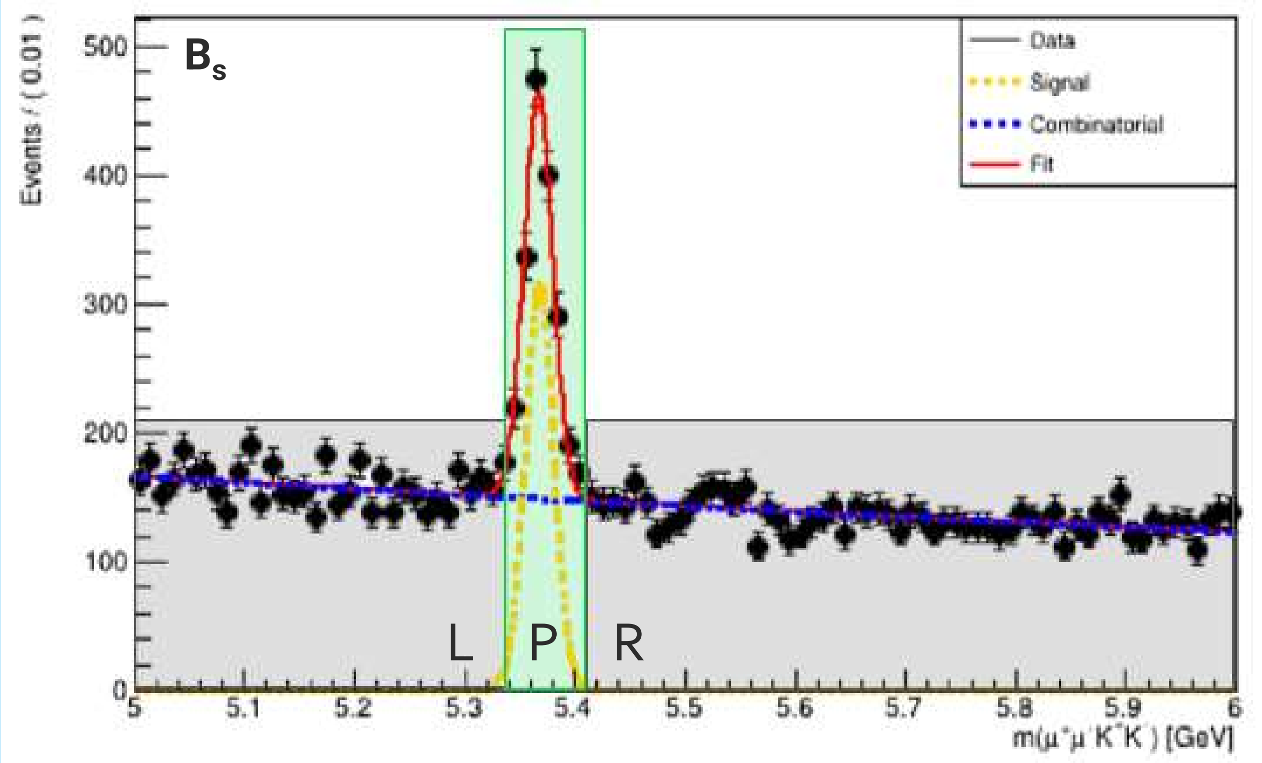


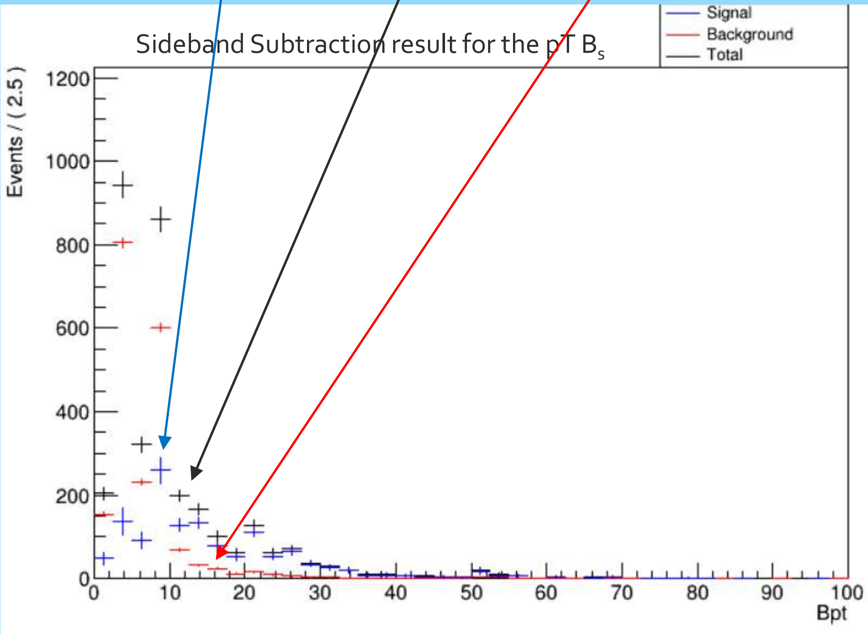


Sideband Subtraction

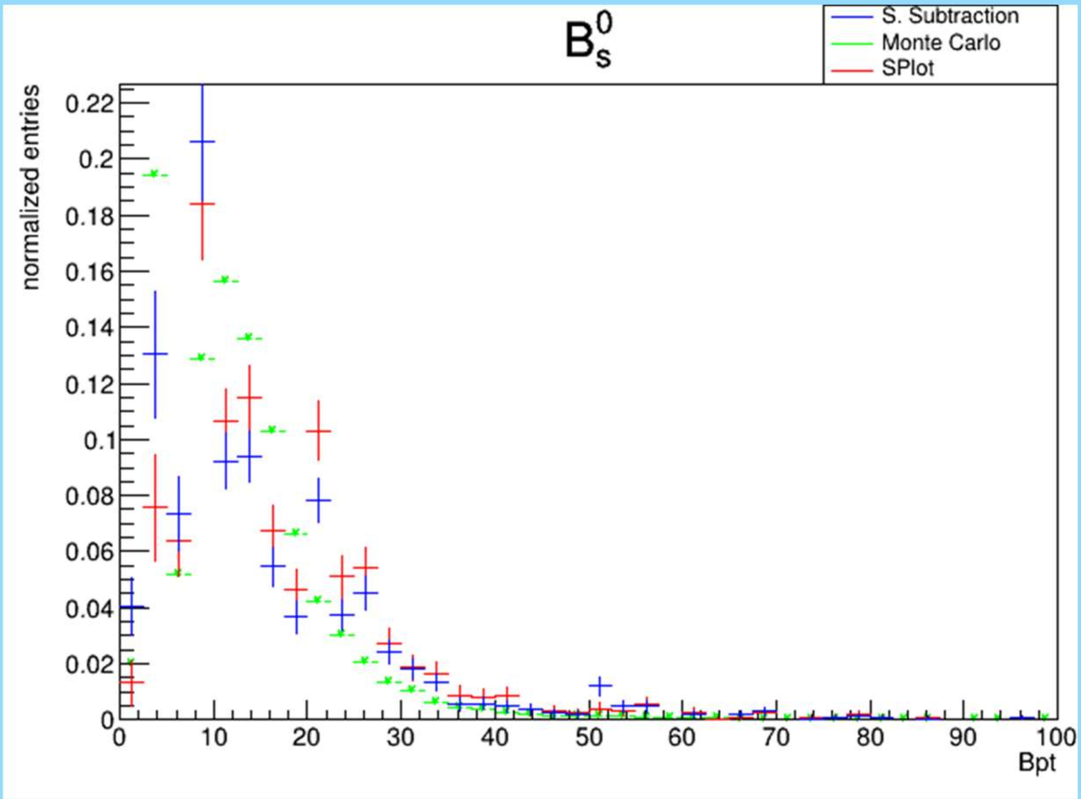
$$V_{signal} = V_{peak} - r\, V_{sideband}$$

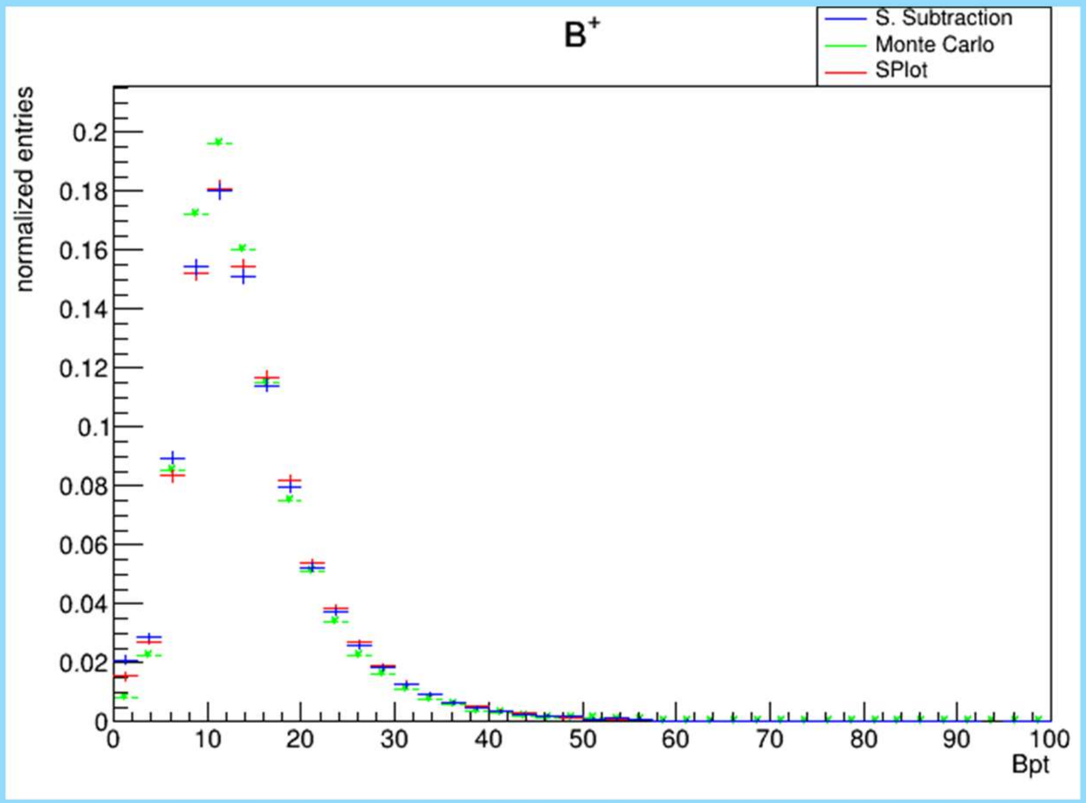
$$r = \frac{P}{L+R}$$



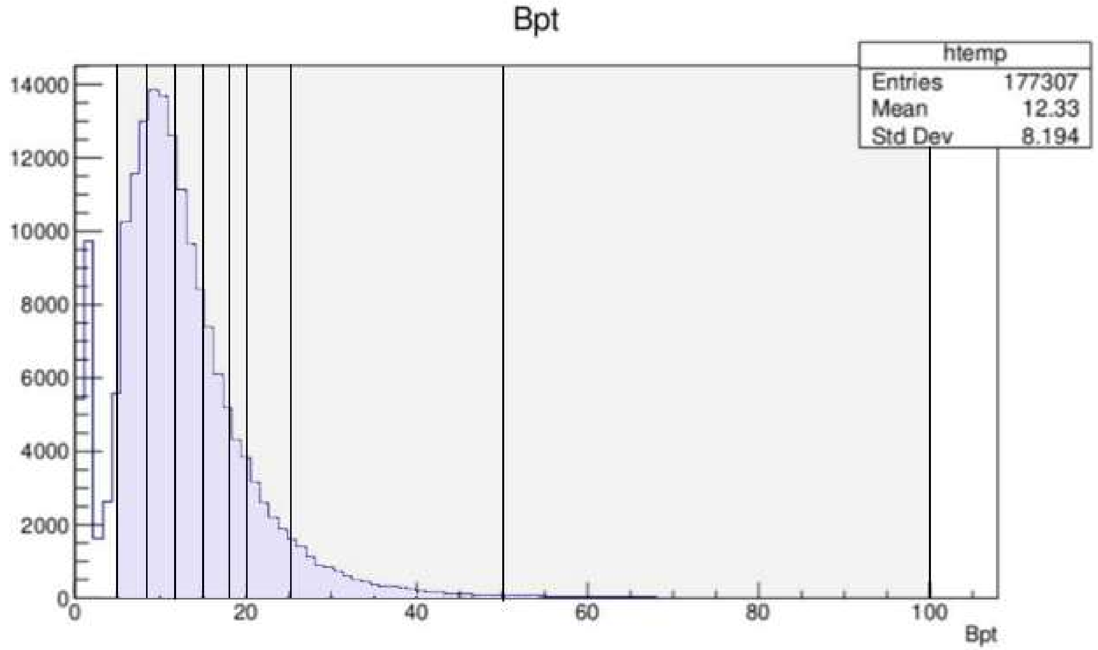


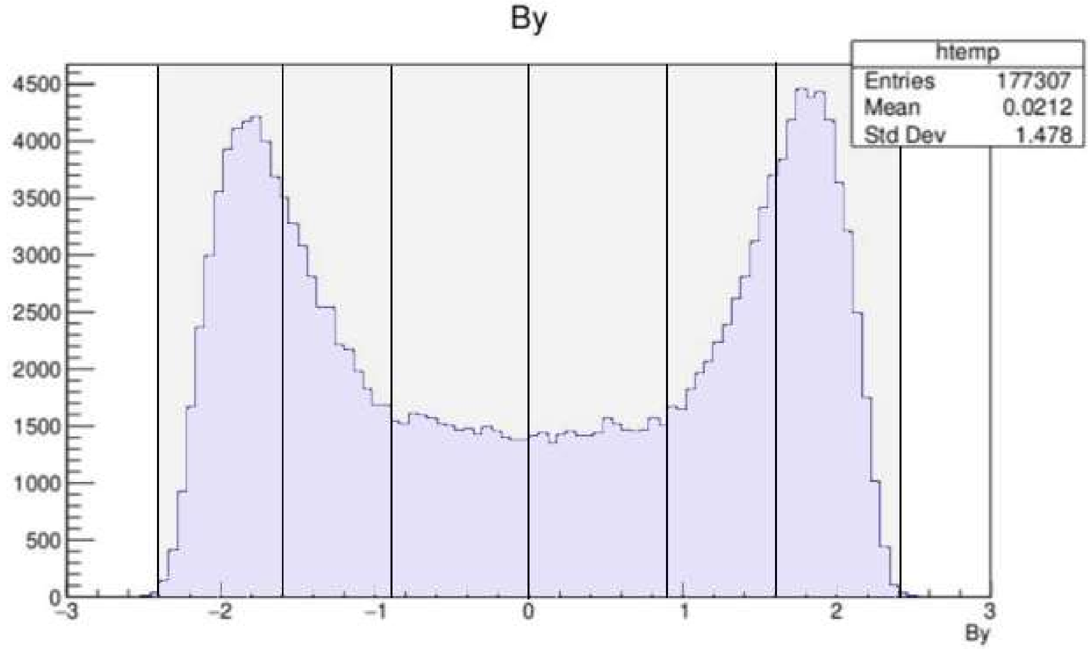
MC vs Data ComparisoN (P_T)

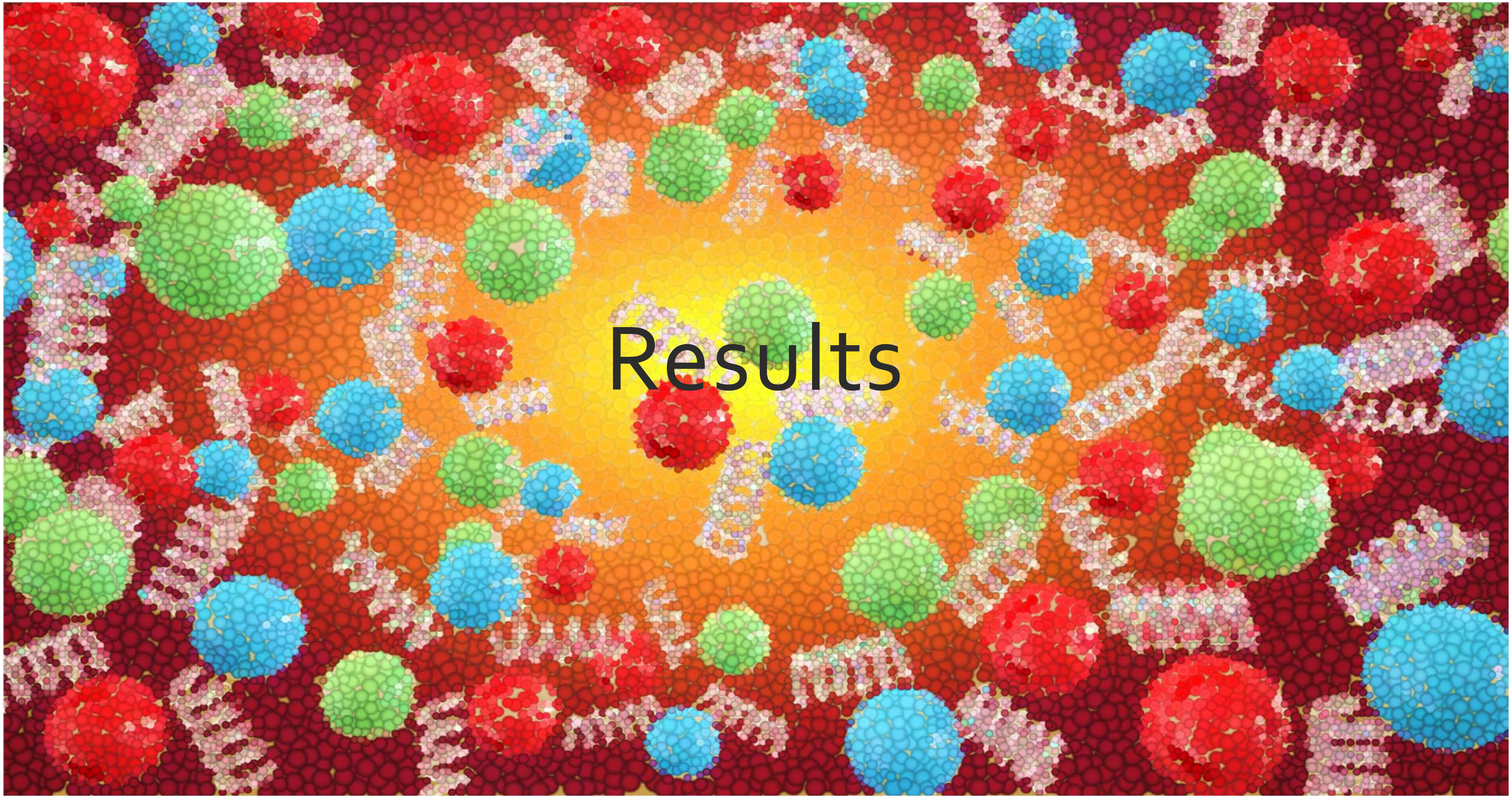




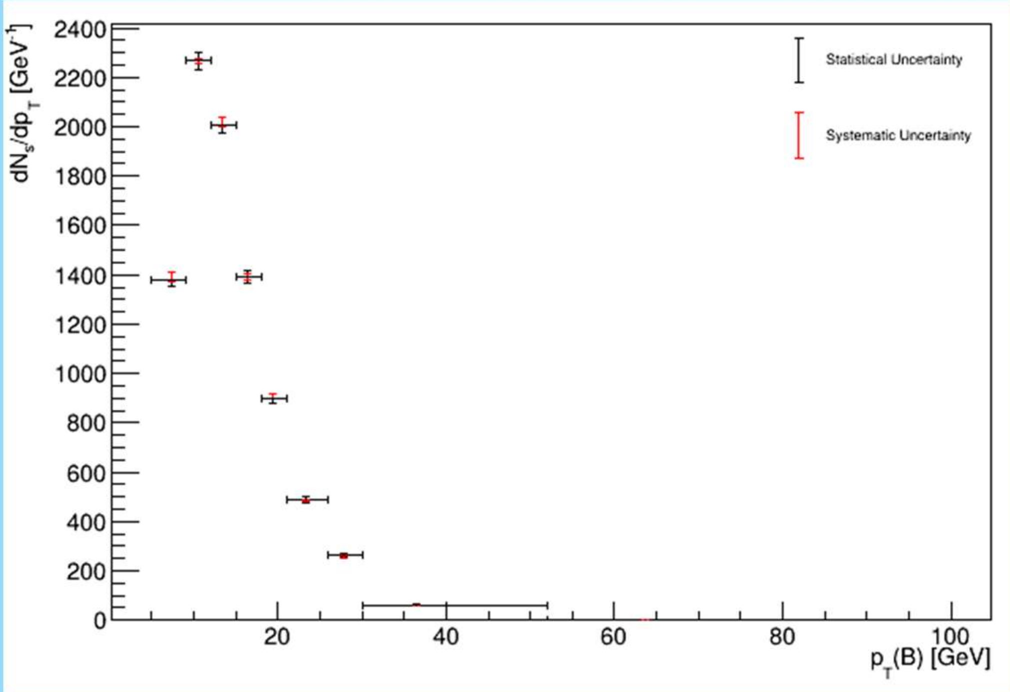
B^+ Transverse Momentum and Rapidity

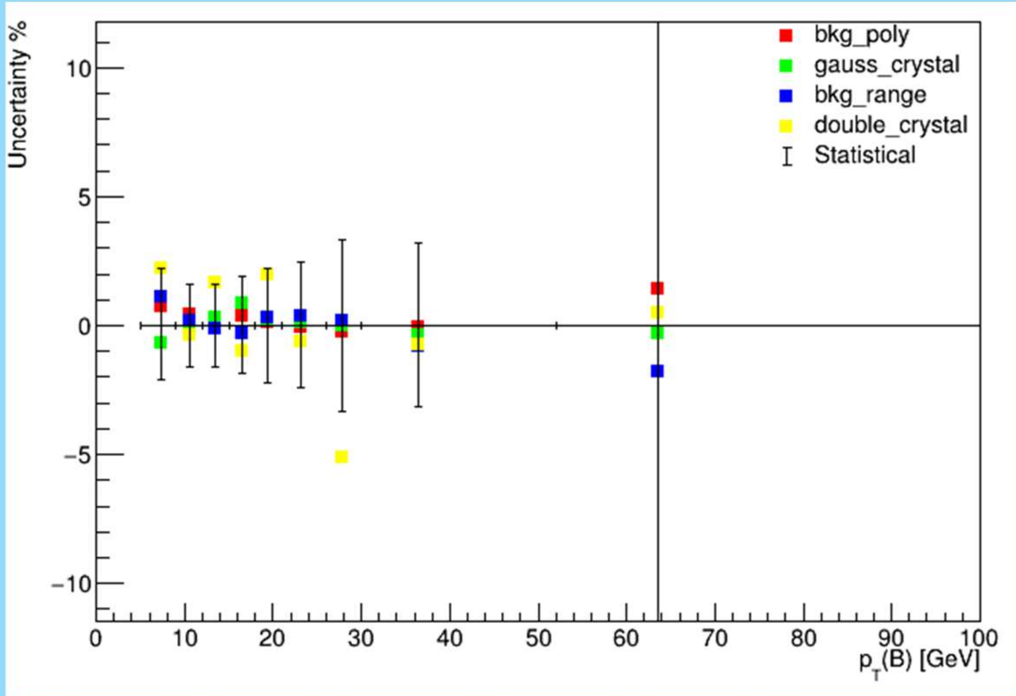





Results

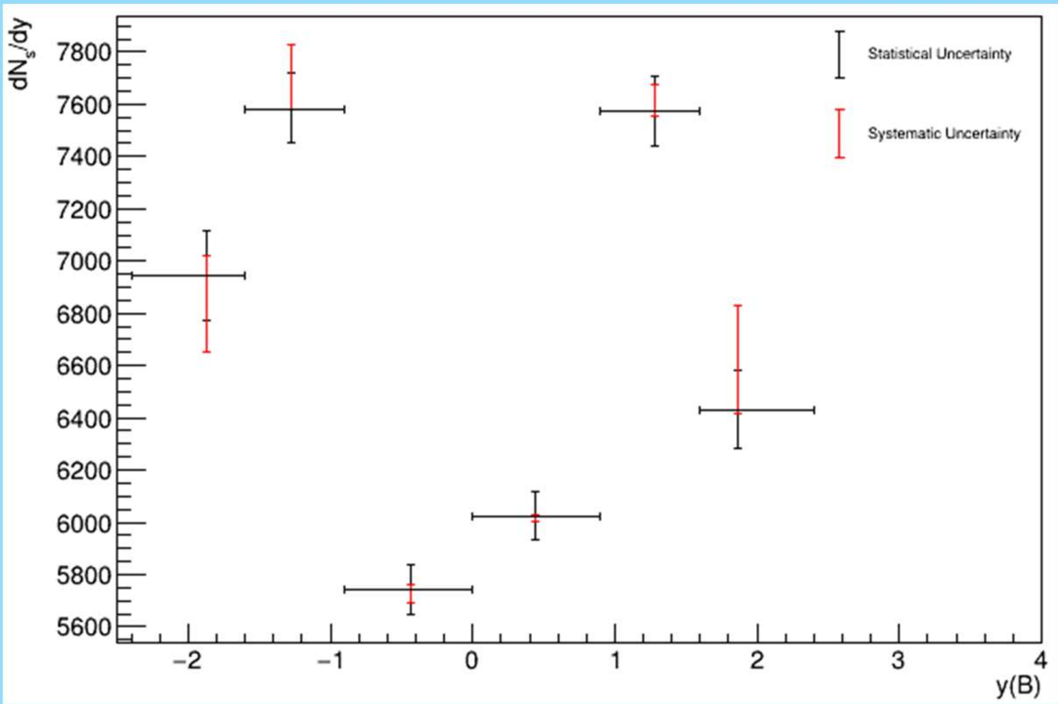
B^+ Differential Yield vs P_T

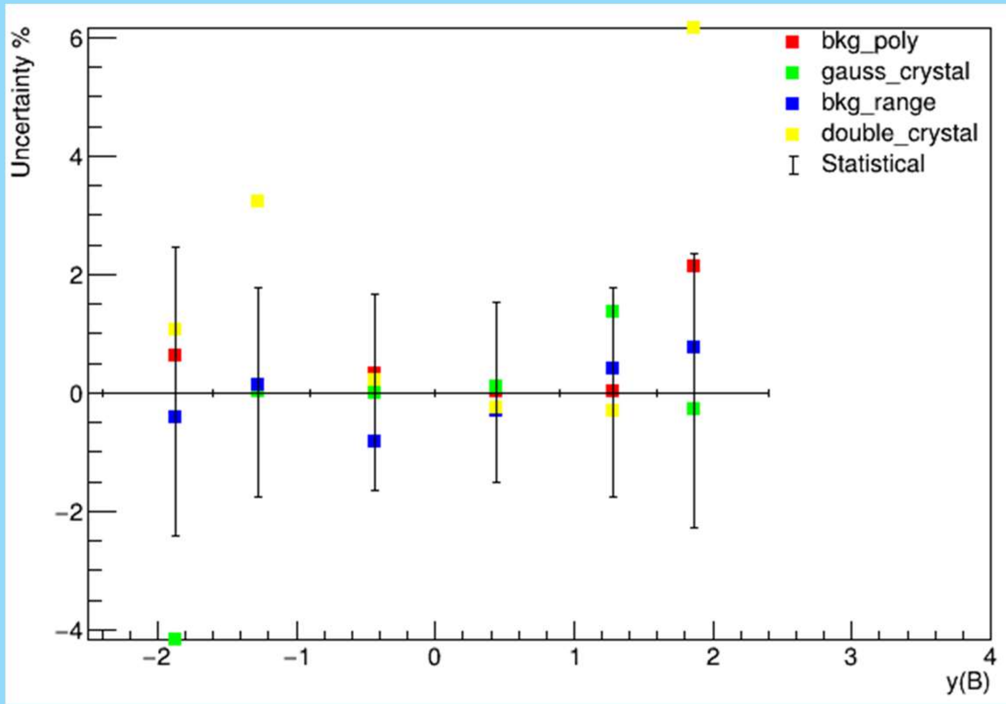




$$\frac{d\sigma}{dp_T} = \frac{1}{\epsilon\ L\ B}\boxed{\frac{\boldsymbol{dN_s}}{\boldsymbol{dp_T}}}$$

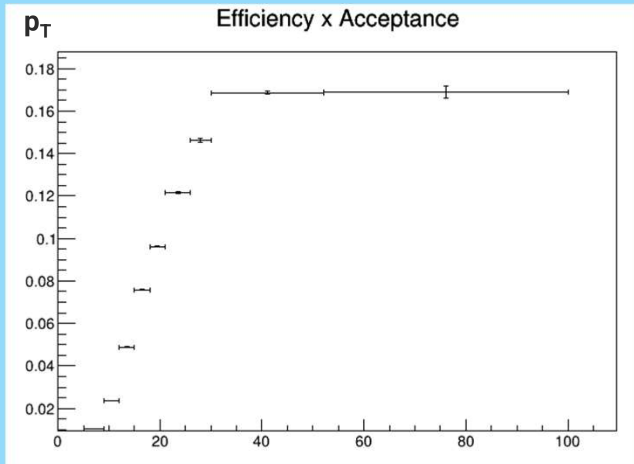
B^+ Differential Yield vs By

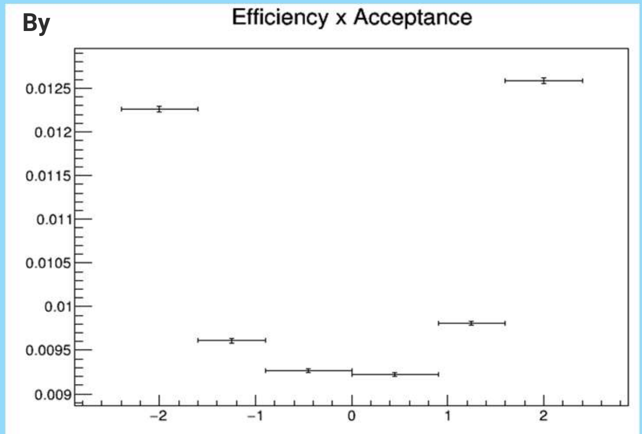




$$\frac{d\sigma}{dy} = \frac{1}{\epsilon\, L\, B} \boxed{\frac{\boldsymbol{dN_s}}{\boldsymbol{dy}}}$$

B^+ Efficiency





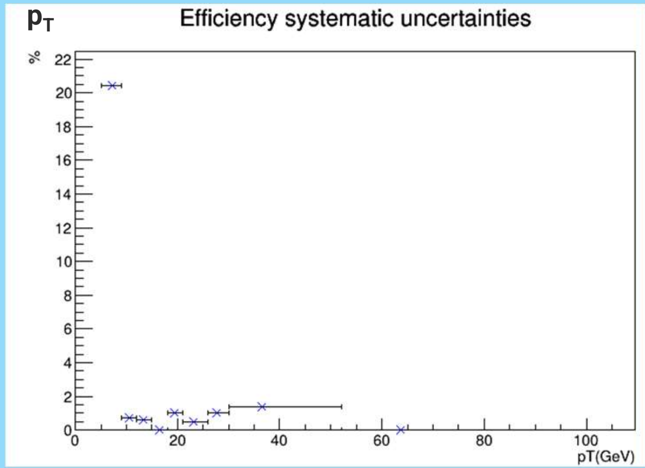
$$\frac{d\sigma}{dp_T} = \frac{1}{\epsilon\, L\, B} \frac{dN_s}{dp_T}$$

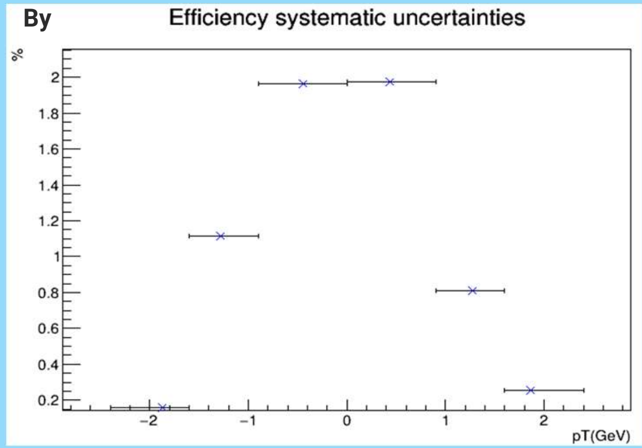
$$\epsilon = \frac{N_{after\ cuts}}{N_{before\ cuts}}$$

$$\Delta = \frac{\epsilon^1 - \epsilon^0}{\epsilon^0}$$

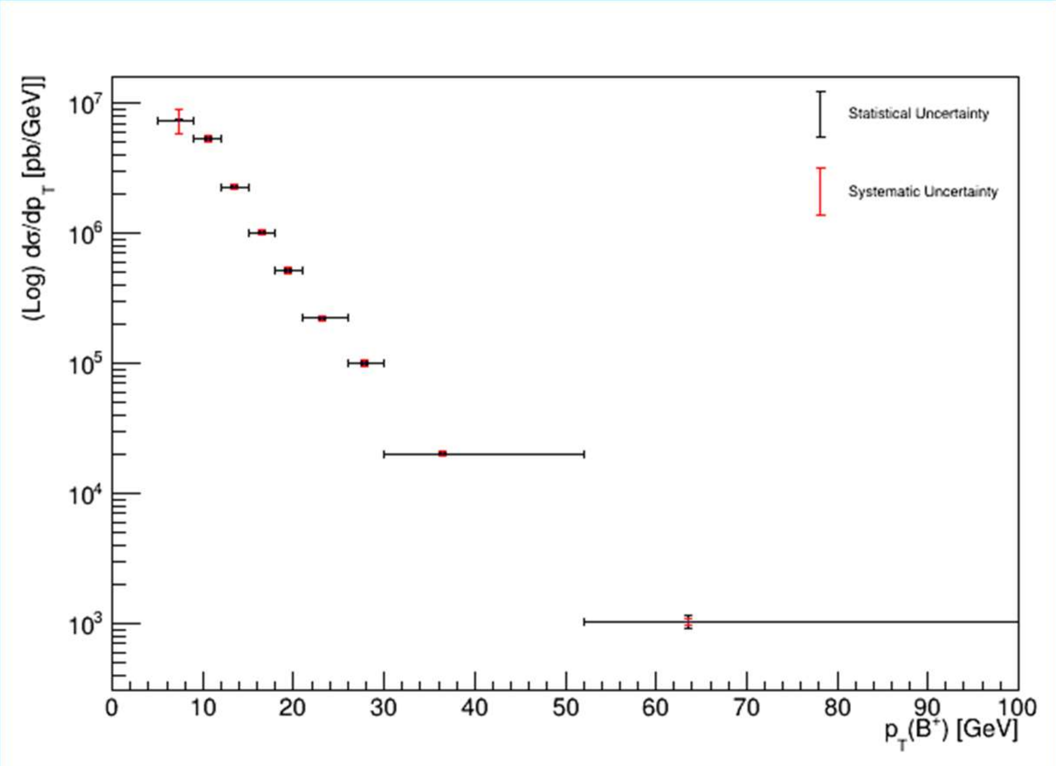
$\epsilon^1 \Rightarrow$ with data/MC weights

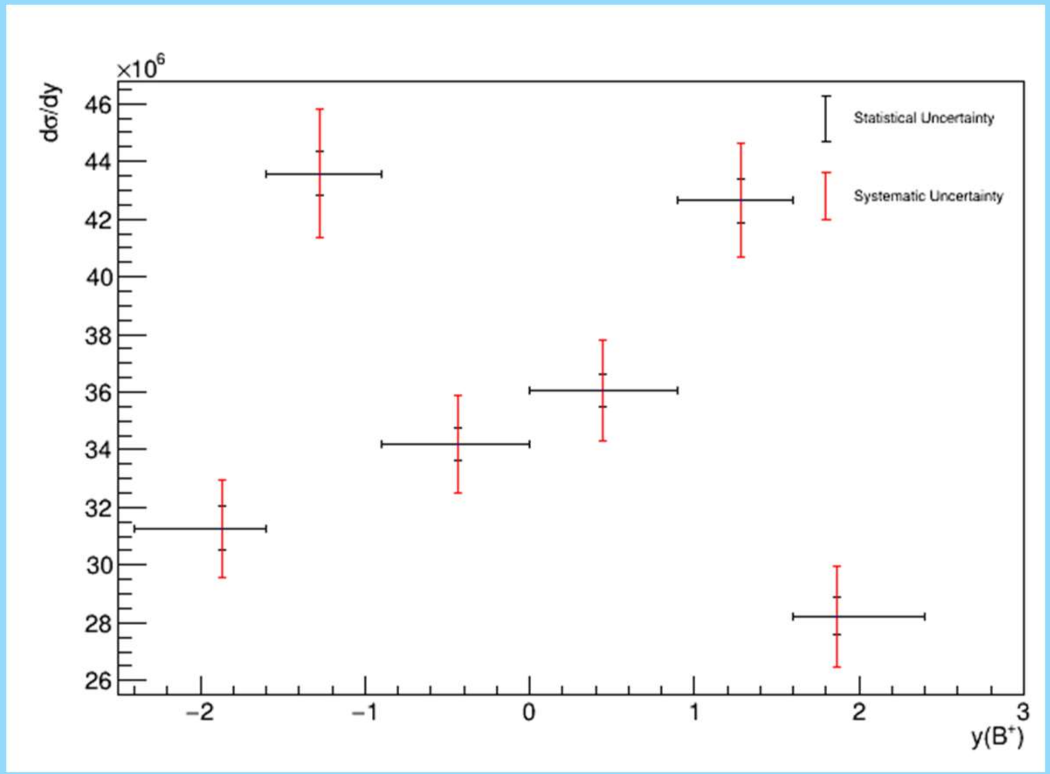
$\epsilon^0 \Rightarrow$ without data/MC weights





Differential Cross Sections






Final Regards

Next Steps

Improve the MC simulation for Bs and check the data sample

Measure the fragmentation fraction Bs/B^+

Compare the p-p results to the Pb-Pb results

Conclusion

We have studied the production of B^0_s and B^+ mesons at LHC using the CMS detector

Signal Yield (N_s) was extracted from data using the likelihood method.

Differential Signal Yield obtained as function of :

- Transverse Momentum (p_T)
- Rapidity (By)
- Multiplicity

Detector efficiency was estimated using Monte Carlo simulations (and validated)

All the associated uncertainties were estimated

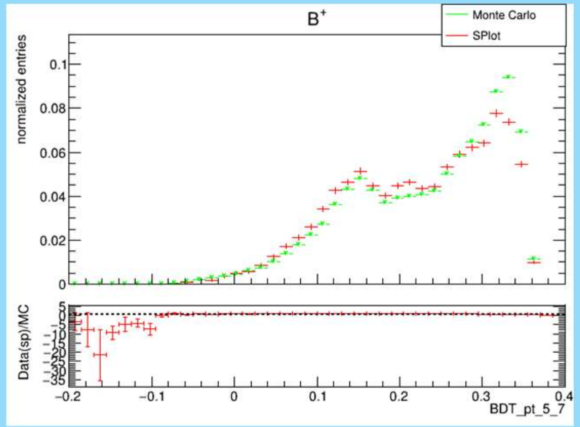
B^+ Cross Section at $\sqrt{s} = 5$ TeV was measured as function of By and p_T

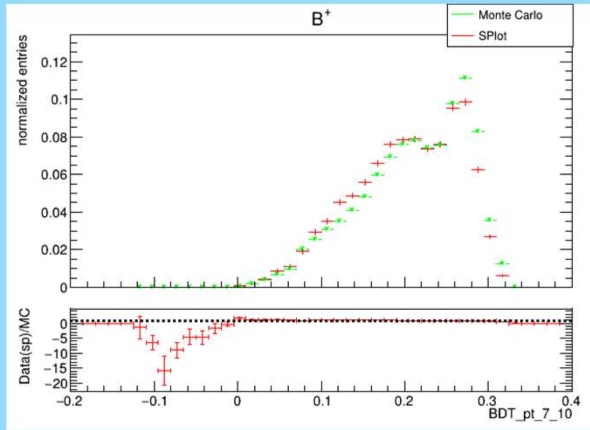
THE END

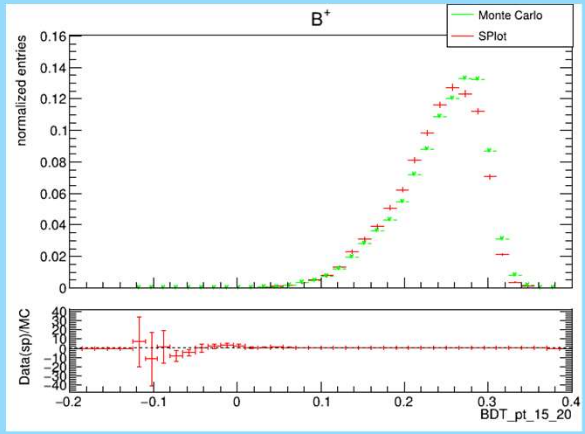
Thank you for your attention!

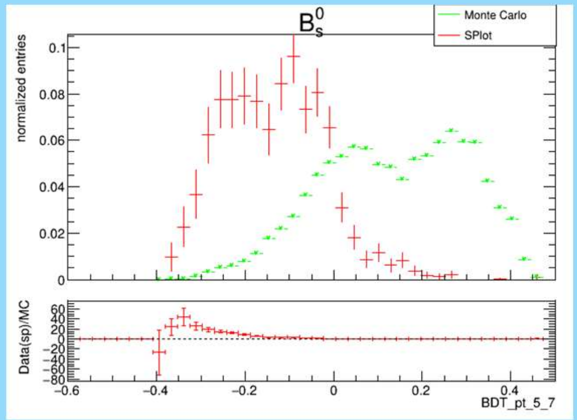
Any question ?

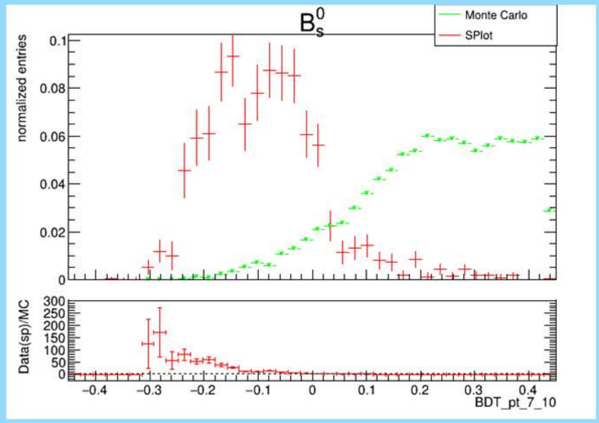
MC vs Data Comparisson

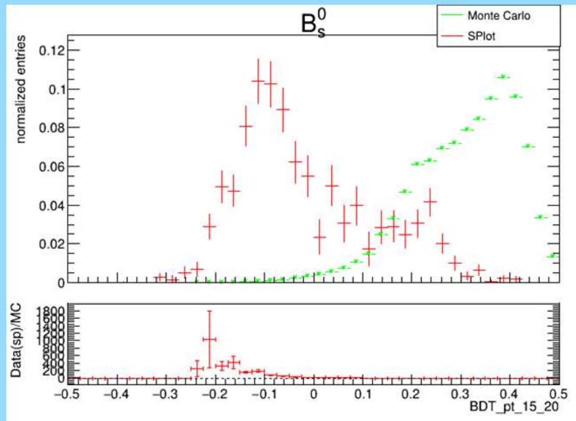




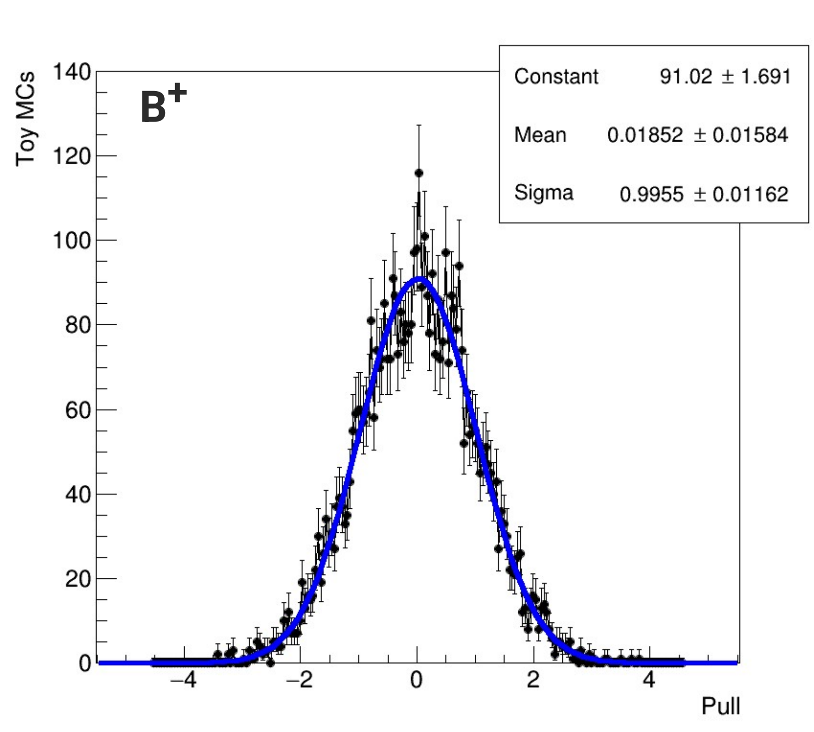


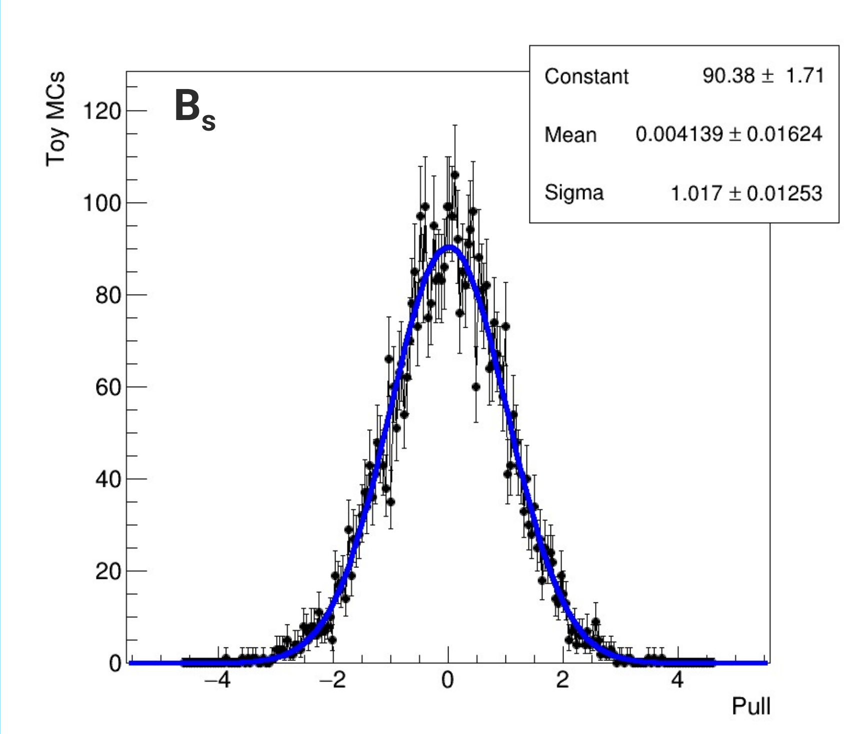






Data Fitting Validation





$$Pull = \frac{N_i - N_s}{\sigma_i}$$

N_i: signal yield of pseudo-data i
N_s: signal yield of data
σ_i: uncertainty on N_i