



# Time-based studies of the benchmark channels for the DAQ system

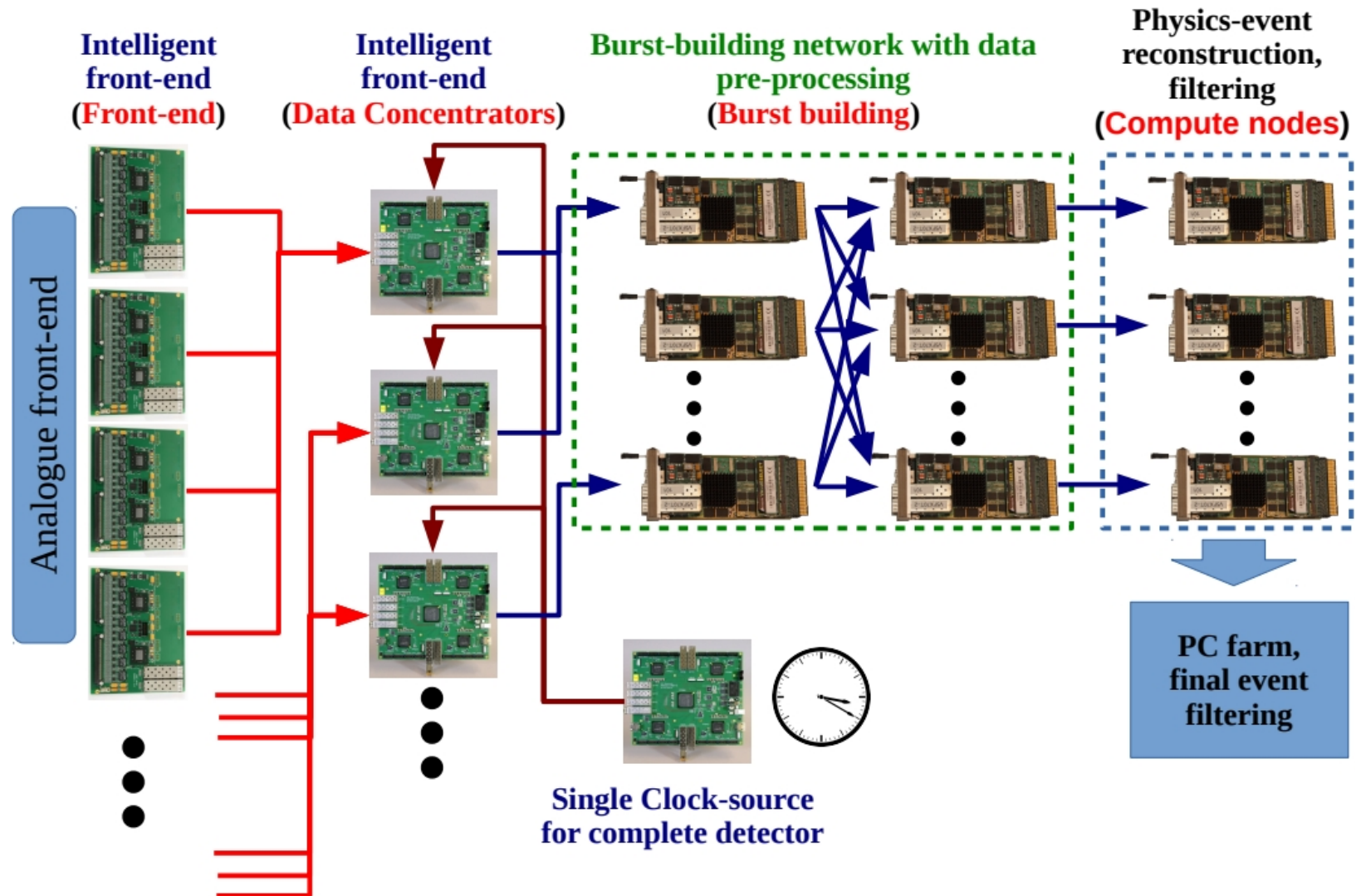
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**Myroslav Kavatsyuk**

ESRIG, University of Groningen

Oct 26, 2021,  $\bar{P}$ ANDA CM 21/3

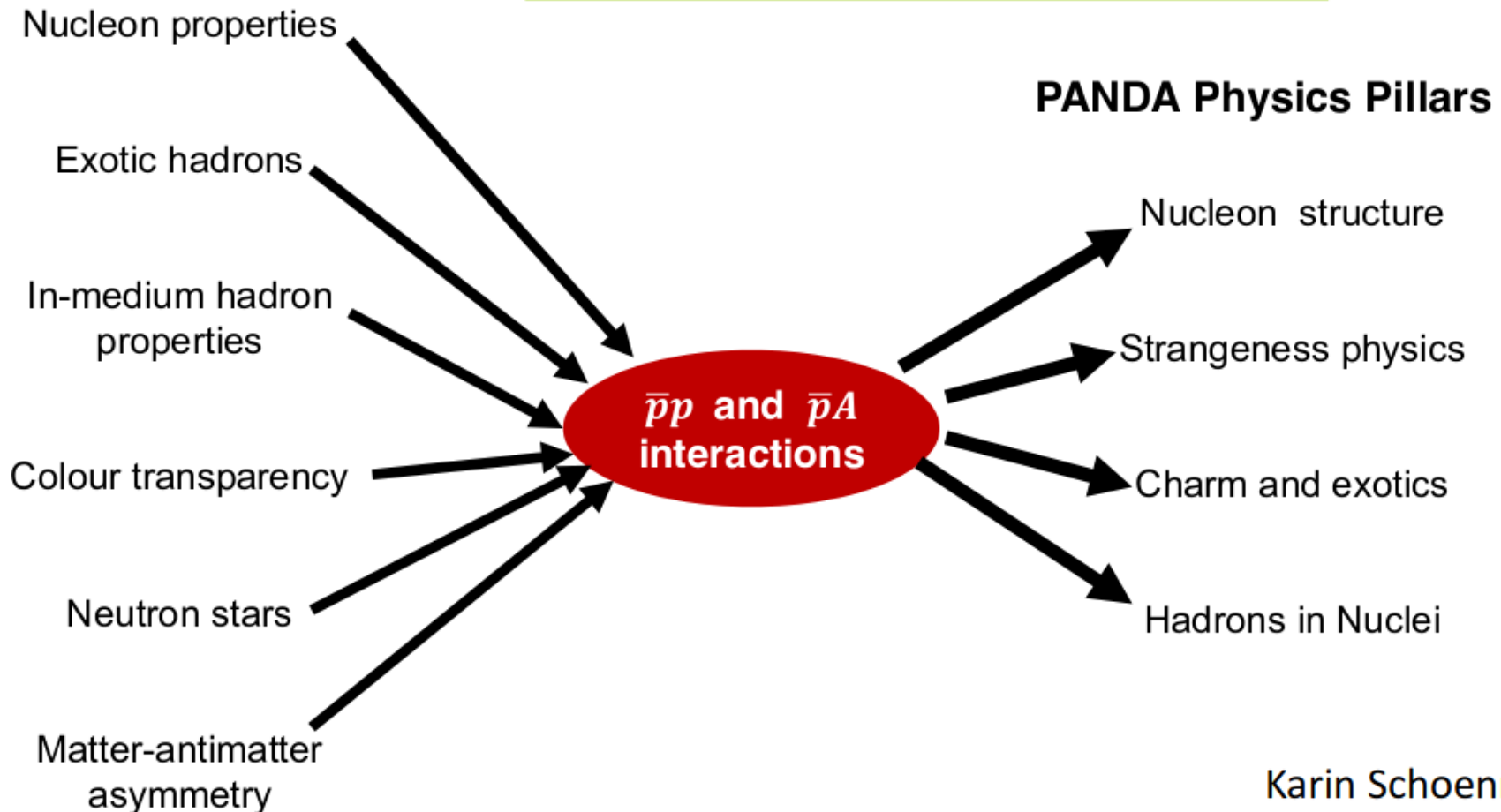
# Triggerless DAQ system



# PANDA Physics

## Key questions

Impact by *precision* (statistics, resolution)  
and *uniqueness* (terra incognita)



# Benchmark channels for the DAQ

1)  $\bar{p}p \rightarrow \Lambda^0(\rightarrow p\pi^-)\bar{\Lambda}^0(\rightarrow \bar{p}\pi^+)$  at  $E_{\text{cm}} = 2.304 \text{ GeV}$ .

Study of hyperon spin observables for probing QCD in the confinement domain

2)  $\bar{p}p \rightarrow J/\psi(\rightarrow \mu^+\mu^-)\pi^+\pi^-$  at  $E_{\text{cm}} = 3.872 \text{ GeV}$ .

Study of charmonium exotic candidate X(3872)

3)  $\bar{p}p \rightarrow e^+e^-$  at  $E_{\text{cm}} = 2.256 \text{ GeV}$ .

Study of electric and magnetic form factors of the proton in the time-like region

4)  $\bar{p}p \rightarrow e^+e^-\pi^0(\rightarrow \gamma\gamma)$  at  $E_{\text{cm}} = 2.256 \text{ GeV}$ .

In addition to previous one, this reaction allows to study time-like form factors of the proton below the threshold of the proton pair production of  $(2M_p)^2$

**Main requirement : A reasonable efficiency after background suppression.**

# Benchmark channels for the DAQ

## Previous studies

**Framework:** Geant3, FairRoot v.17.10b and FairSoft  
oct17p1;

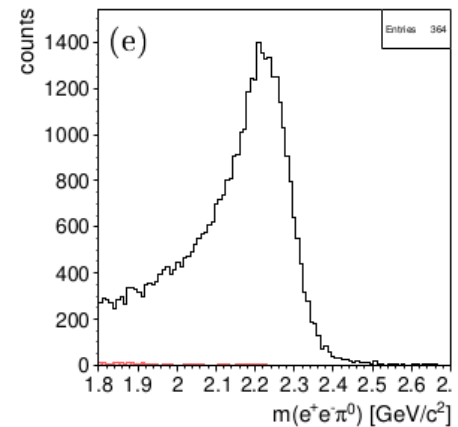
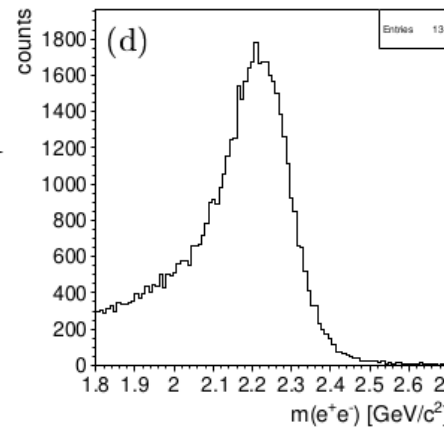
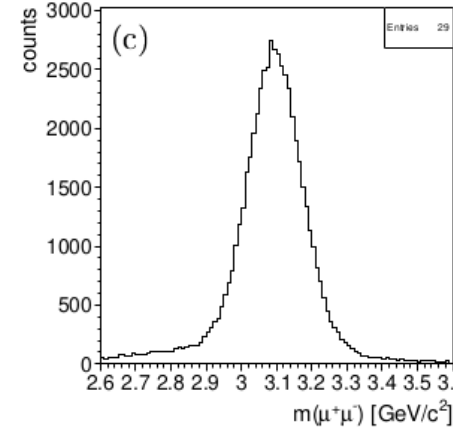
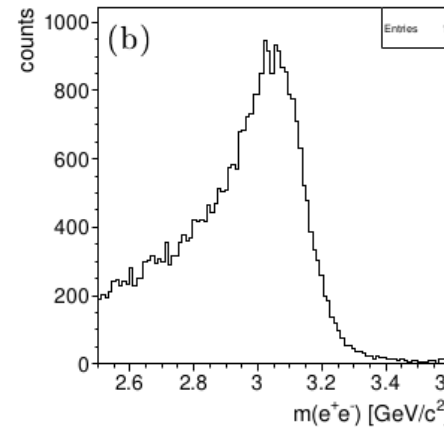
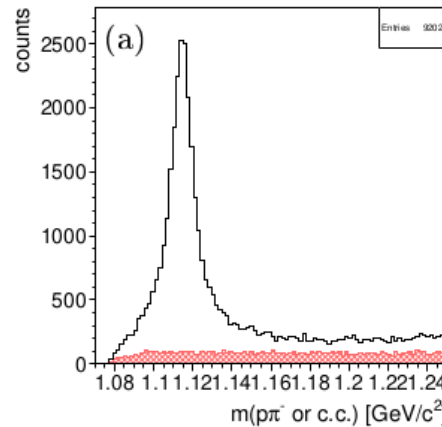
**Data sample:**  $10^5$  signal events (EvtGen);  $10^6$   
background events (DPM)

**Fully event-based**

**Smearing procedure is applied to tracks and  
clusters**

# Benchmark channels for the DAQ

## Previous studies

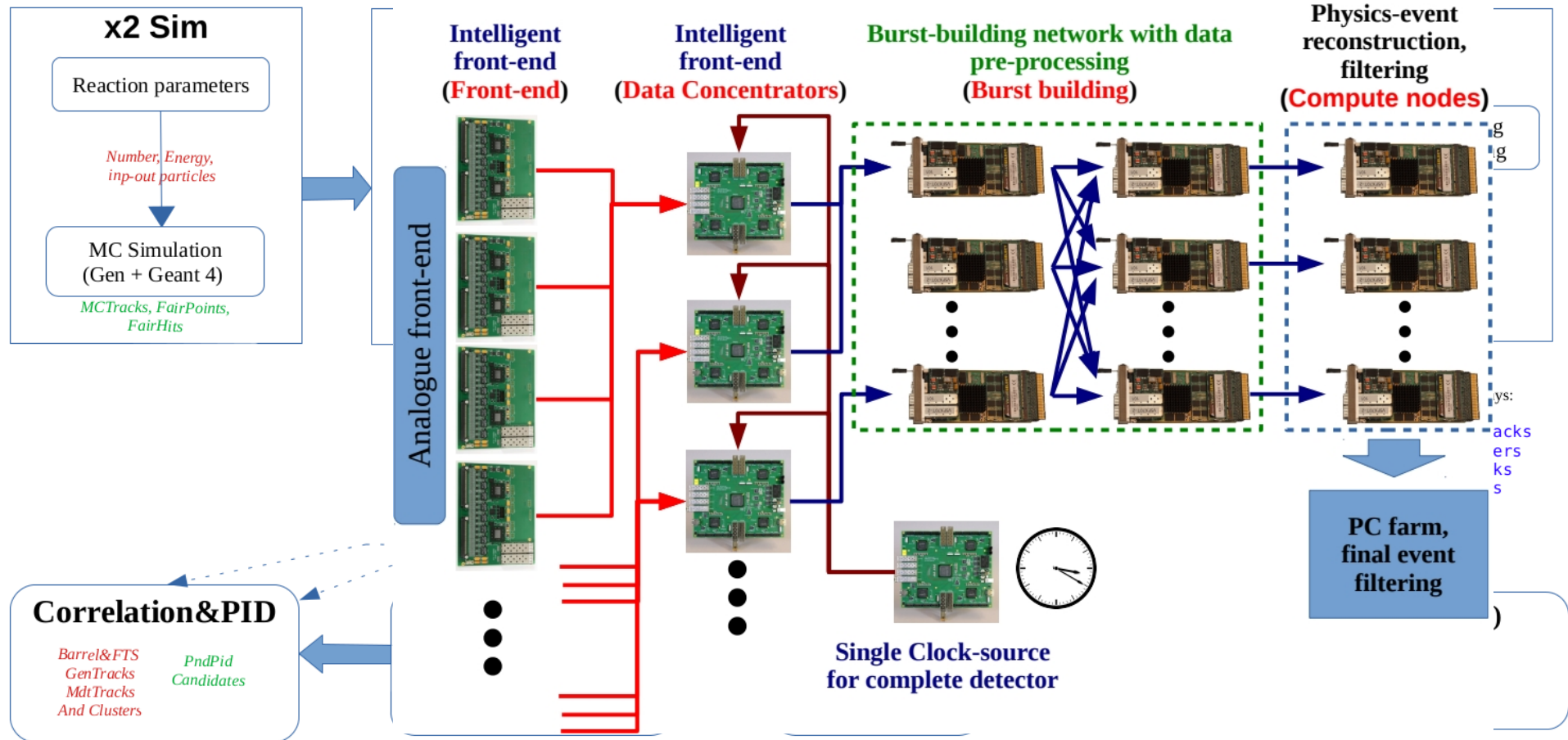


Channel	$\epsilon_S[\%]$	$\epsilon_B[\%]$	$f_{\text{sup}} [\times 1000]$
$\Lambda \rightarrow p\pi^-$	30.0	0.82	0.121
$J/\psi \rightarrow e^+e^-$	24.7	0.0001	$> 303^*$
$J/\psi \rightarrow \mu^+\mu^-$	56.3	0.0038	$> 22.2^*$
$\bar{p}p \rightarrow e^+e^-$	40.9	0.0009	$> 76.3^*$
$\bar{p}p \rightarrow e^+e^-\pi^0$	16.5	0.0156	6.41

# Motivation

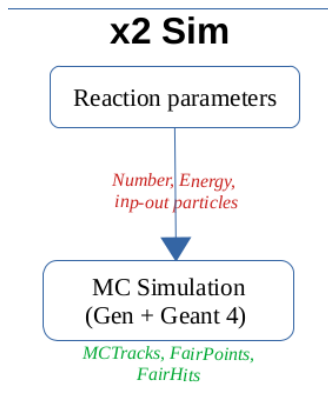
**Repeat these studies for each benchmark channel in the new framework, which will be more realistic and will correspond to the future DAQ system.**

# Simulation workflow



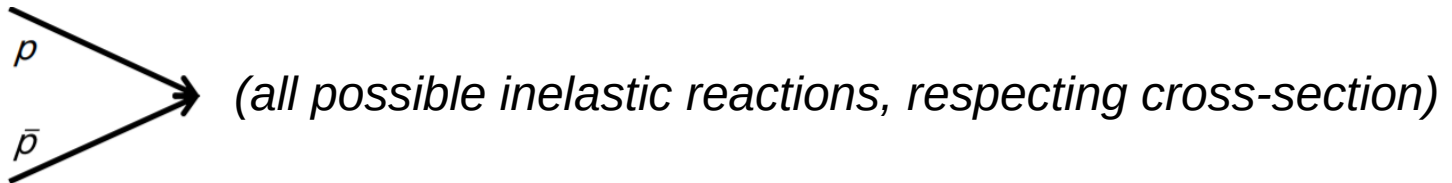


# Monte Carlo information (local machine)

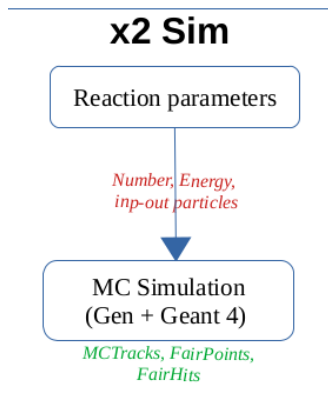


Two files were generated for each benchmark channel:

1. **SIGNAL** – 1000 events at the channel's  $P_{beam}$  momentum from EvtGen.
2. **BACKGROUND** – 2000 events at the channel's  $P_{beam}$  momentum from FTF generator:

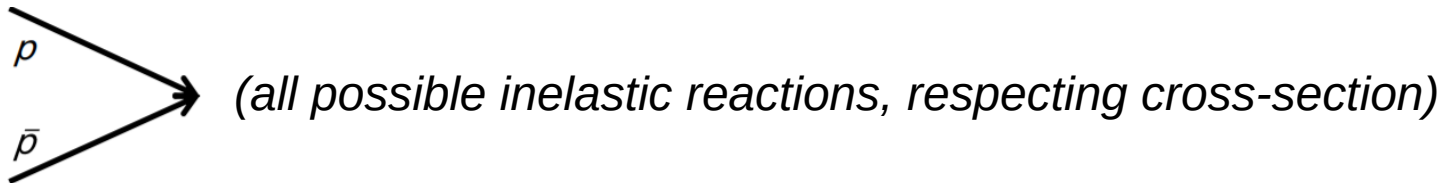


# Monte Carlo information (VIRGO)



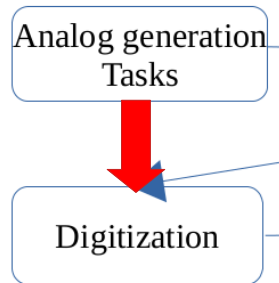
Two files were generated for each benchmark channel:

1. **SIGNAL** –  $10^5$  events at the channel's  $P_{beam}$  momentum from EvtGen.
2. **BACKGROUND** –  $10^6$  events at the channel's  $P_{beam}$  momentum from FTF generator:



# Digitization

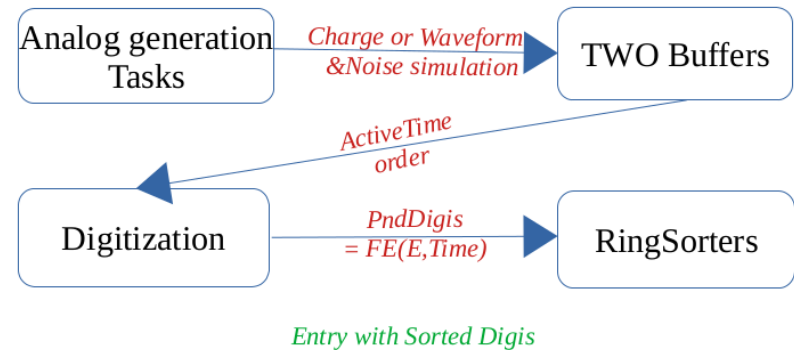
## Digitization macro



### Event-based

- generation of analogue signals
- digitization of analogue signals
  - no overlap possibility
    - no time sorting
    - isolated events

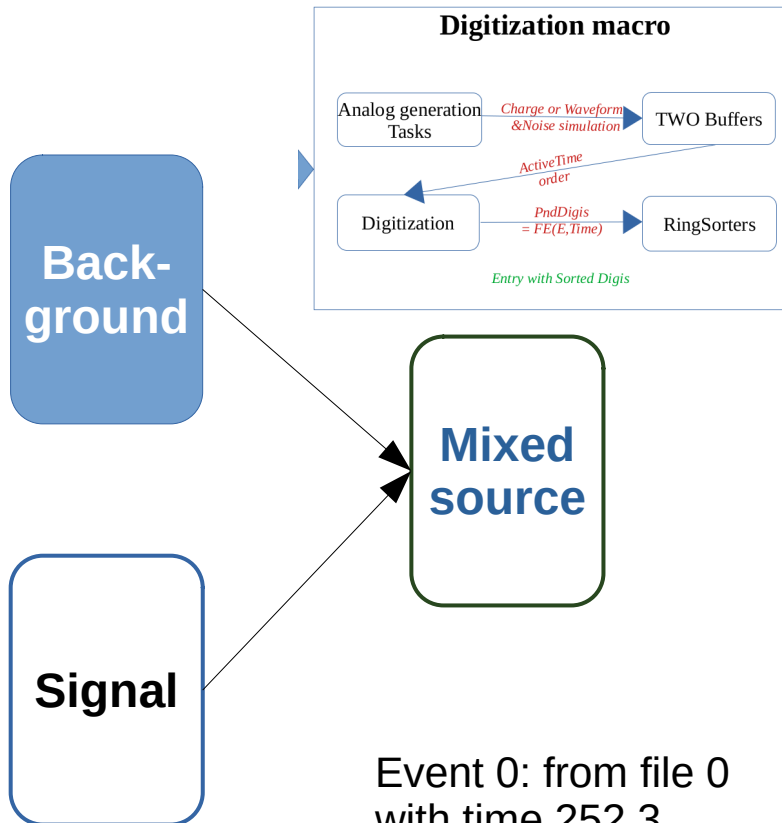
## Digitization macro



### Time-based

- generation of analogue signals
- digitization of analogue signals
- overlap possibility (TWO Buffers)
  - time sorting (Ring Sorters)
    - time-ordered stream

# Time-based Simulation



Event 0: from file 0  
 with time 252.3  
 Event 1: from file 1  
 with time 728.6  
 .....  
 Event 50: from file 0  
 with time 7854.7

## Time-based

- generation of analogue signals
- digitization of analogue signals
- overlap possibility (TWO Buffers)
  - time sorting (Ring Sorters)
  - time-ordered stream

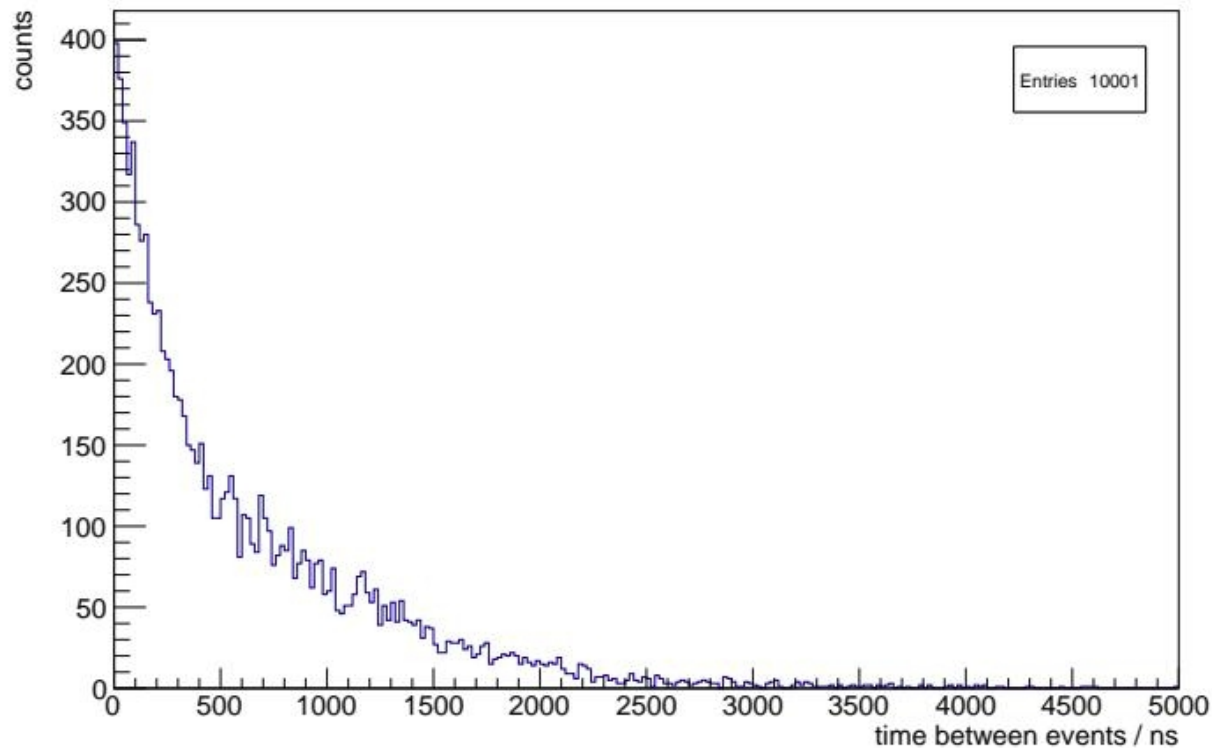
`source->BGWindowWidthNo(2,1);`

`source->SetEventMeanTime(500);`

`source->SetBeamTime(1600, 400);`

# Time-based Simulation

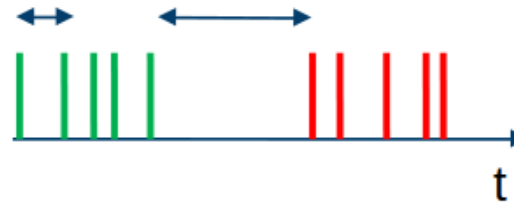
Time gap between two consecutive events



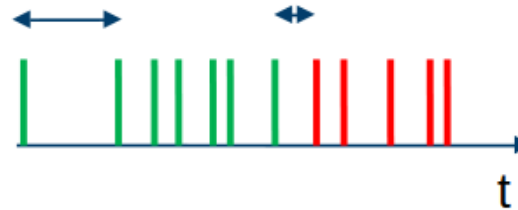
**10000 anti-proton target interactions**  
**with a mean time duration of events 500 ns.**

# Time-gap event building in a nutshell

It is based on the time difference between adjacent hits

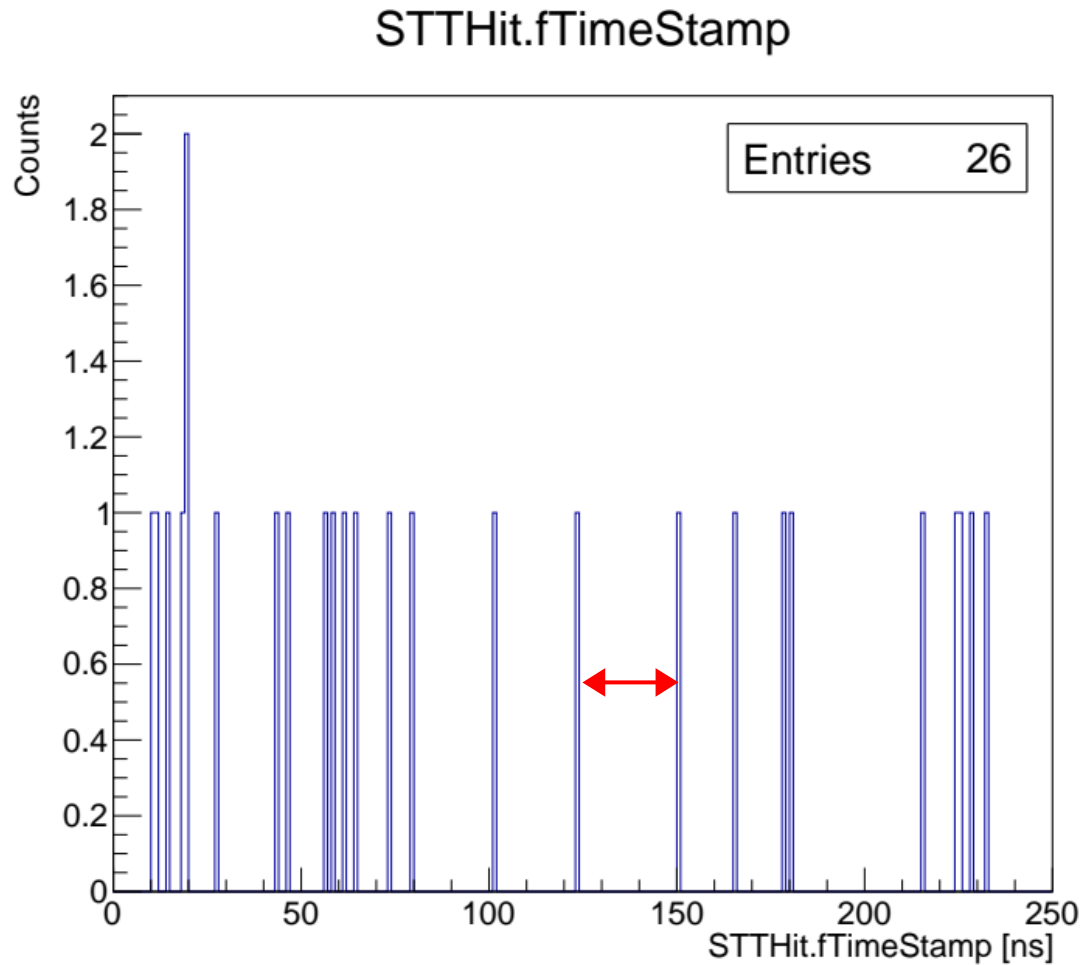


It performs well as long as a time difference between events is big



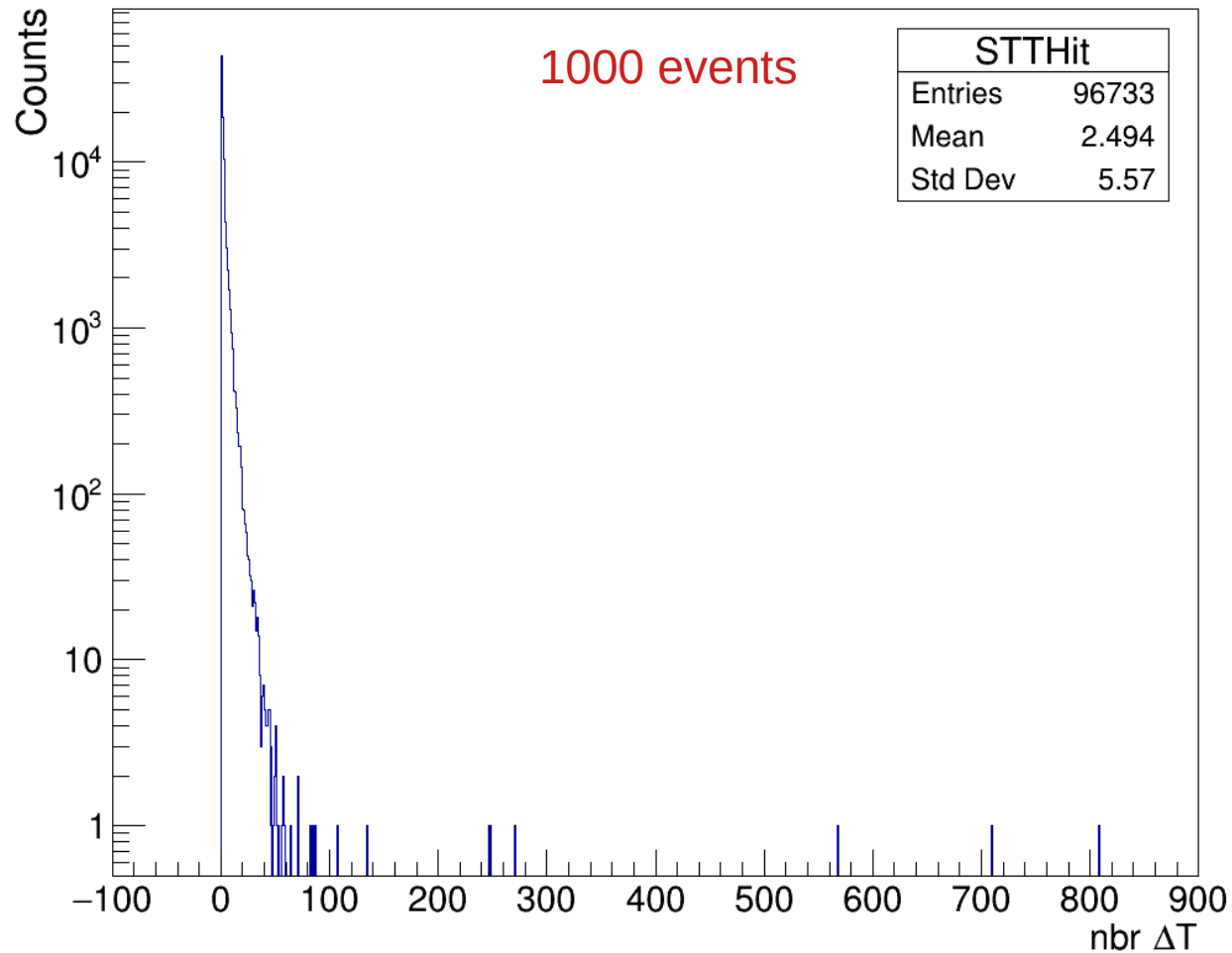
Picture is taken from Tobias Stockmanns' presentation.

# Event-based studies



# Event-based studies

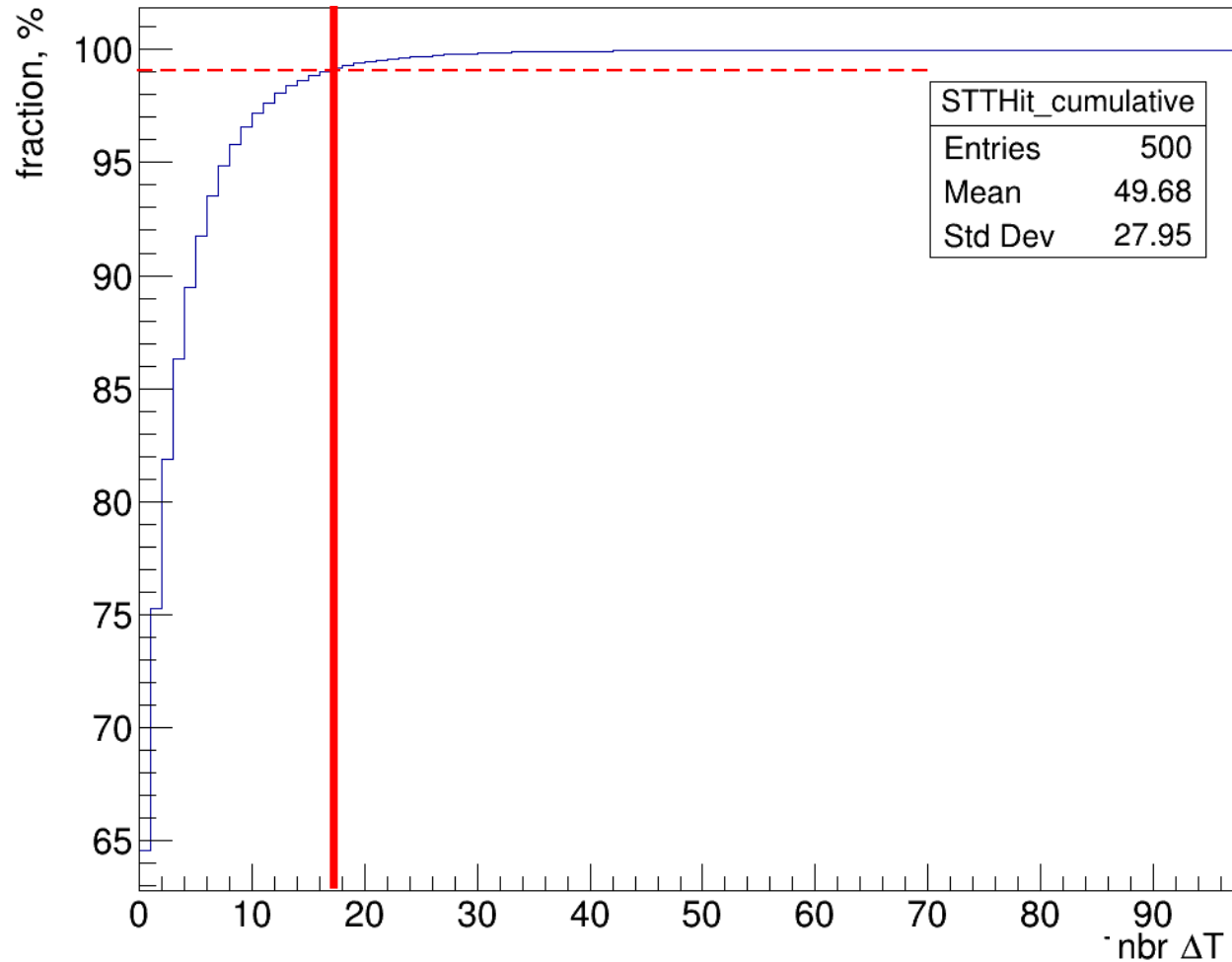
nbr time diff



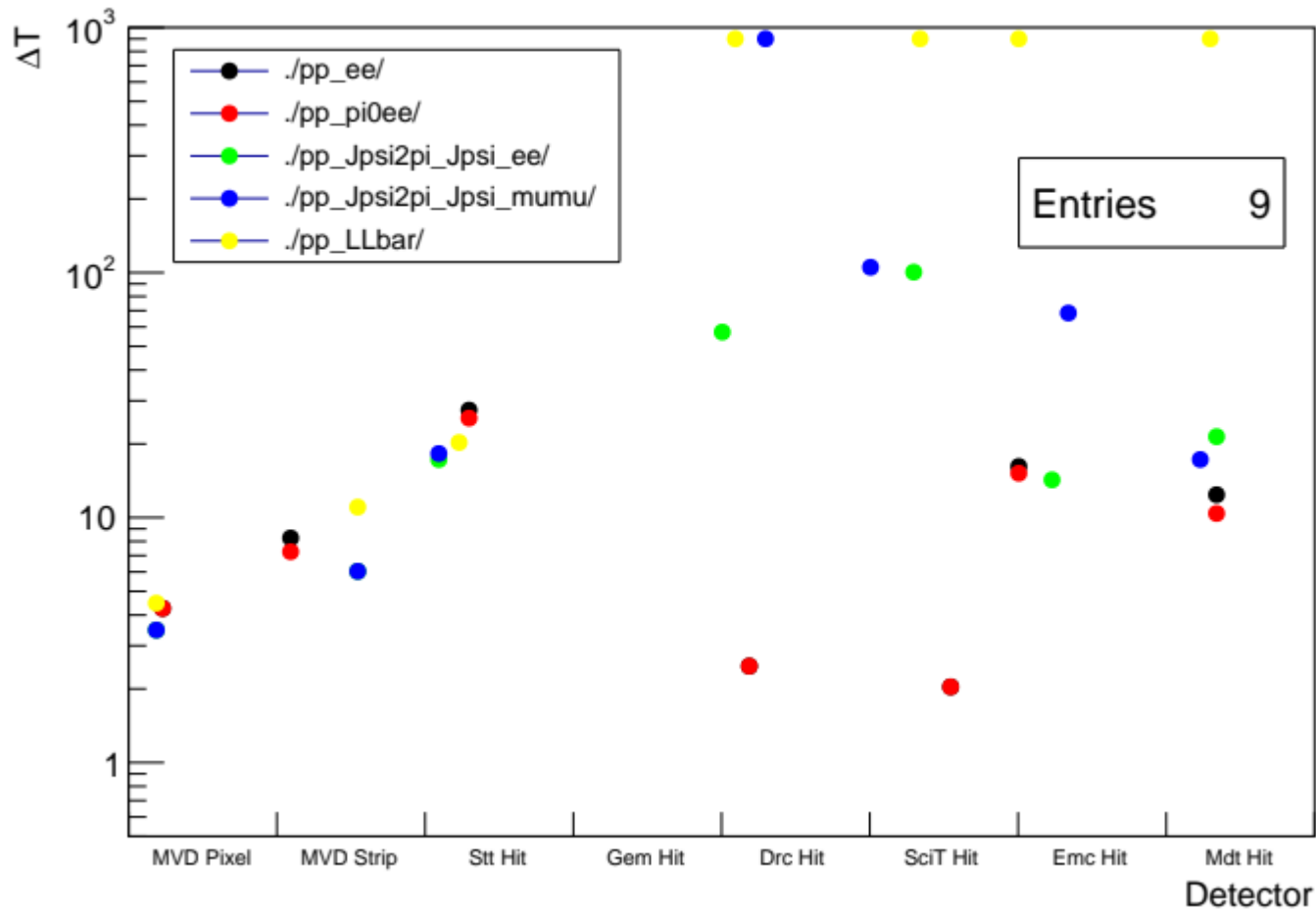


# Event-based studies

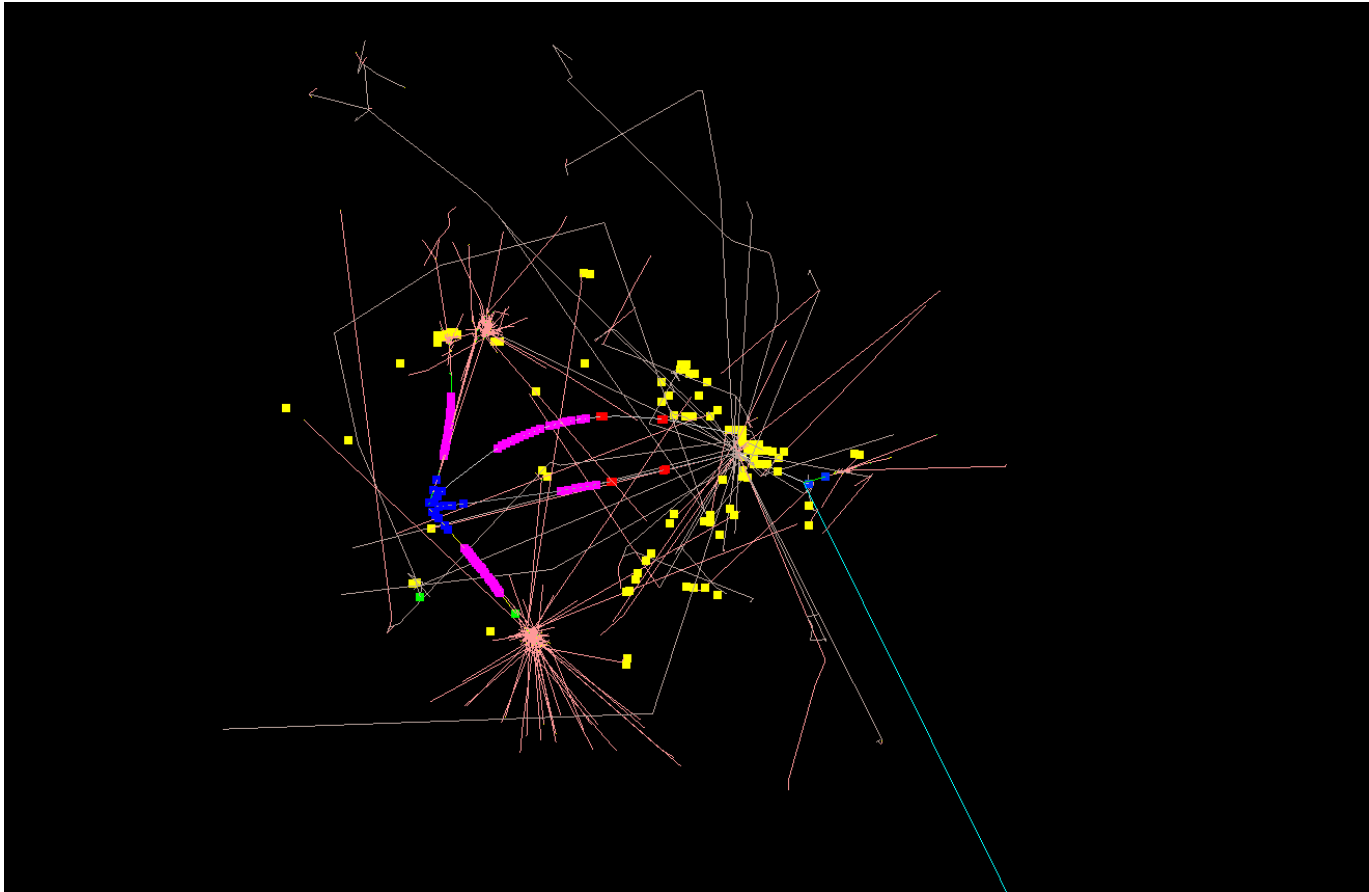
Cumulative integral



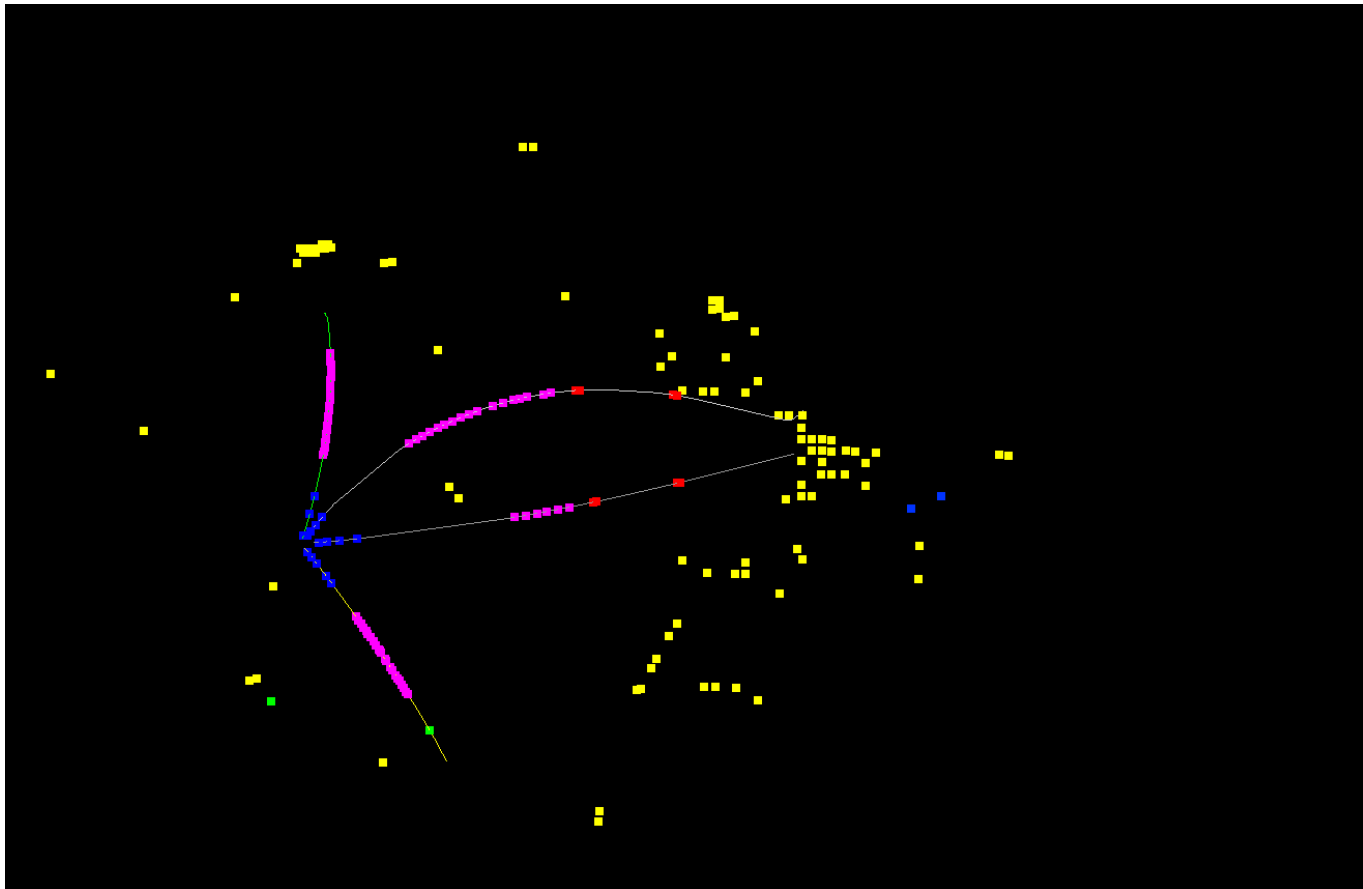
# Event-based studies



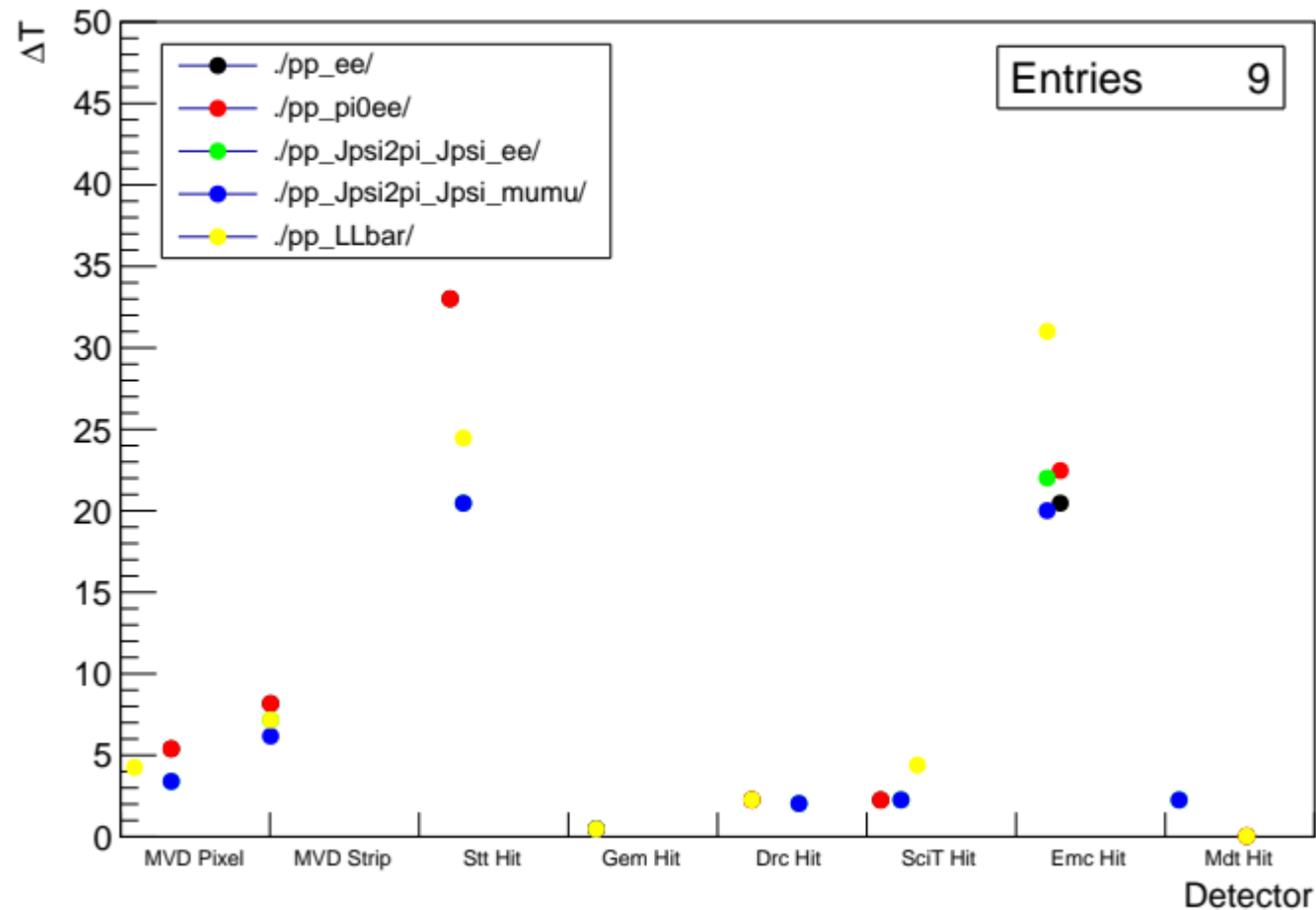
# Event-based studies



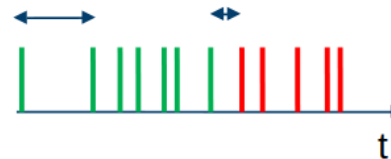
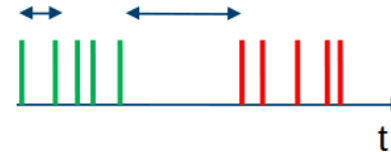
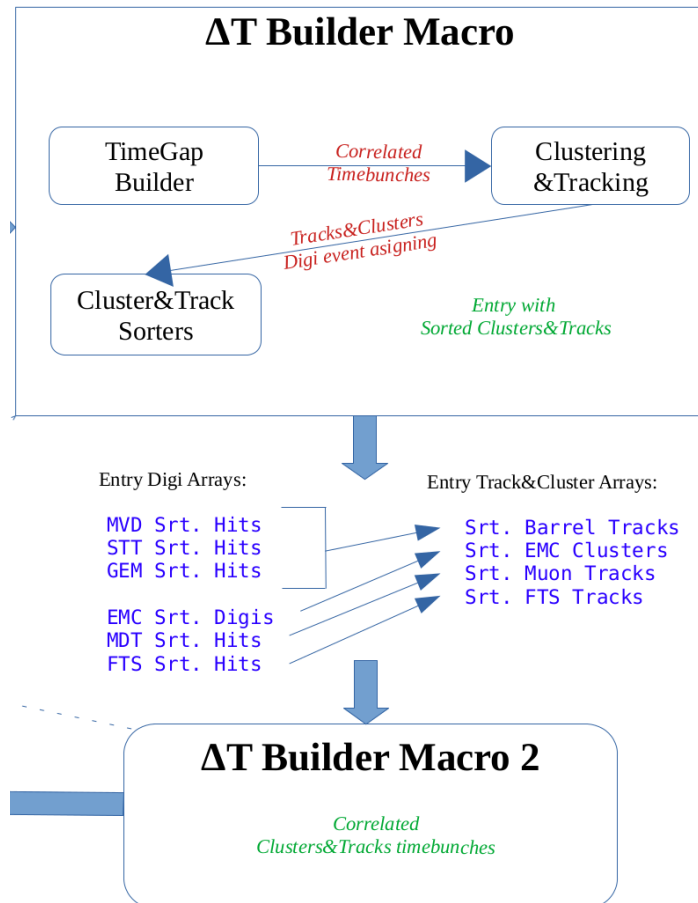
# Event-based studies



# Event-based studies

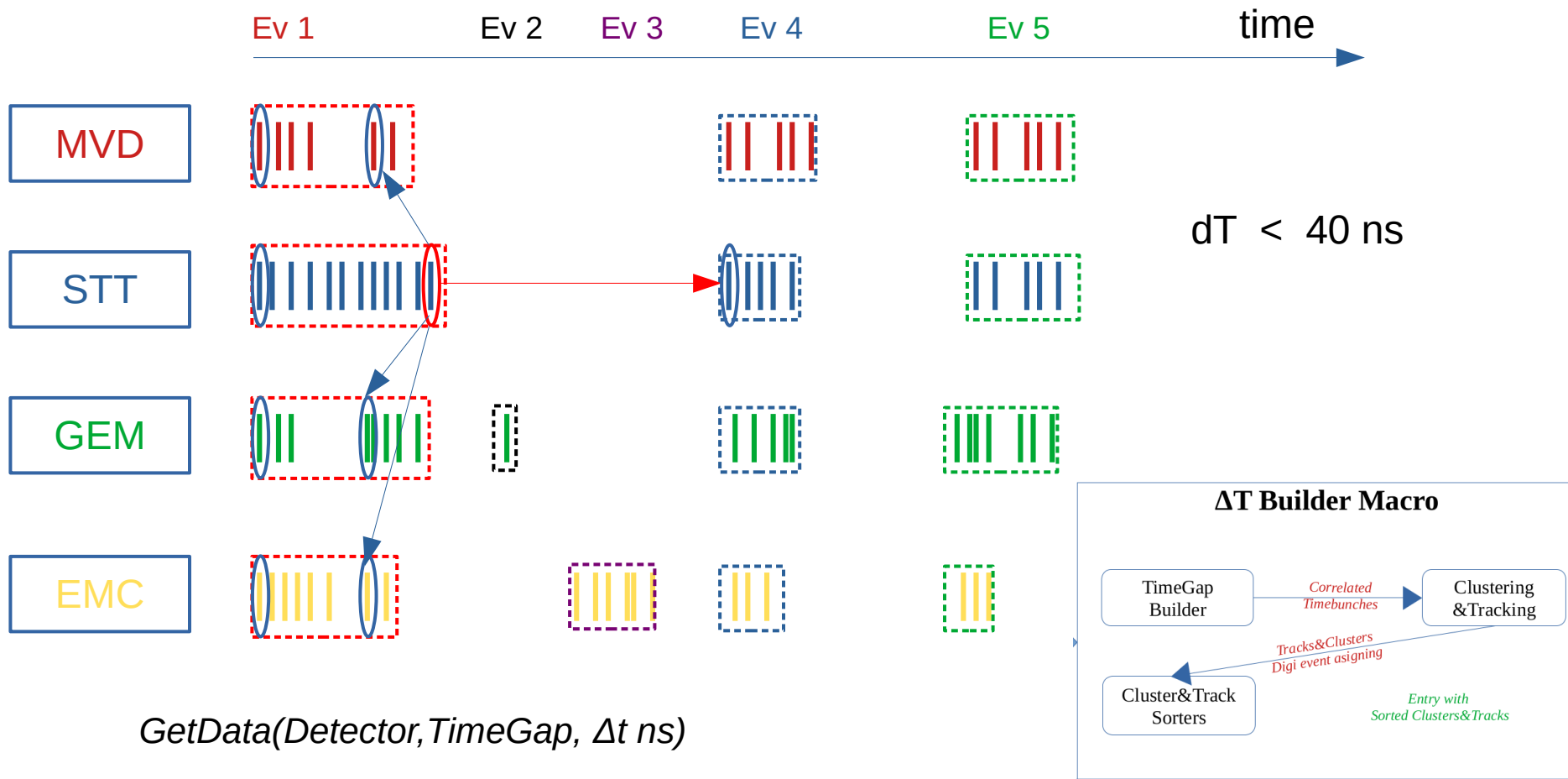


# Timebunch creation

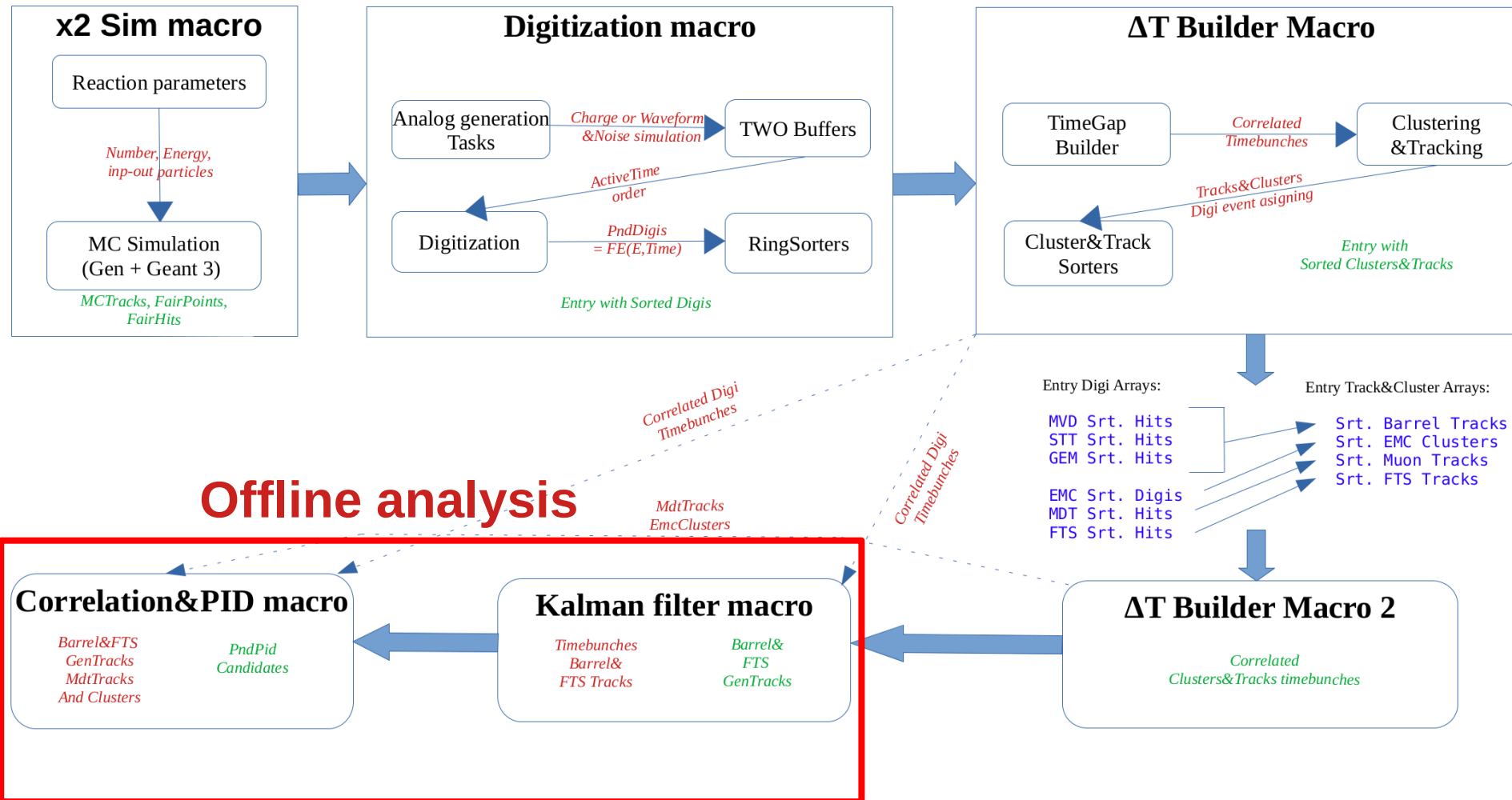


- processing digi-bunches by the time-gap builder
- clustering&tracking, within created timebunches
- cluster&track sorting
- processing tracks&cluster bunches by the time-gap builder

# Time-gap event builder algorithm

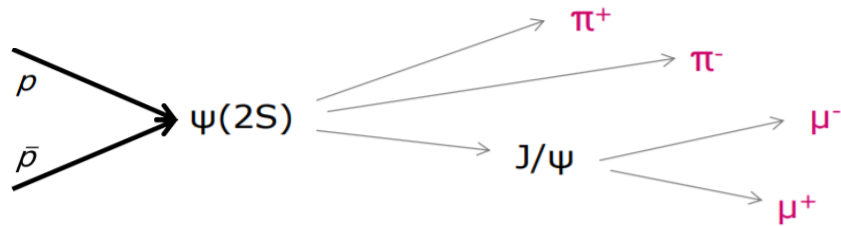


# Simulation workflow





# Offline analysis

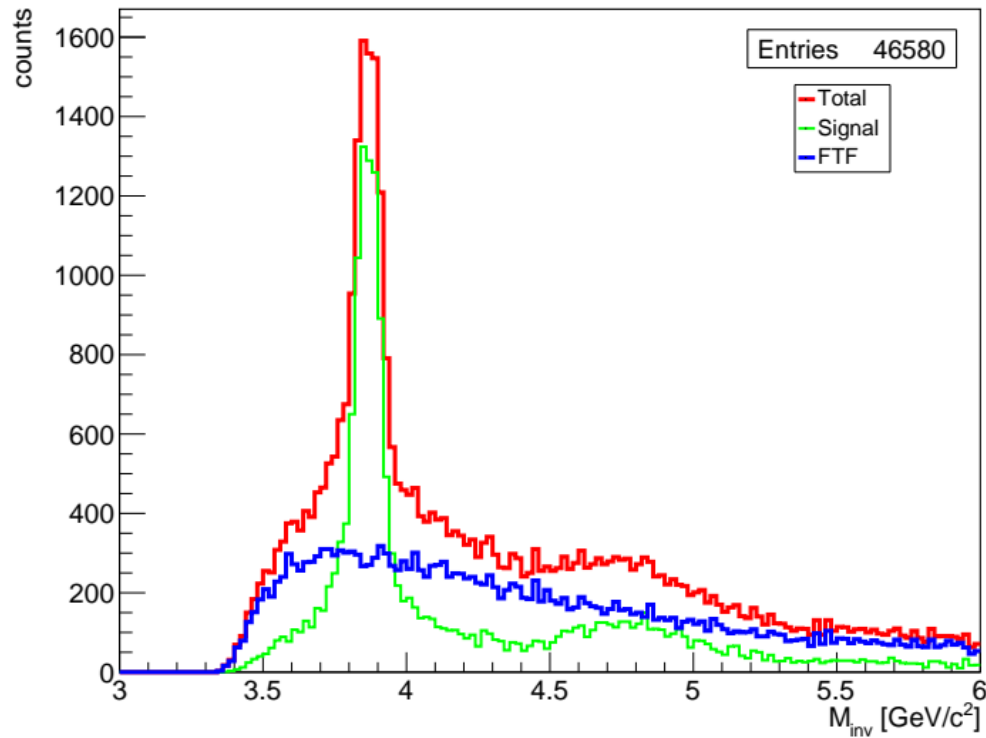


0.1 GeV mass cut for  
the J/psi candidates is applied

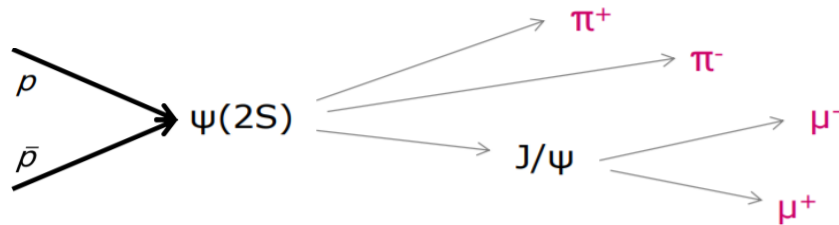
$E_{v_{\text{sig}}} : E_{v_{\text{b}}} = 1 : 9$   
 Total number = 1000000

## Event-based (Sum)

pbp invariant mass



# Offline analysis

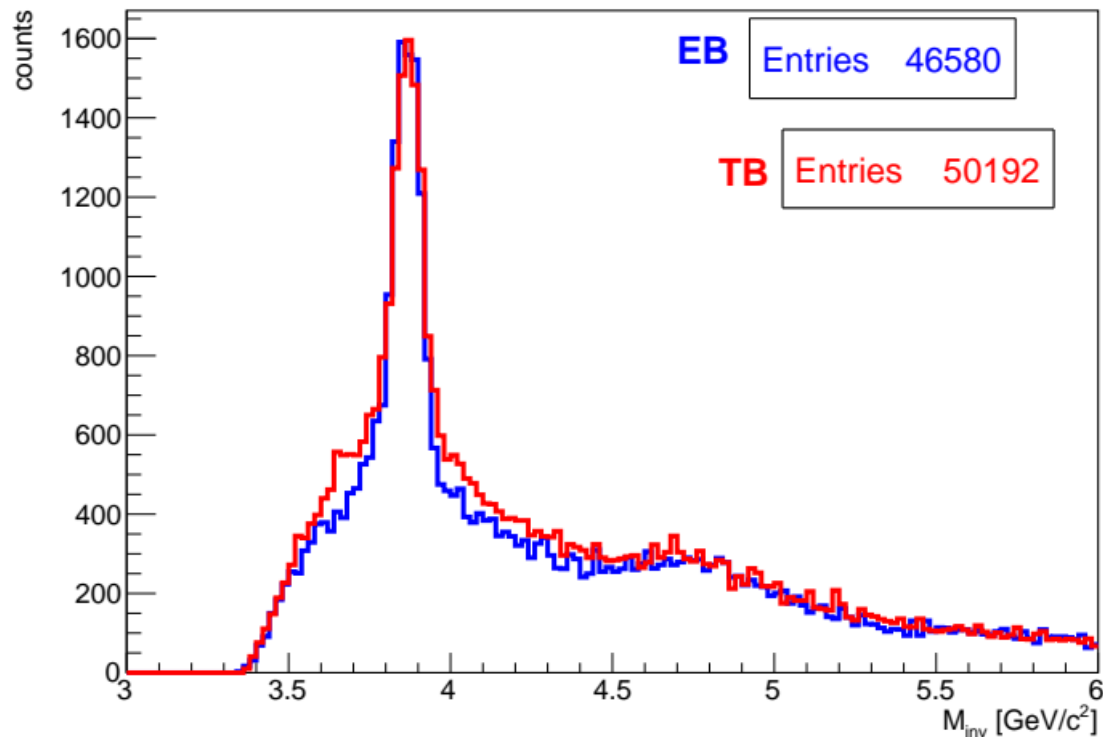


0.1 GeV mass cut for the J/psi candidates is applied

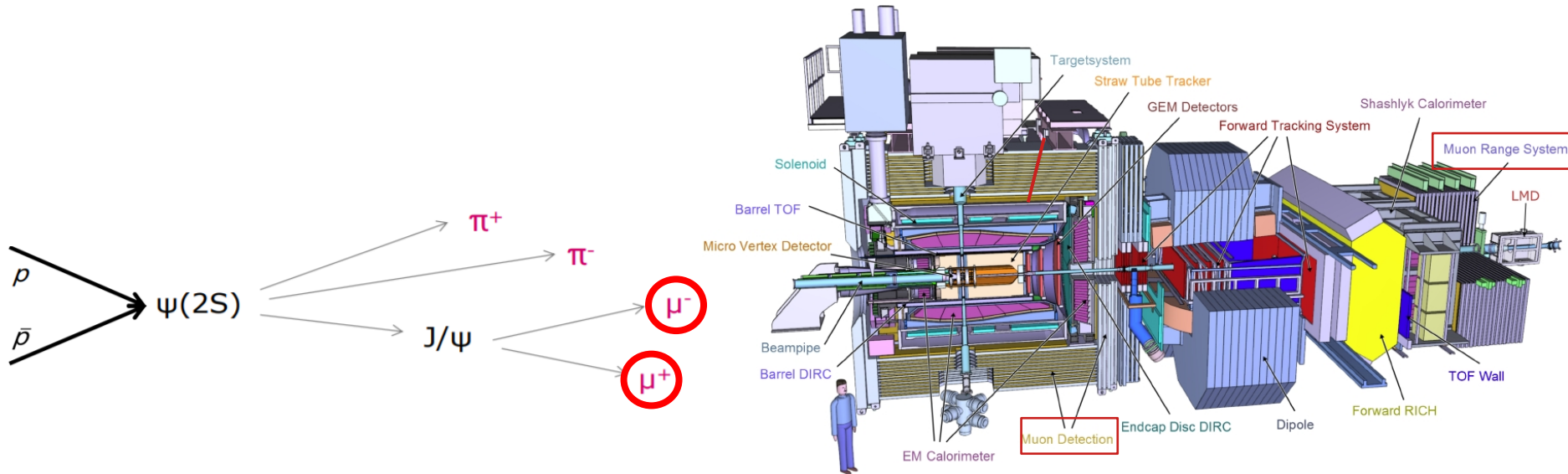
$E_{v_{sig}} : E_{v_b} = 1 : 9$   
 Total number = 1000000

## Time-based (Time-Gap)

pbp invariant mass



# Event Filtering



## Kalman filter macro

*Timebunches*  
*Barrel&*  
*FTS Tracks*

*Barrel&*  
*FTS*  
*GenTracks*

## Event filter

*Timebunches*

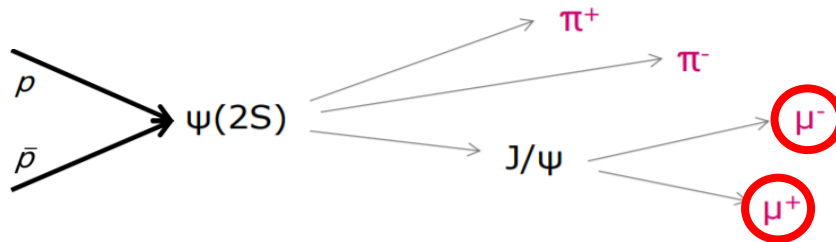
*Passed*  
*Timebunches*

## $\Delta T$ Builder Macro 2

*Correlated*  
*Clusters&Tracks timebunches*

**Two Mdt tracks with**  
**iron distance  $> 40$  cm**

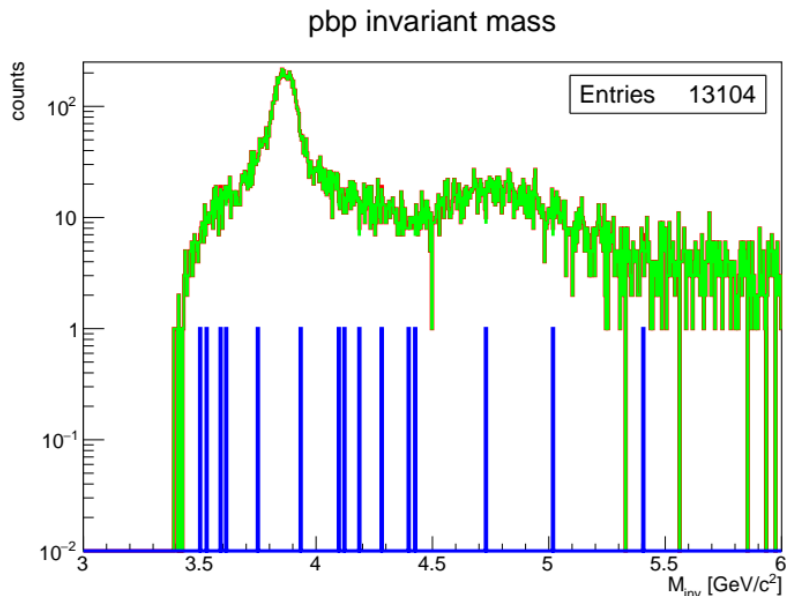
# Offline analysis (Filter)



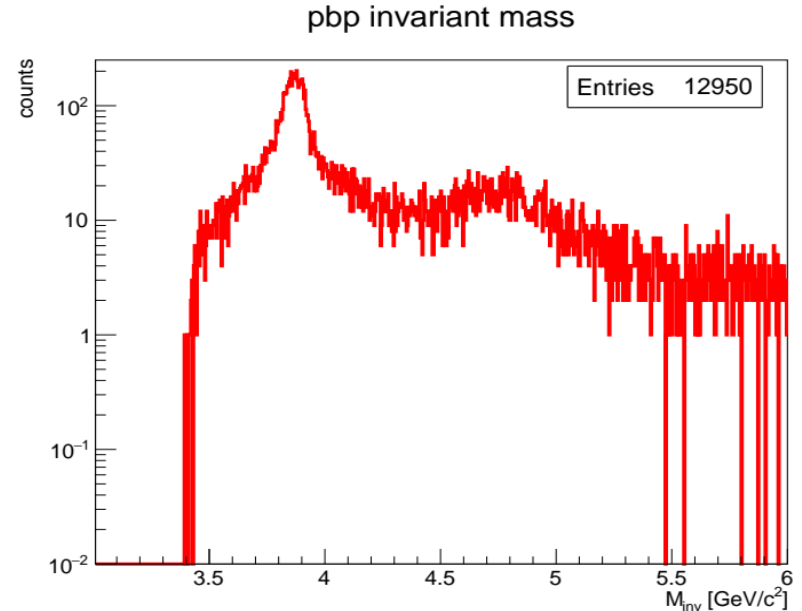
0.1 GeV mass cut for the J/psi candidates is applied

$E_{v_{\text{sig}}} : E_{v_{\text{b}}} = 1 : 9$   
Total number = 1000000

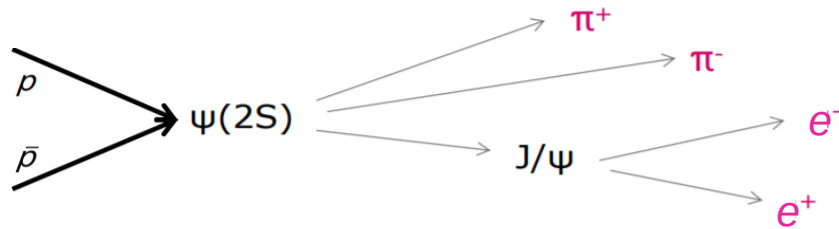
## Event-based (Sum)



## Time-based (Time-Gap)



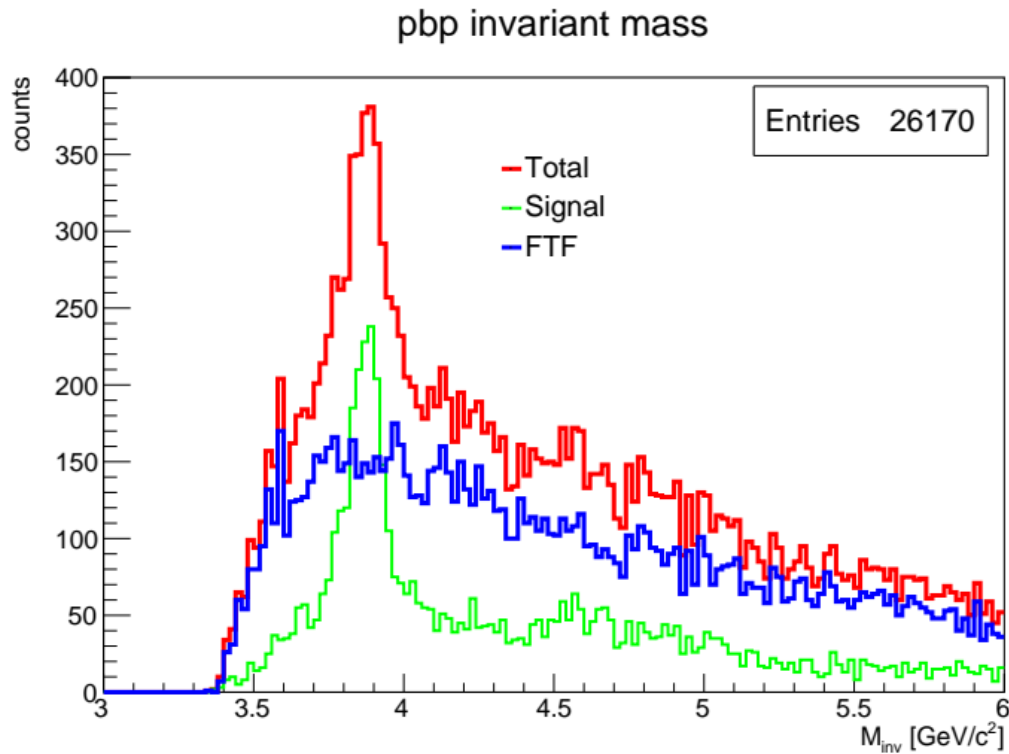
# Offline analysis



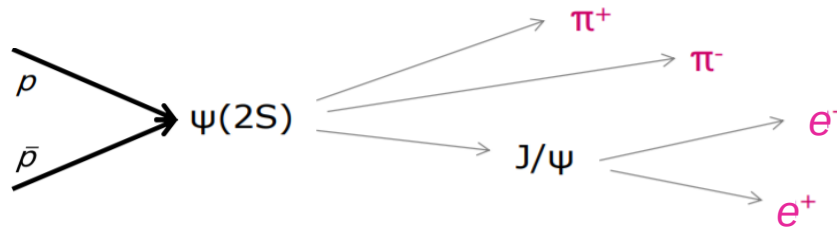
0.1 GeV mass cut for the J/psi candidates is applied

$E_{v_{\text{sig}}} : E_{v_{\text{b}}} = 1 : 9$   
 Total number = 1000000

## Event-based (Sum)



# Offline analysis

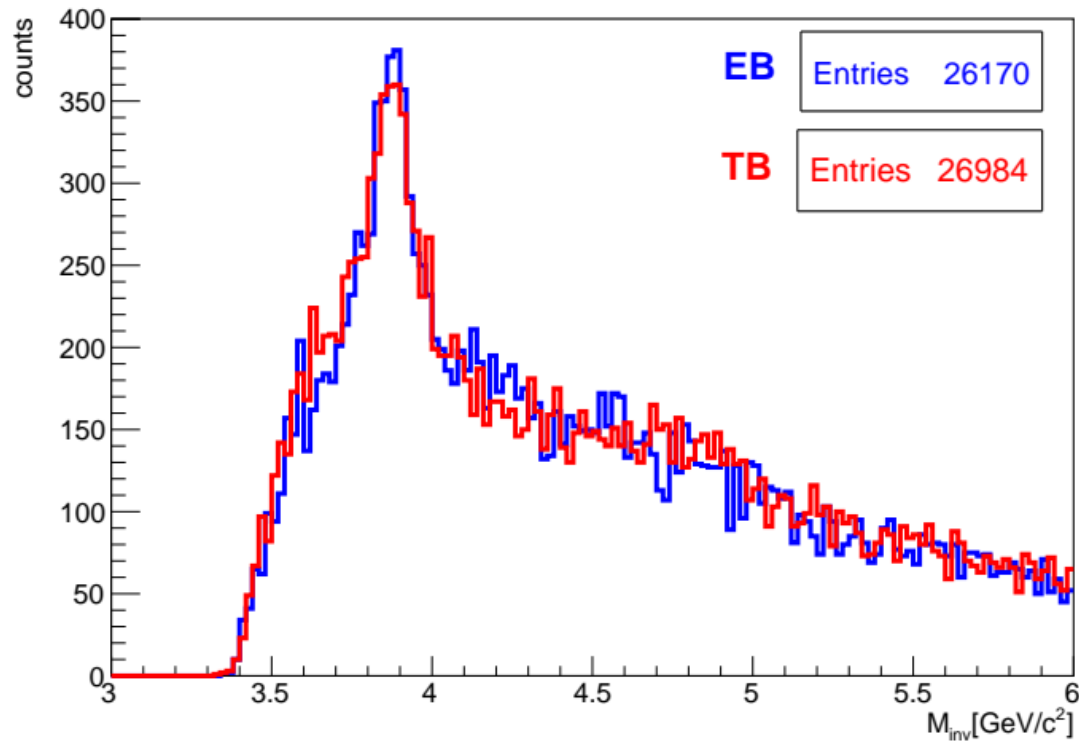


0.1 GeV mass cut for the J/psi candidates is applied

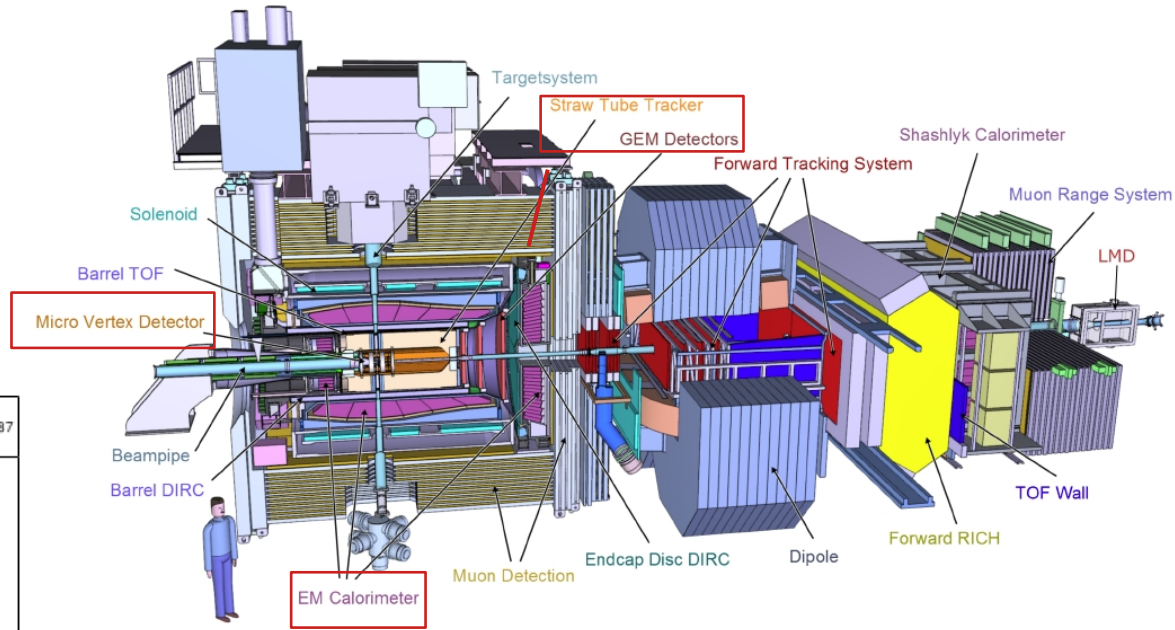
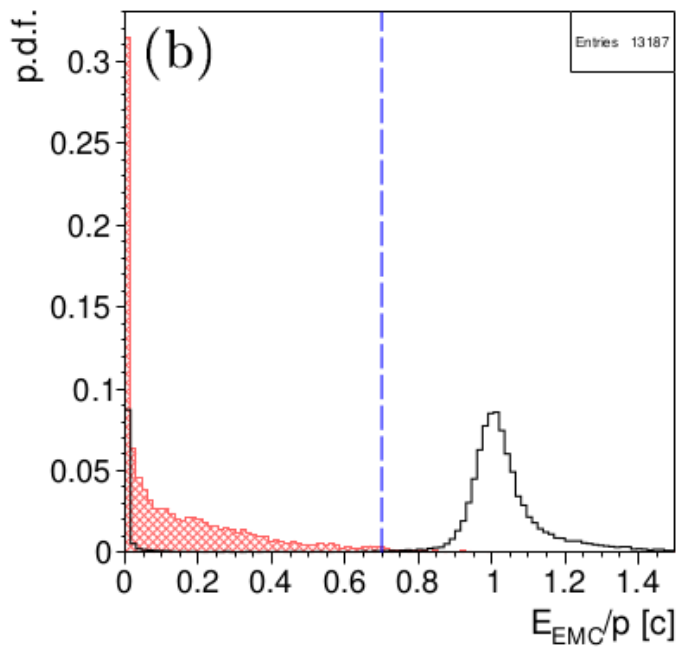
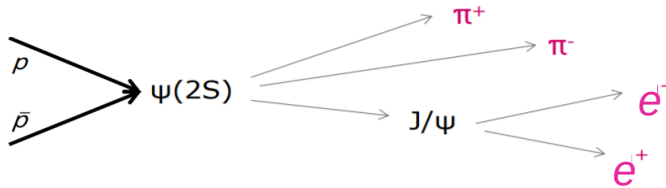
$E_{v_{\text{sig}}} : E_{v_{\text{b}}} = 1 : 9$   
 Total number = 1000000

## Time-based (Time-Gap)

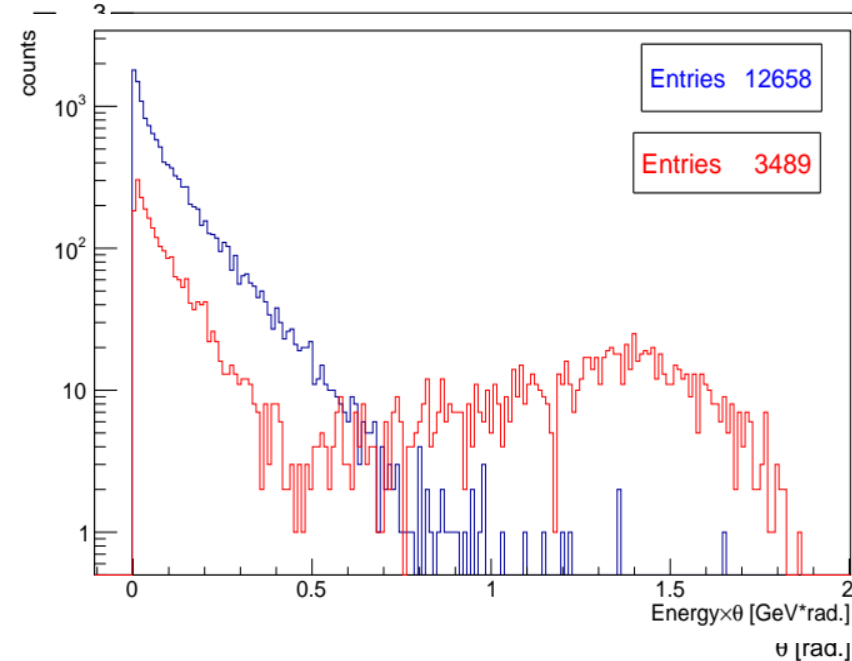
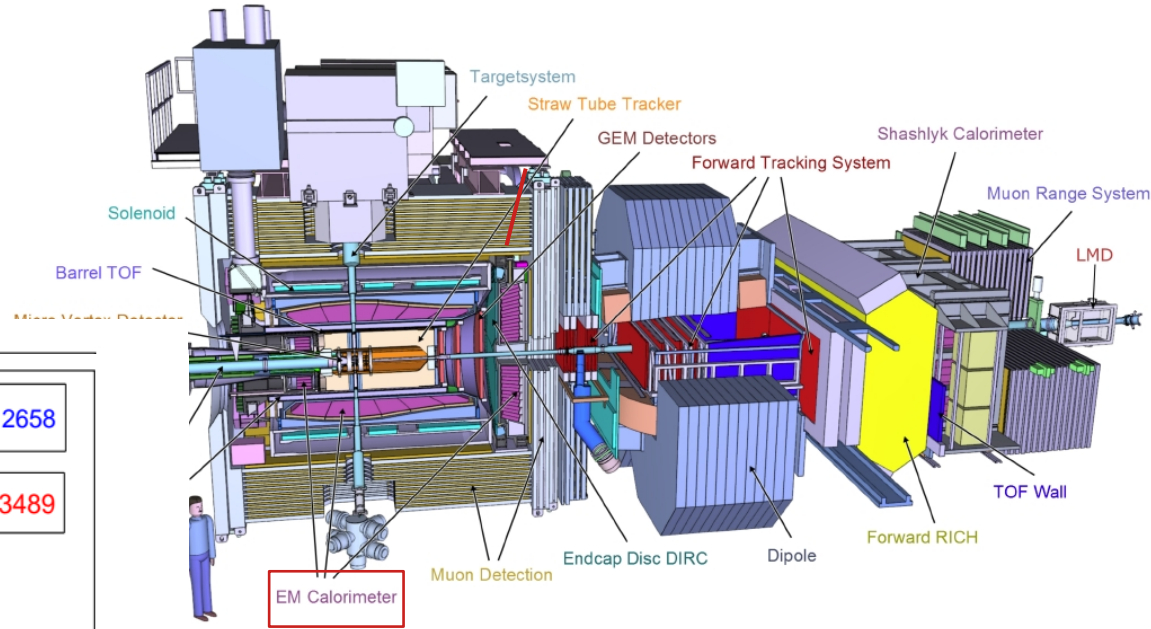
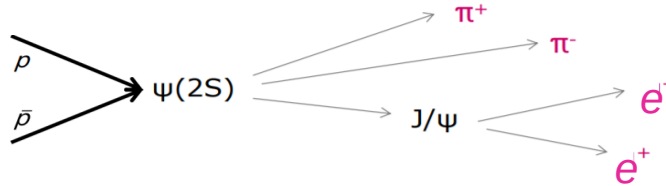
pbp invariant mass



# Event Filtering



# Event Filtering

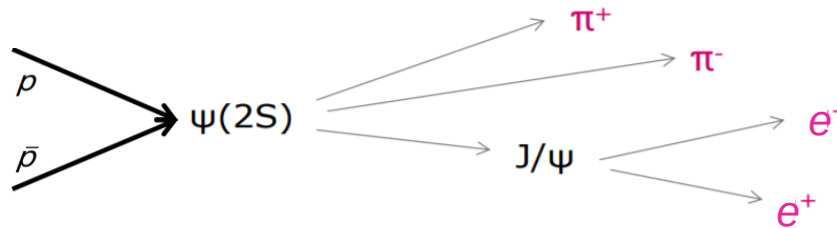


TVector3(x, y, z)  $\longrightarrow$  Theta angle

**Polar angle correlation with  
energy of cluster**



# Offline analysis (Filter)



0.1 GeV mass cut for the J/psi candidates is applied

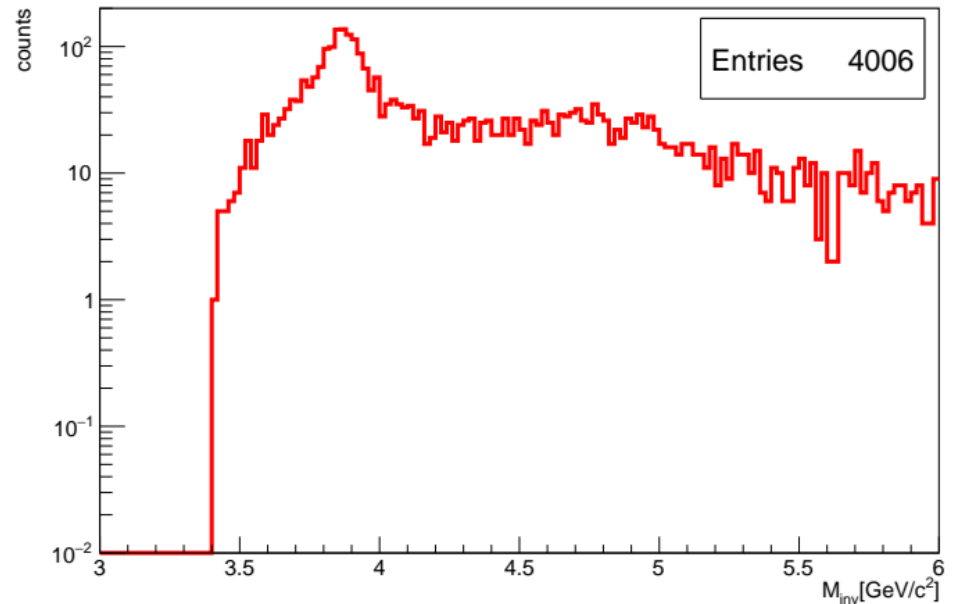
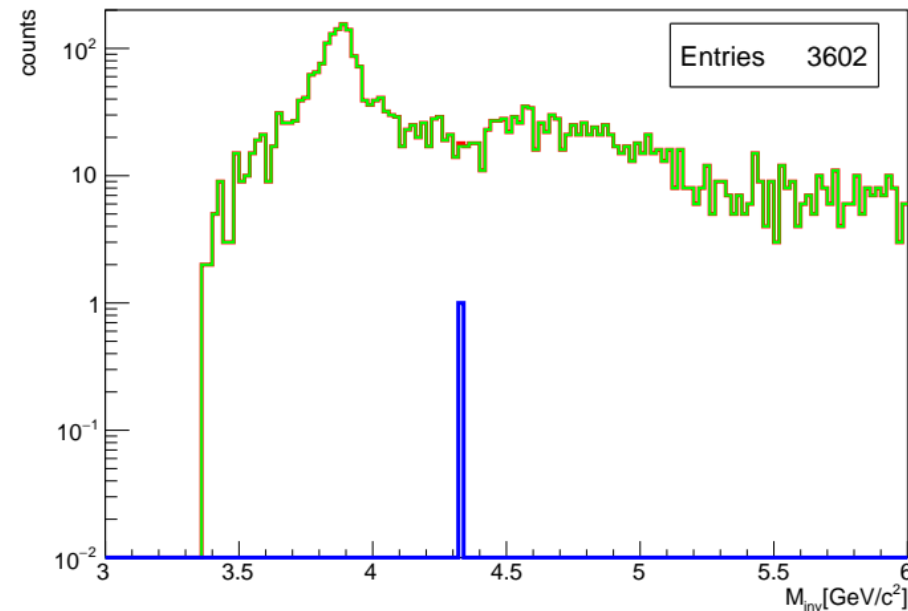
$E_{v_{\text{sig}}} : E_{v_b} = 1 : 9$   
 Total number = 1000000

## Event-based (Sum)

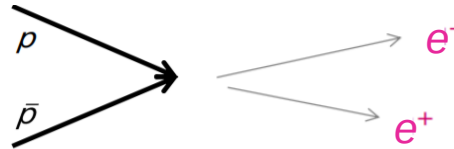
## Time-based (Time-Gap)

pbp invariant mass

pbp invariant mass



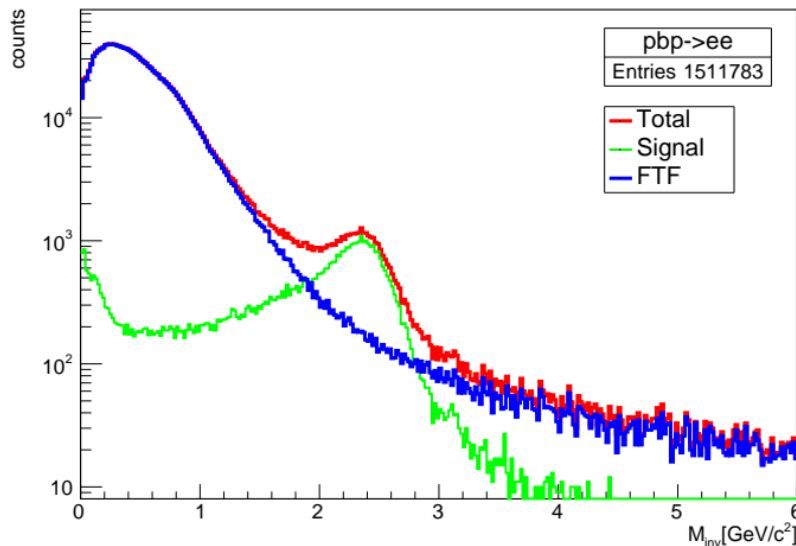
# Offline analysis



$Ev_{\text{sig}} : Ev_{\text{b}} = 1 : 9$   
 Total number = 1000000

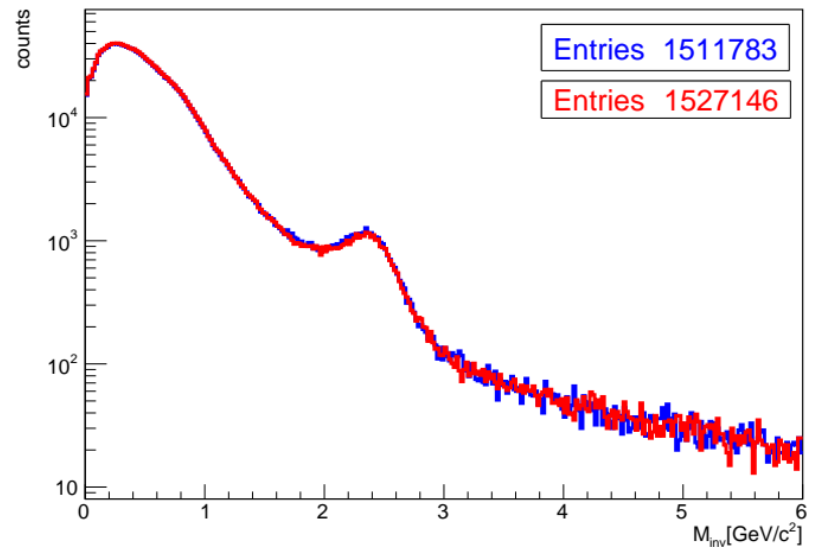
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pbp invariant mass

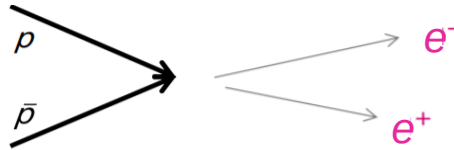


## Time-based (Time-Gap)

pbp invariant mass

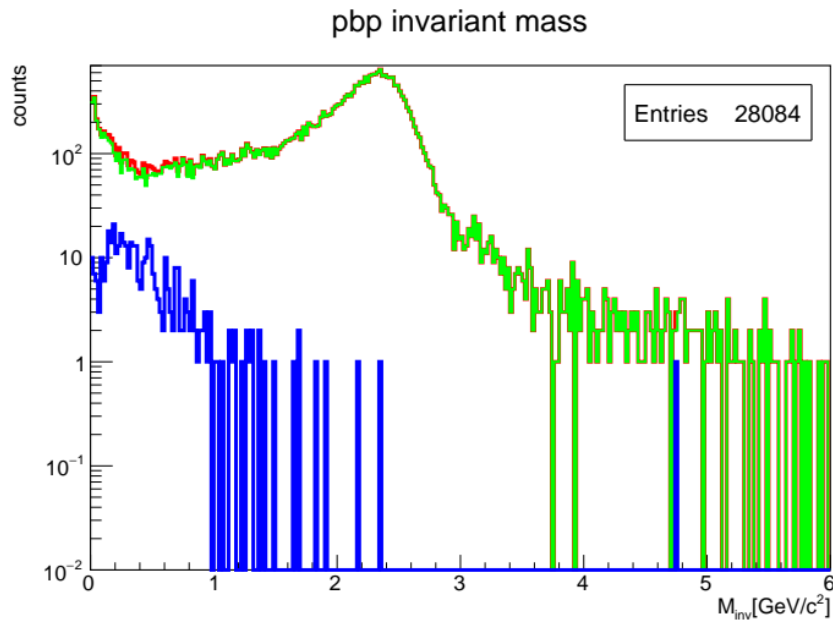


# Offline analysis (Filter)

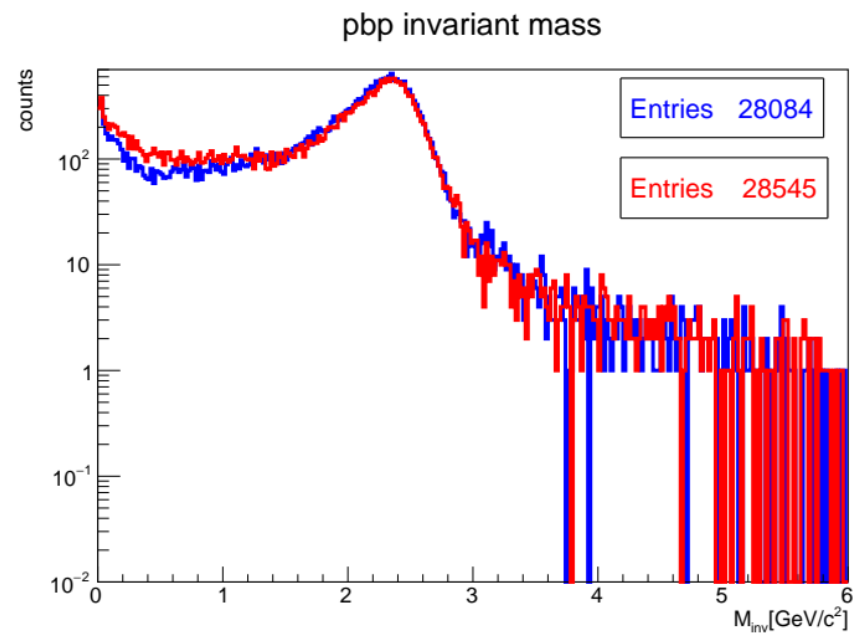


$Ev_{\text{sig}} : Ev_{\text{b}} = 1 : 9$   
 Total number = 1000000

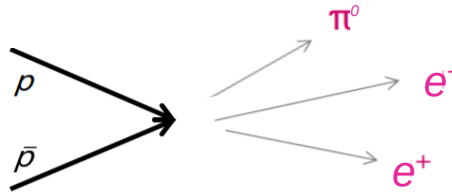
## Event-based (Sum)



## Time-based (Time-Gap)



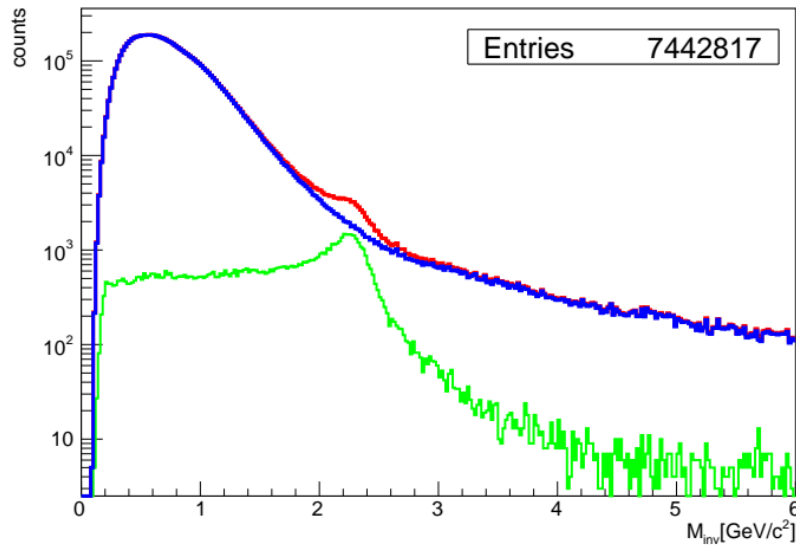
# Offline analysis



$Ev_{\text{sig}} : Ev_{\text{b}} = 1 : 9$   
 Total number = 1000000

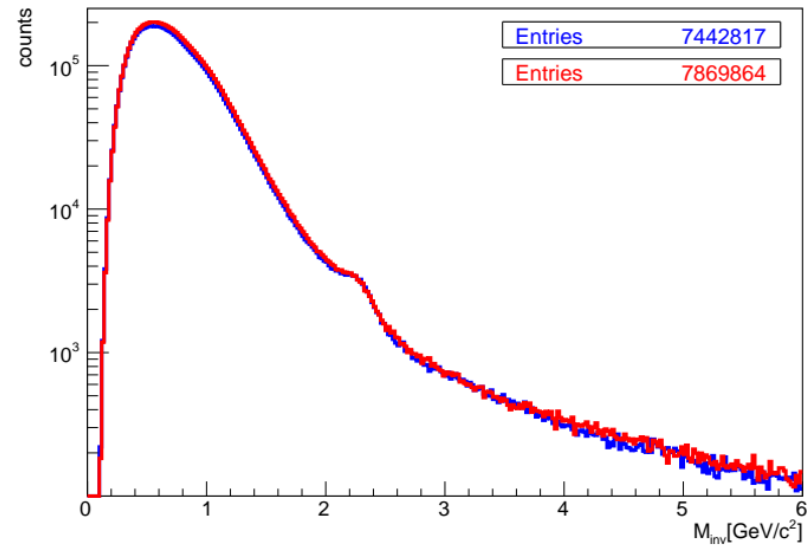
## Event-based (Sum)

pbp invariant mass

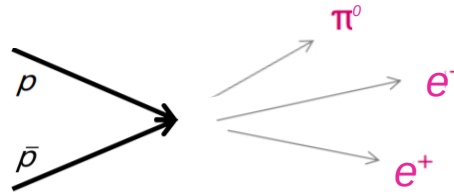


## Time-based (Time-Gap)

pbp invariant mass



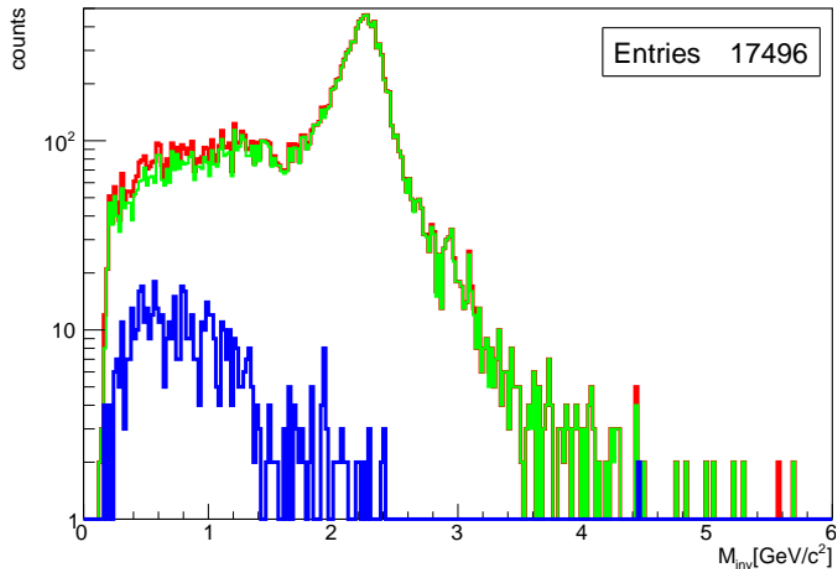
# Offline analysis (Filter)



$Ev_{\text{sig}} : Ev_{\text{b}} = 1 : 9$   
 Total number = 1000000

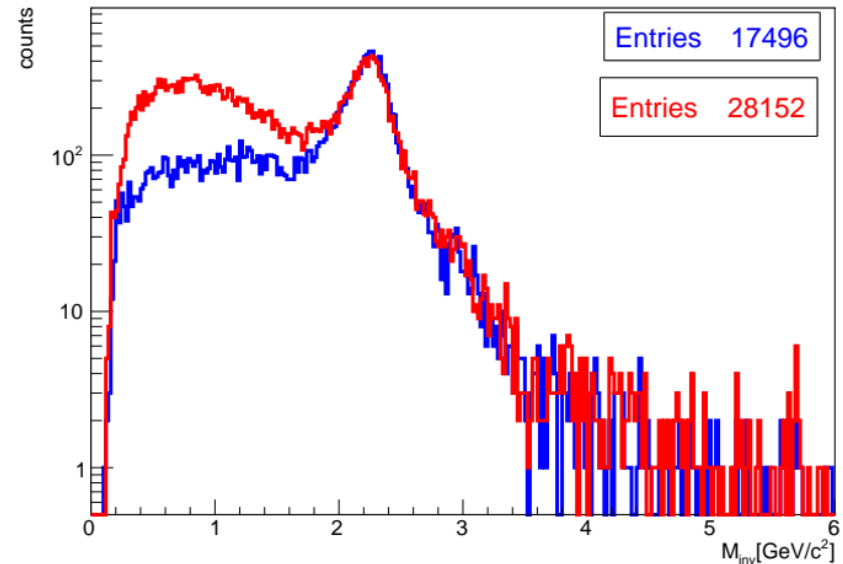
## Event-based (Sum)

pbp invariant mass

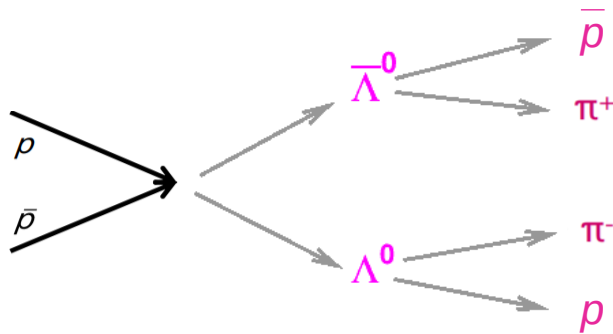


## Time-based (Time-Gap)

pbp invariant mass



# Offline analysis

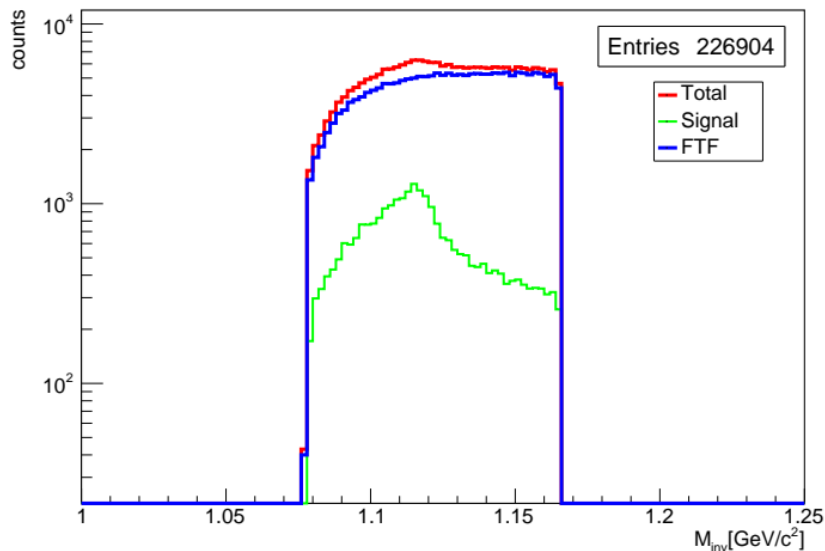


0.1 GeV mass cut for the Lambda candidates is applied

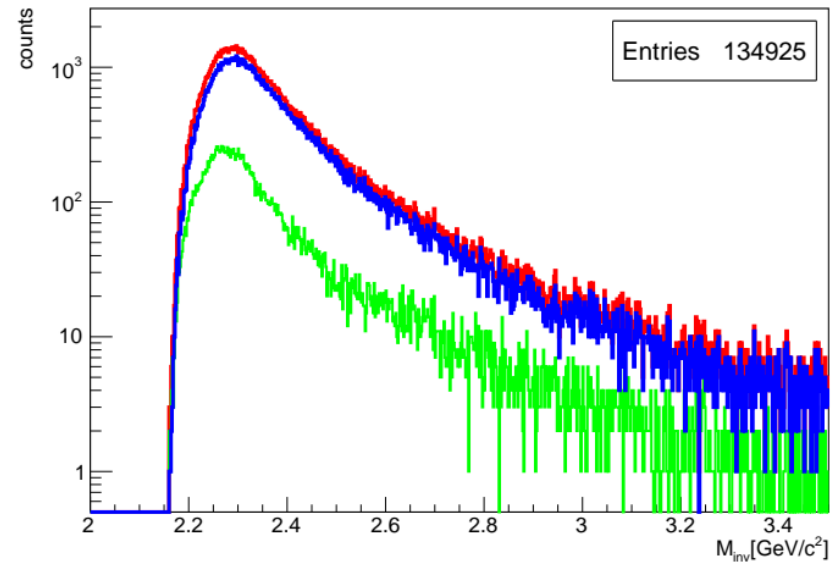
$E_{v_{\text{sig}}} : E_{v_{\text{b}}} = 1 : 9$   
 Total number = 1000000

## Event-based (Sum)

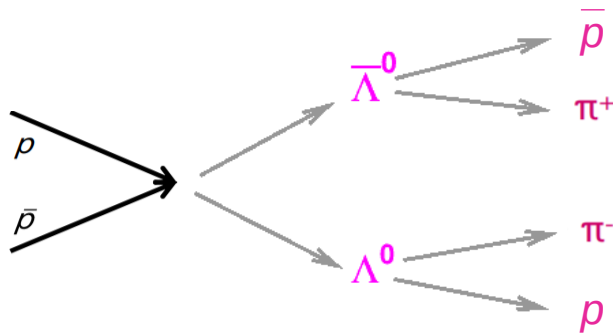
Lambda->p+pi- invariant mass



pbp invariant mass



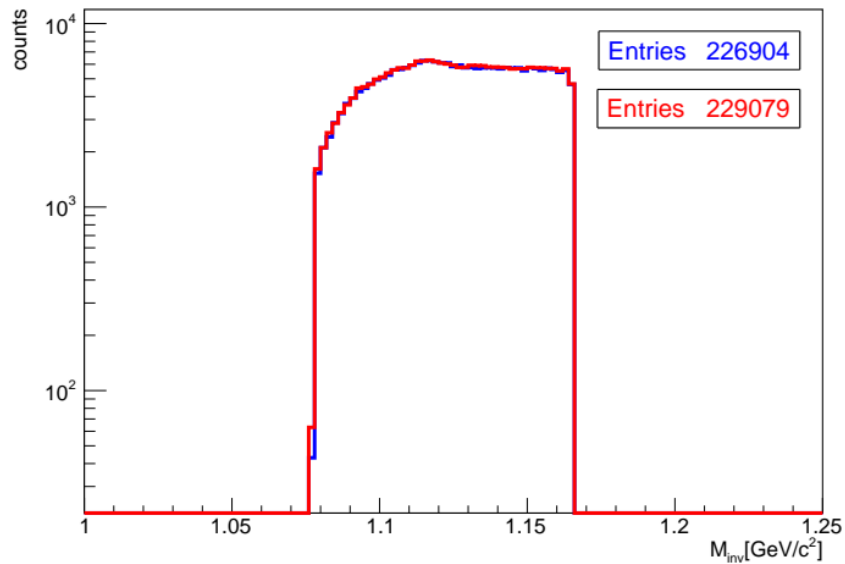
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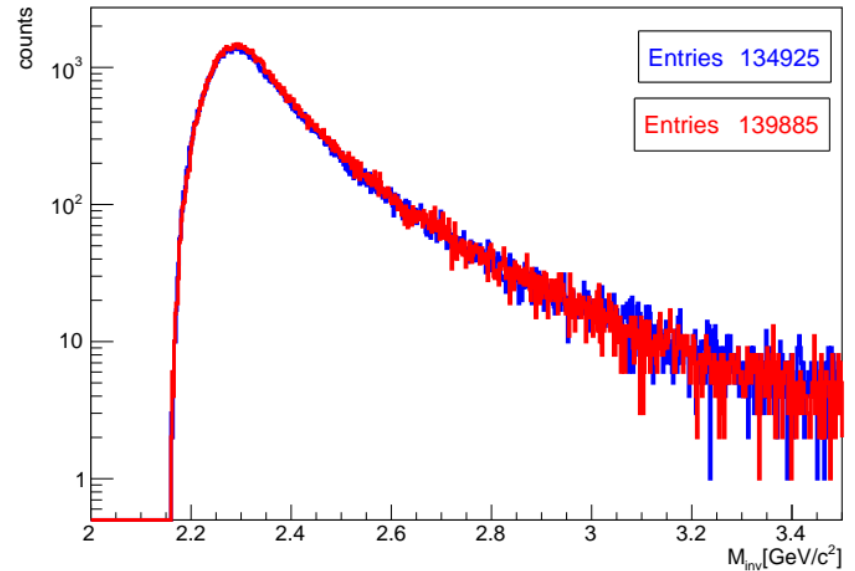
$E_{v_{\text{sig}}} : E_{v_{\text{b}}} = 1 : 9$   
 Total number = 1000000

## Time-based (Time-Gap)

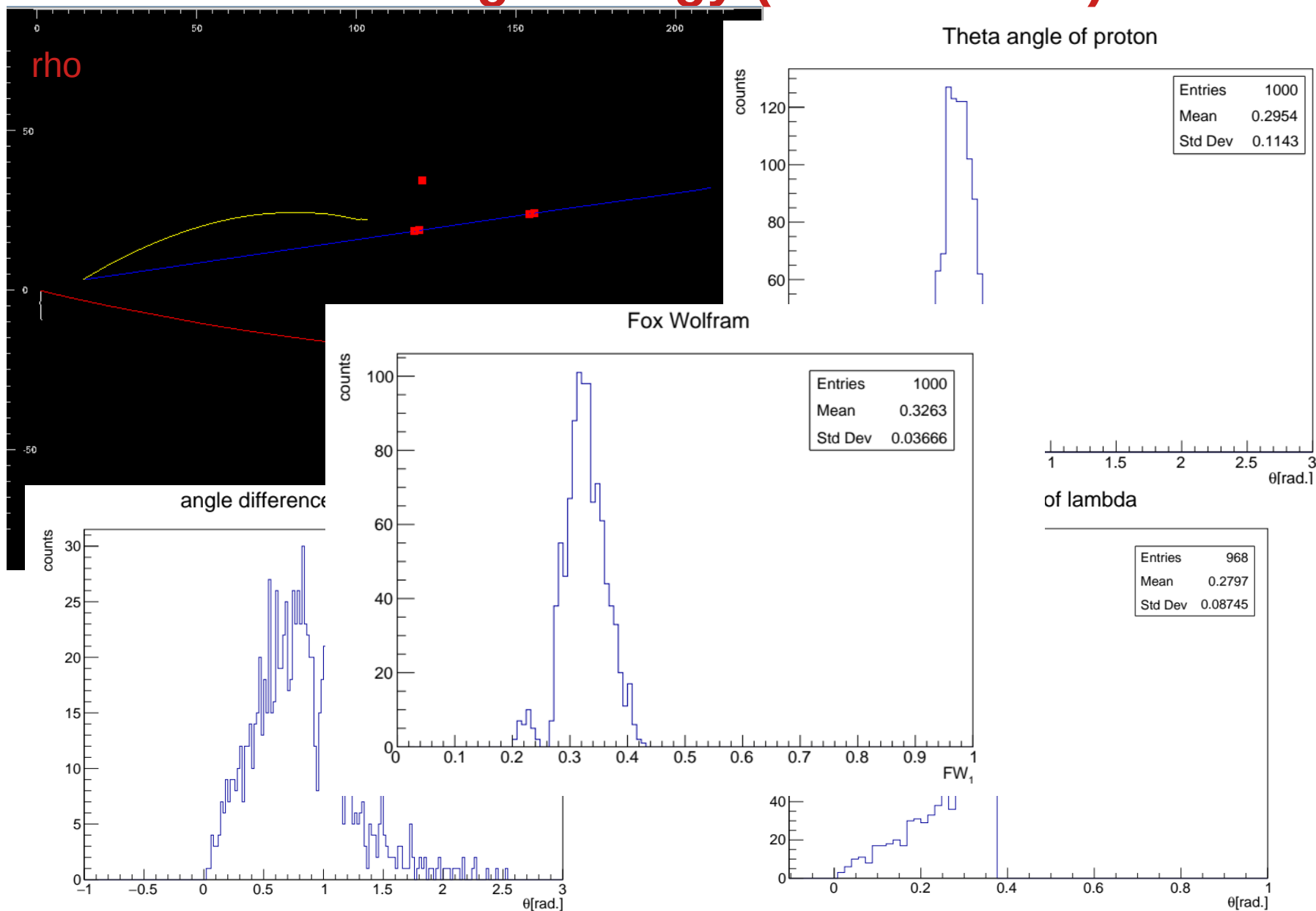
Lambda  $\rightarrow$  p+pi $^-$  invariant mass



pbp invariant mass

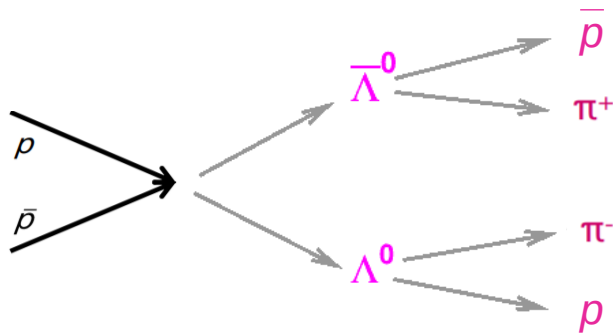


# Filtering strategy (Monte Carlo)

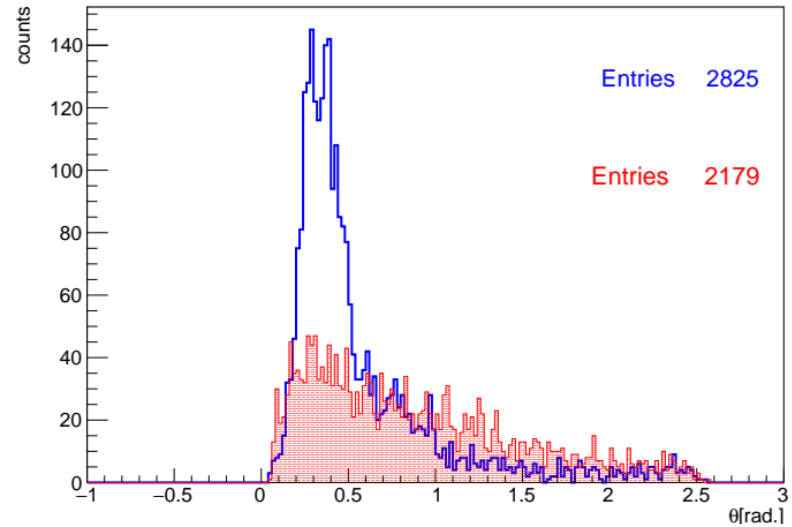




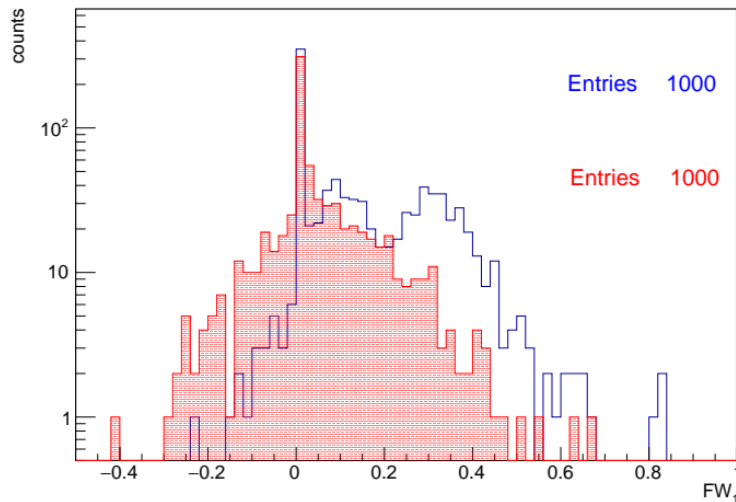
# Filtering strategy (Reconstr.)



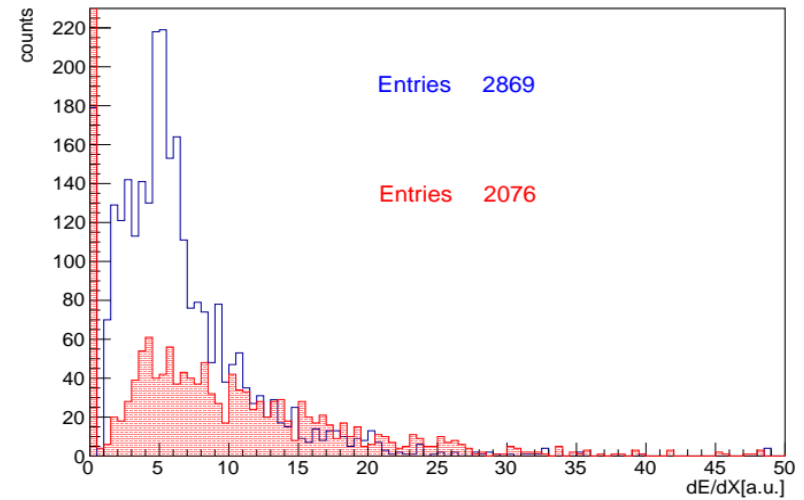
Theta angle of proton



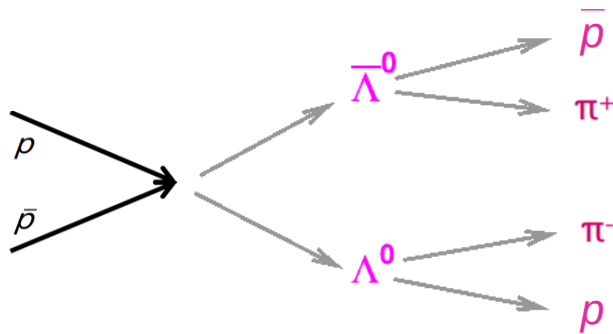
Fox Wolfram



Energy loss for STT



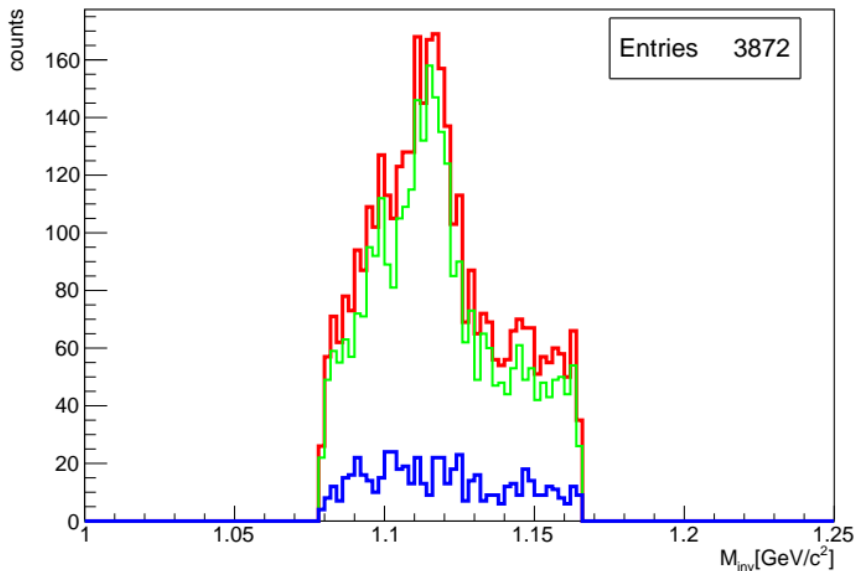
# Offline analysis(Filter)



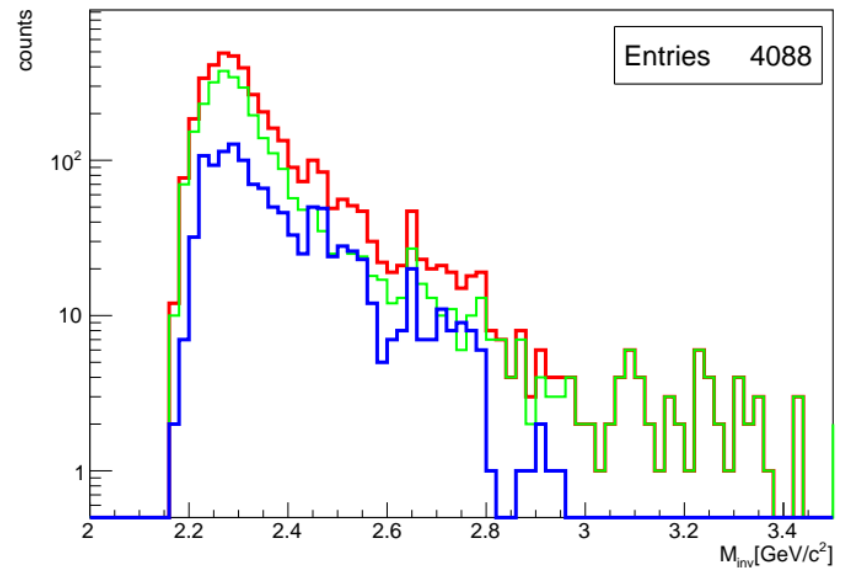
$E_{v_{\text{sig}}} : E_{v_{\text{b}}} = 1 : 9$   
 Total number = 1000000

## Event-based (Sum)

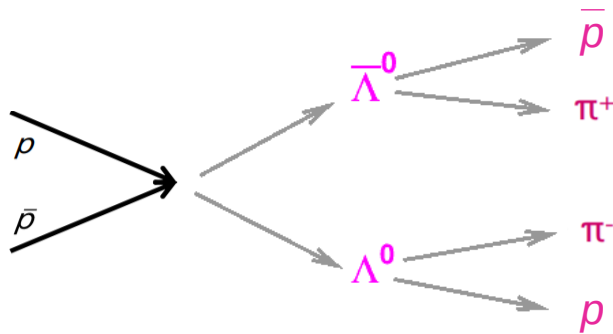
Lambda $\rightarrow$ p+pi- invariant mass



pbp invariant mass



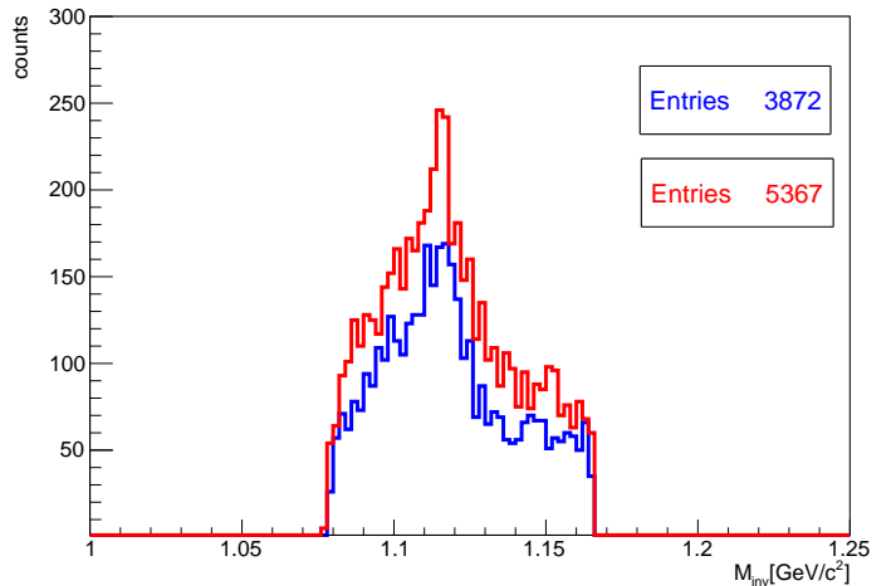
# Offline analysis(Filter)



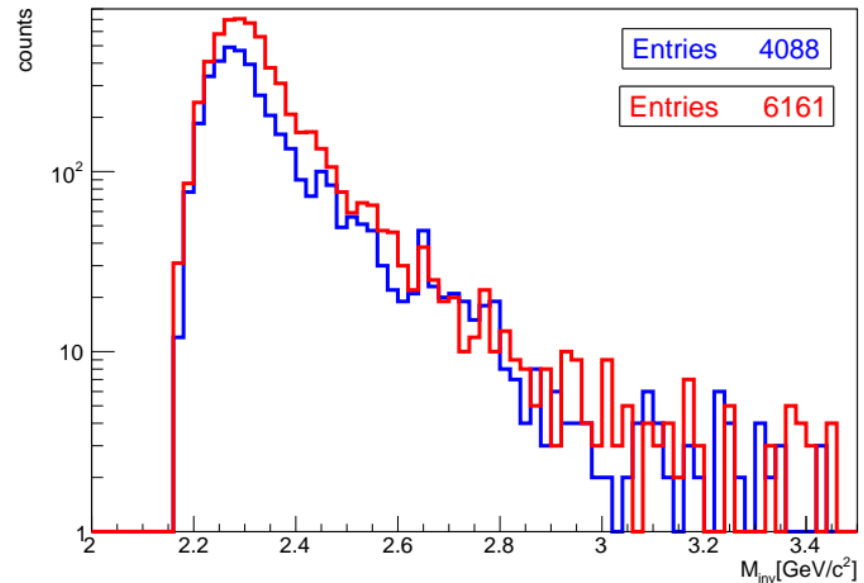
$E_{v_{\text{sig}}} : E_{v_{\text{b}}} = 1 : 9$   
 Total number = 1000000

## Time-based (Time-Gap)

Lambda- $\rightarrow$ p+ $\pi^-$  invariant mass

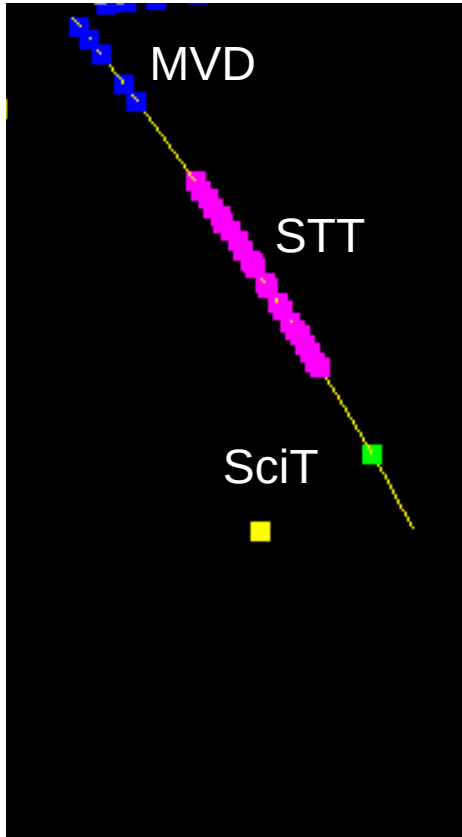


pbp invariant mass



# In progress...

# Event type definition for PndCandidates (MC Truth)



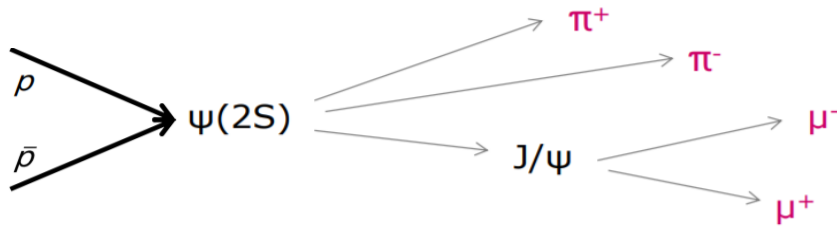
PndDetHit  $\longrightarrow$  FairLinks  $\longrightarrow$  FileId

FileId = 1, file with signal events

FileId = 0, file with background events

$$EvType = \frac{\sum T_{det}}{N_{det}} \quad T_{det} = \frac{\sum FileId_{hit}}{N_{hits}}$$

# Framework performance



$$Ev_{\text{sig}} : Ev_{\text{b}} = 1 : 1$$

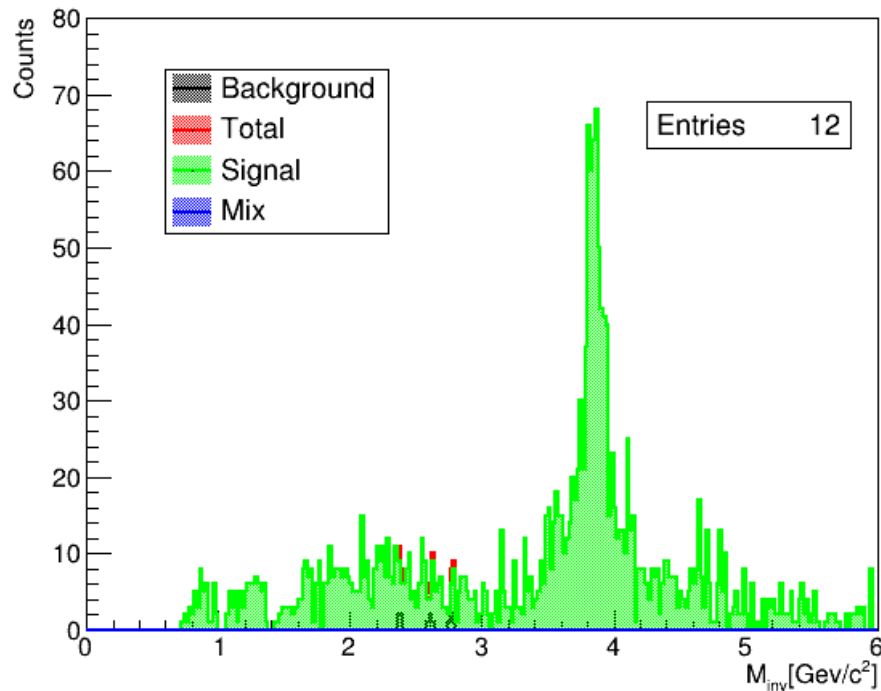
Total number = 2000

Online filtering is used

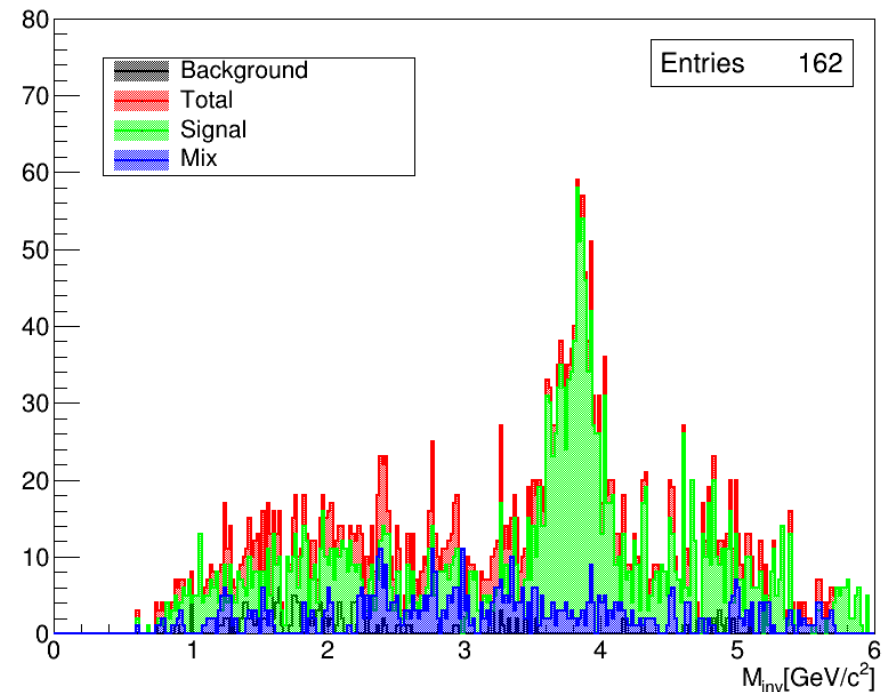
2kHz

2MHz

pbp invariant mass



pbp invariant mass



# Summary

- Framework for event building and event filtering was developed in the PandaRoot
- Performance of the framework was studied by comparing with event-based simulation
- All the benchmark channels can be detected using the proposed framework
- There are discrepancies present due to the mixing and clipping effects

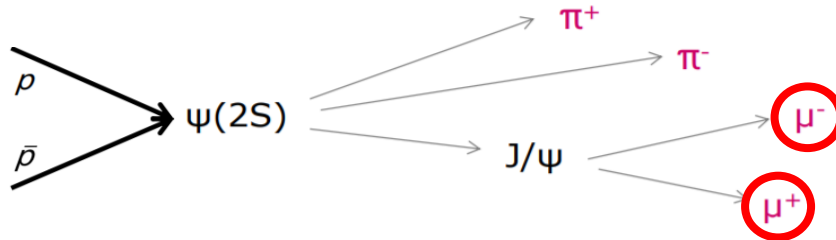
A close-up photograph of a giant panda sitting on a thick, textured tree branch. The panda's mouth is wide open, showing its pink tongue and teeth. Its black and white fur is clearly visible, especially around its eyes and ears. One of its black-furred paws is raised near its head. The background is a soft, out-of-focus green, suggesting a forest environment.

**THANK YOU FOR YOUR ATTENTION  
AND STAY HEALTHY!**



# Backup Slides

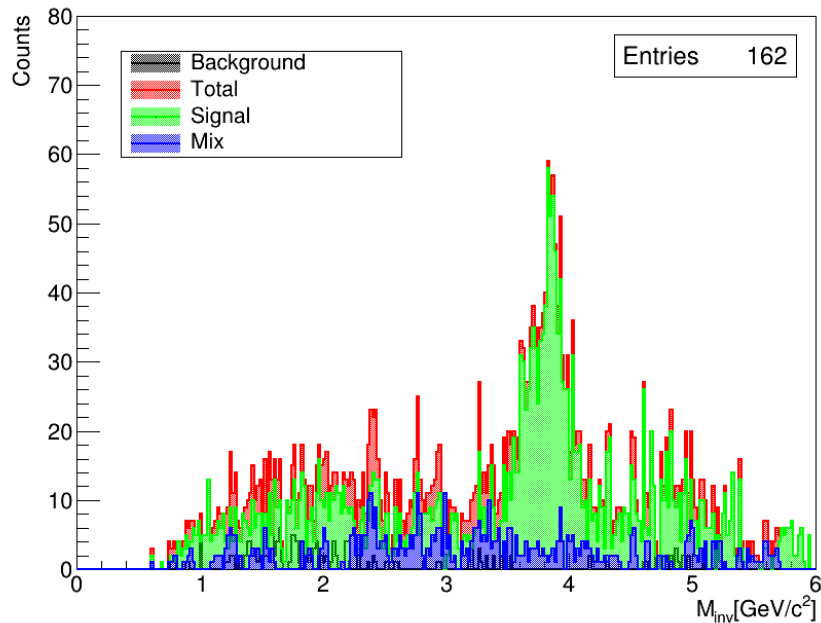
# Offline analysis (Filter)



$Ev_{\text{sig}} : Ev_{\text{b}} = 1 : 1$   
 Total number of events = 2000

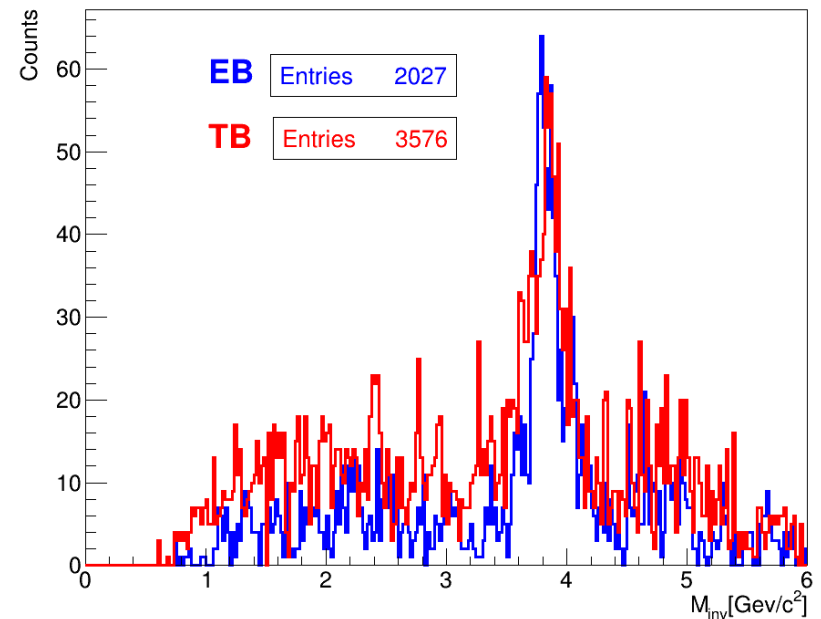
## Time-based (Time-Gap)

pbp invariant mass

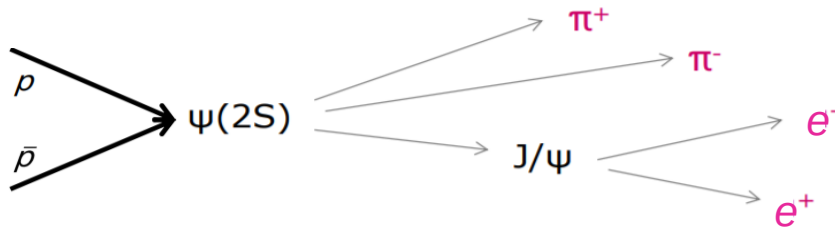


## Comparison

pbp invariant mass



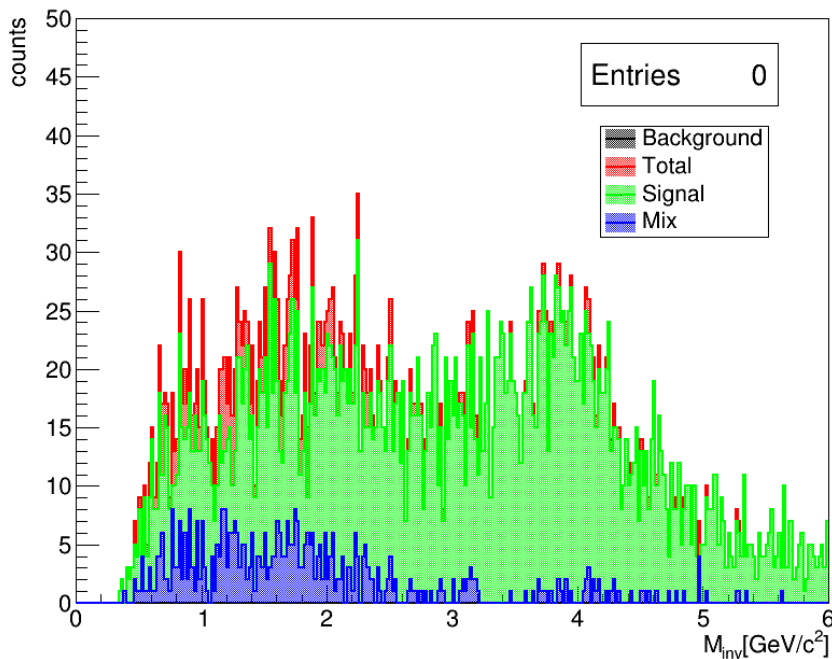
# Offline analysis (Filter)



$Ev_{\text{sig}} : Ev_{\text{b}} = 1 : 1$   
 Total number of events = 2000

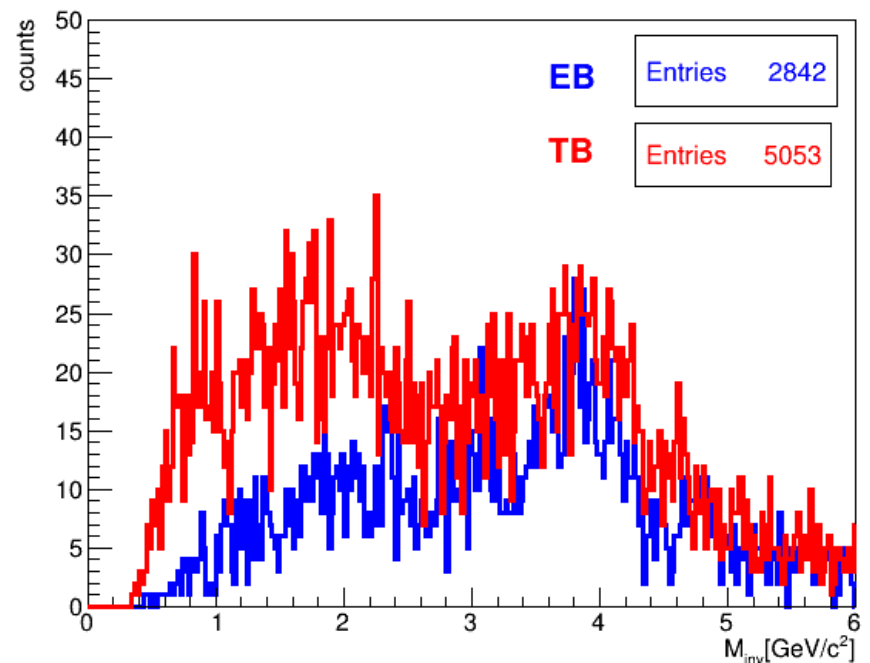
## Time-based (Time-Gap)

pbp invariant mass

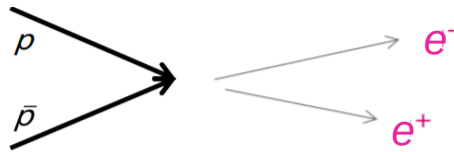


## Comparison

pbp invariant mass



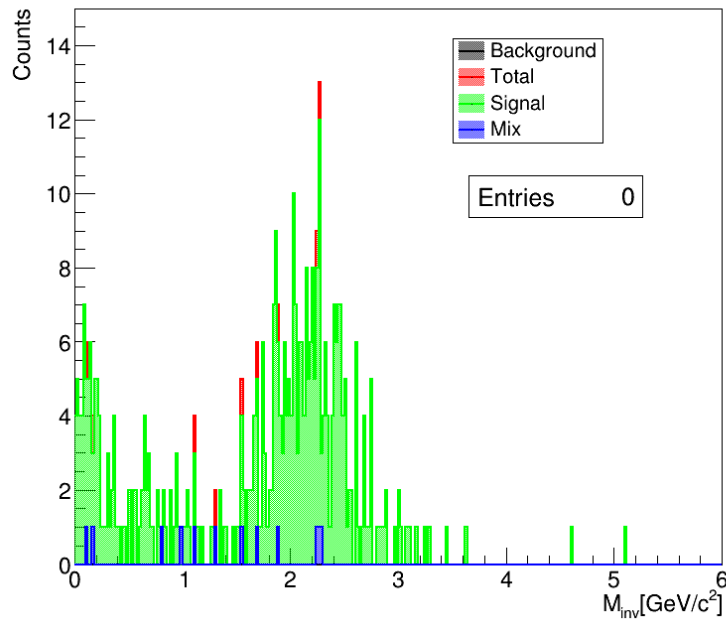
# Offline analysis (Filter)



$Ev_{\text{sig}} : Ev_{\text{b}} = 1 : 1$   
 Total number of events = 2000

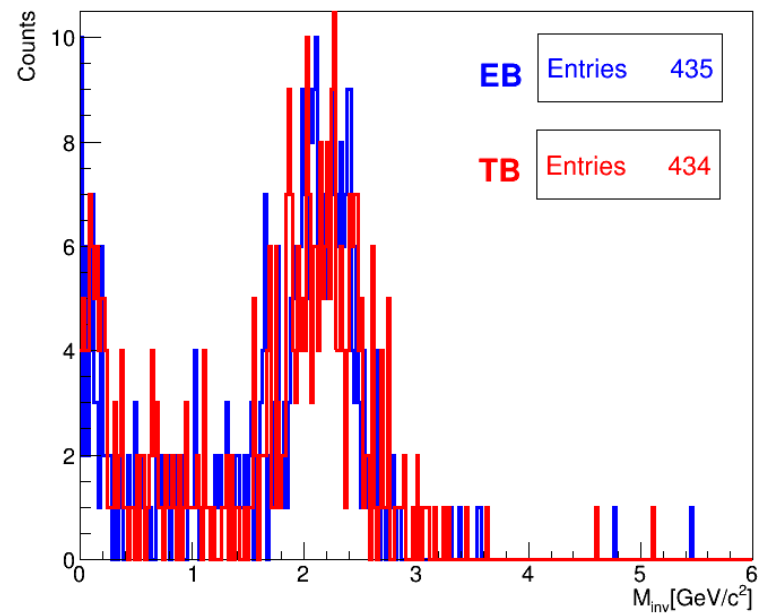
## Time-based (Time-Gap)

pbp invariant mass

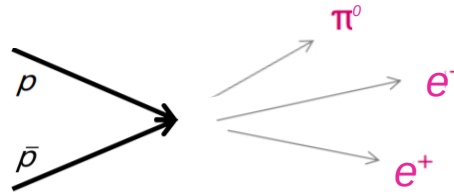


## Comparison

pbp invariant mass



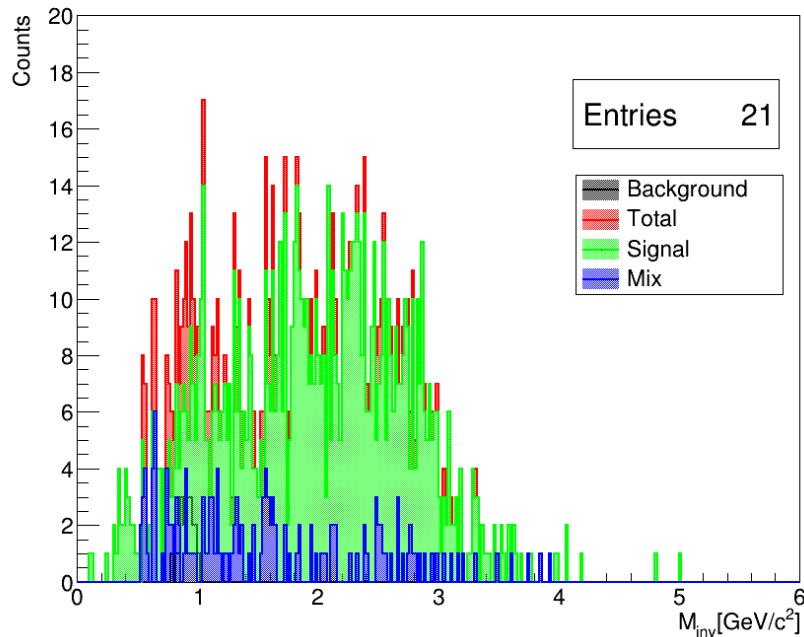
# Offline analysis (Filter)



$Ev_{\text{sig}} : Ev_{\text{b}} = 1 : 1$   
 Total number of events = 2000

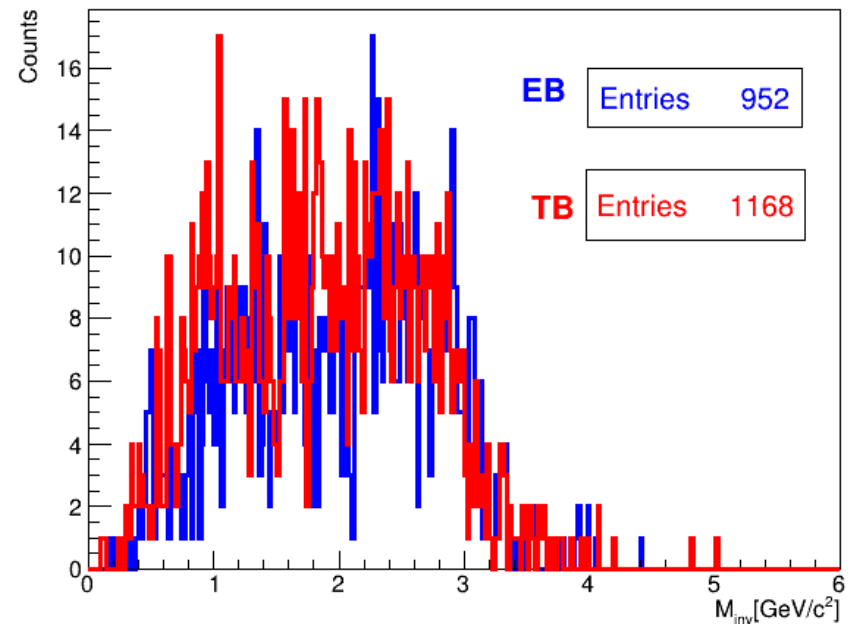
## Time-based (Time-Gap)

pbp invariant mass

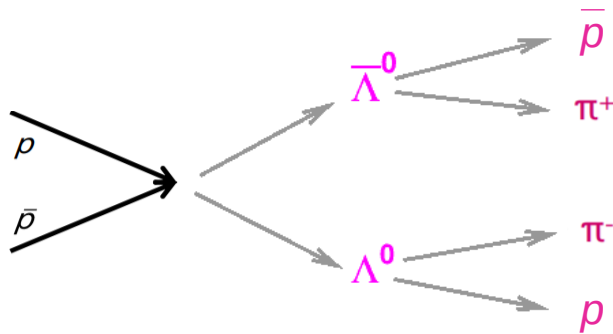


## Comparison

pbp invariant mass



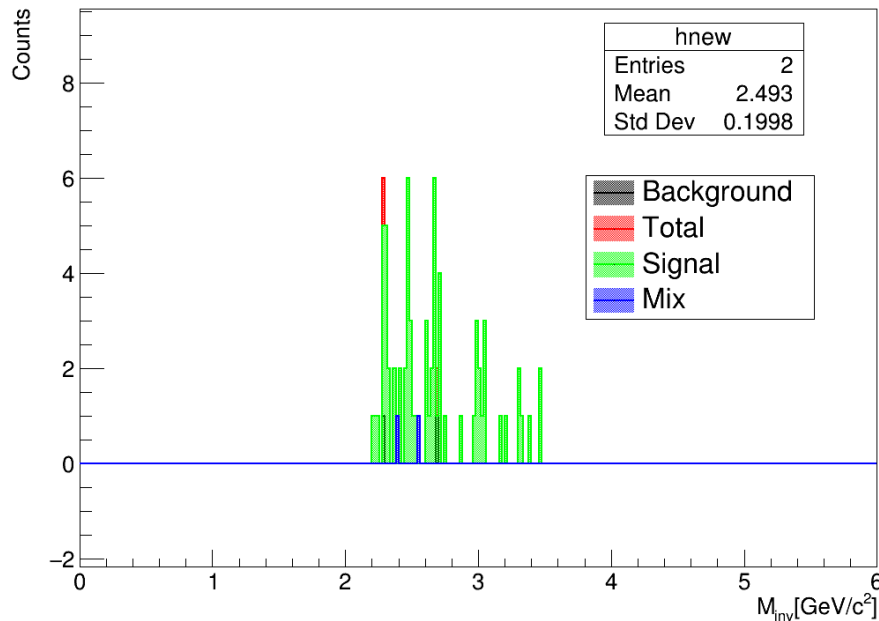
# Offline analysis(Filter)



$Ev_{sig} : Ev_b = 1 : 1$   
 Total number of events = 2000

## Time-based (Time-Gap)

pbp invariant mass



## Comparison

pbp invariant mass

