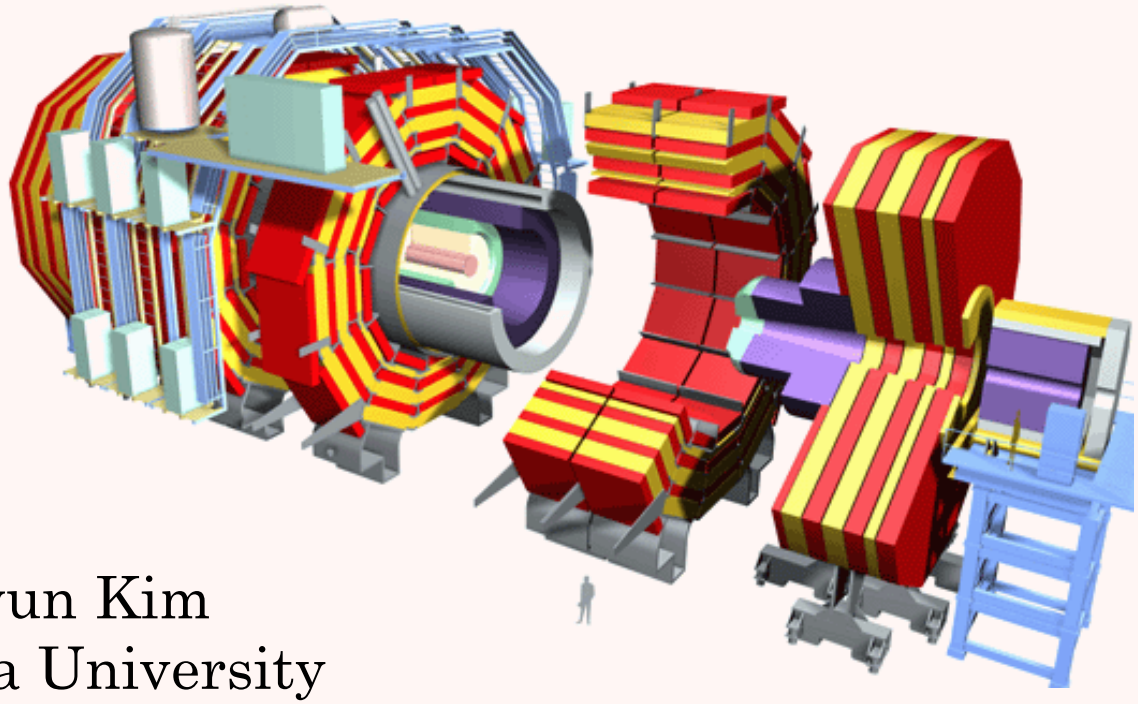
Low-p_T dimuon triggering for quarkonia measurements in p+p collisions in CMS



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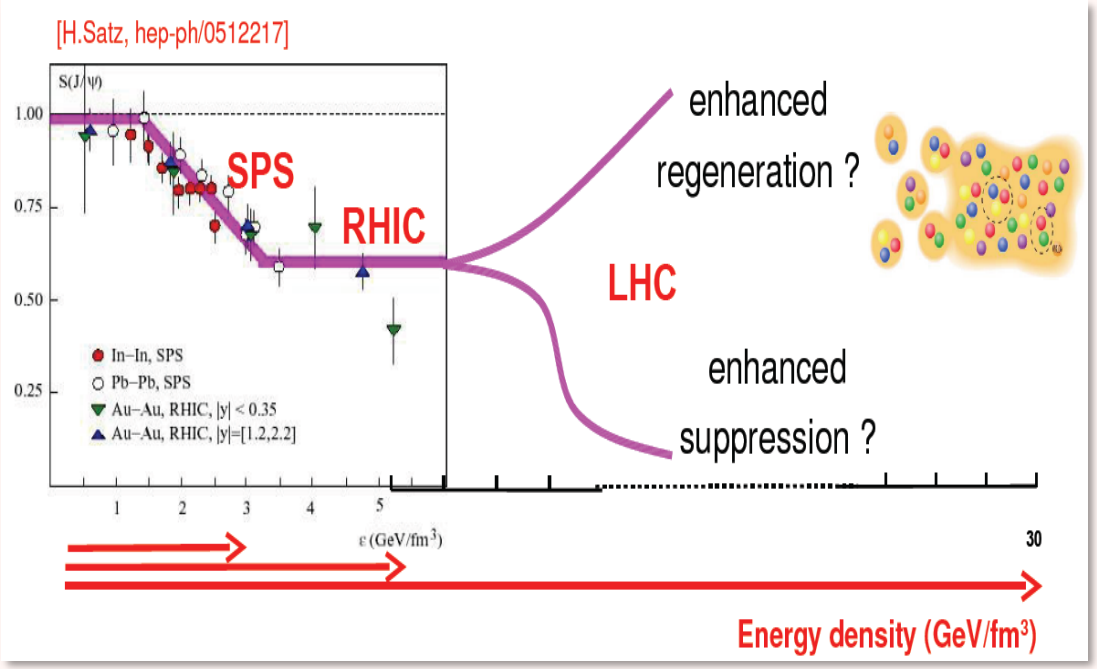
Contents

- Introduction
- Results of Trigger Study
  - Event generation
  - Trigger efficiency
- Trigger rates and Statistics

Introduction

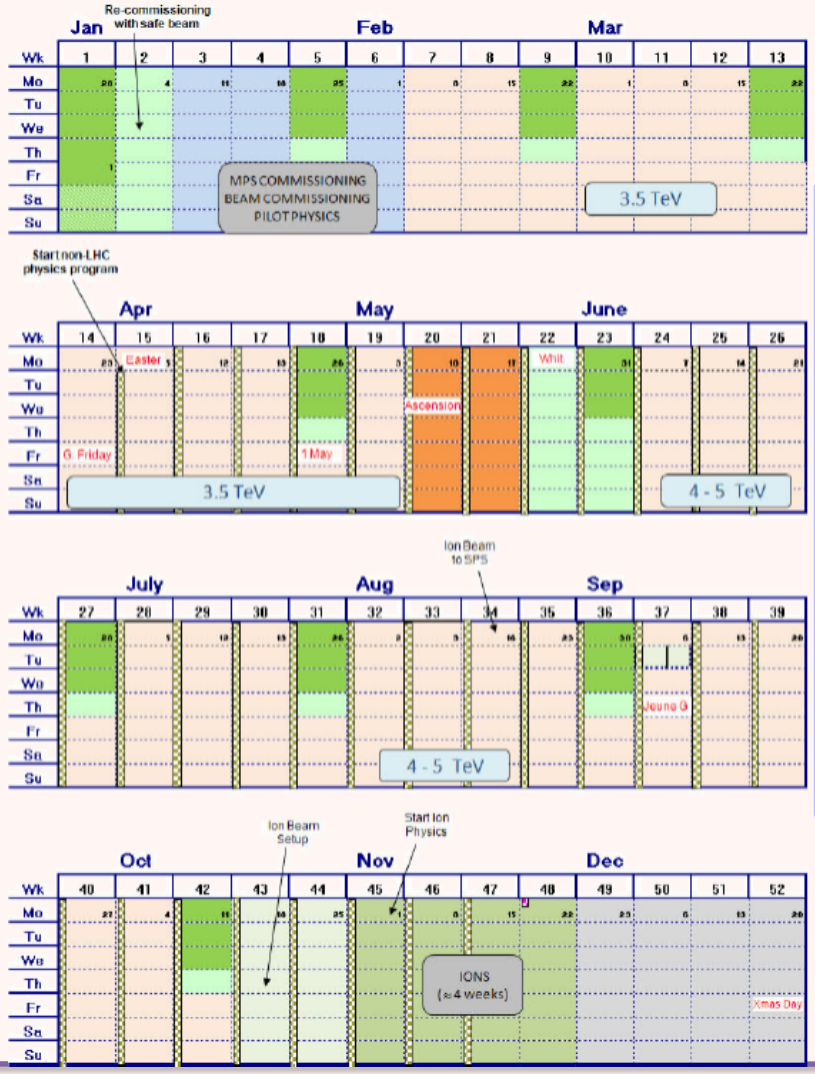
Motivation

- Quarkonia physics in CMS at LHC
  - Pb+Pb collisions will create high-density partonic matter at very high temperature where the phase transition to the QGP is expected.
  - Heavy quarkonia (J/ψ, Υ) suppression is an ideal signature of the QGP.
  - We need p+p data as a reference.



$$R_{AA} = \frac{N_{AA}}{N_{coll} N_{pp}}$$

LHC2010 – very draft



- **2009**:
  - 1 month commissioning
- **2010**:
  - 1 month pilot & commissioning
  - 3 month 3.5 TeV
  - 1 month step-up
  - 5 month 4 - 5 TeV
  - 1 month ions

CMS Physics Week, Bologna, Sep. 7-11 2009

pp and HI group should discuss a lot about their physics goal and necessities.

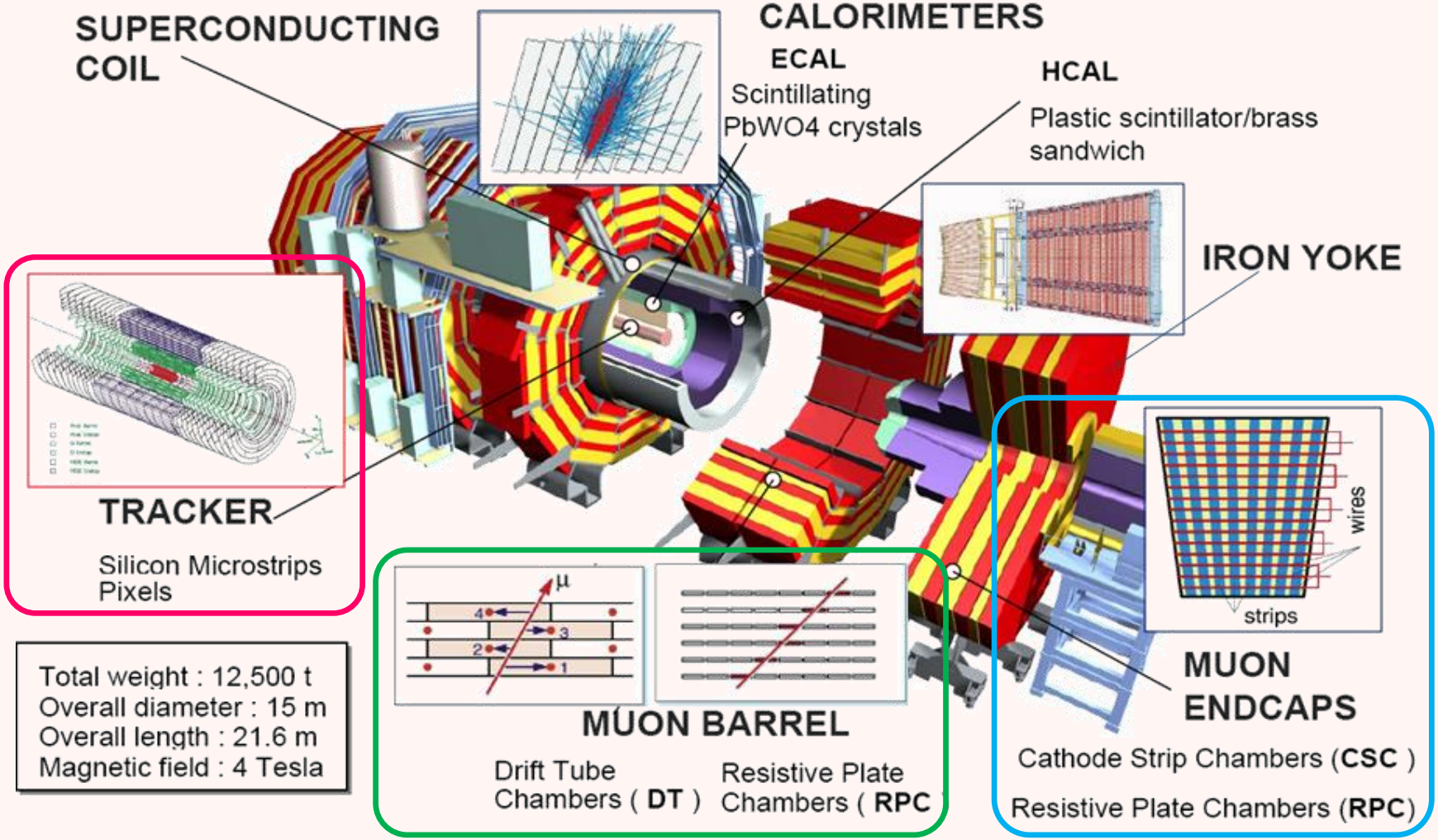
CMS week

Goal of Trigger Study

- Why is the trigger important?
  - **No trigger means No data!**
  - p+p and heavy-ion trigger menu is different.
  - **Identical, or at least** similar trigger setting as in HI is needed for p_T spectrum of quarkonia(extended to low-p_T region) in p+p for R_{AA}.

- CMS Trigger Strategy for 2009
  - For 2009 physics data taking in p+p, new compact trigger menu was developed and focus on specific luminosity scenarios(L=8E29, 1E31) by **trigger review procedure**.

CMS Muon Detectors



CMS Muon Trigger

L1 Muon Trigger

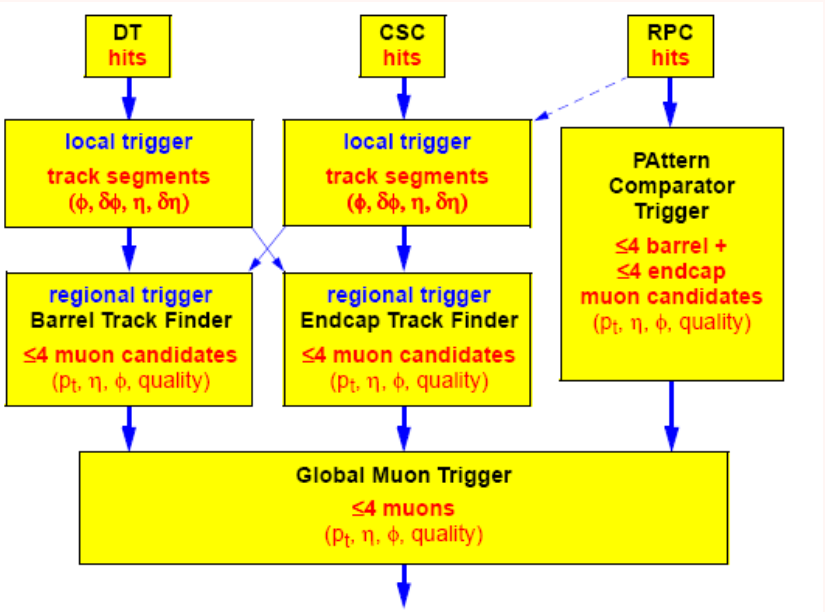
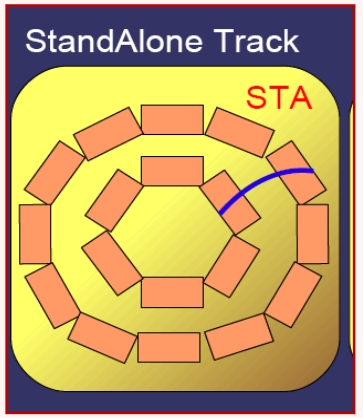


Fig. 8.6: Muon Trigger data flow.

Finally up to 4 highest p_T muons are transmitted to the GT among at most 16 muons candidates.

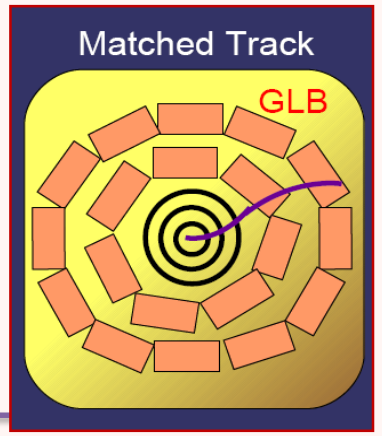
L2 Muon Trigger (StandAloneMuon)

- Seeded by Level-1 muon.
- Kalman filtering technique.
- Fit track with beam constraint.
- Filter : p_T, invariant mass, etc.



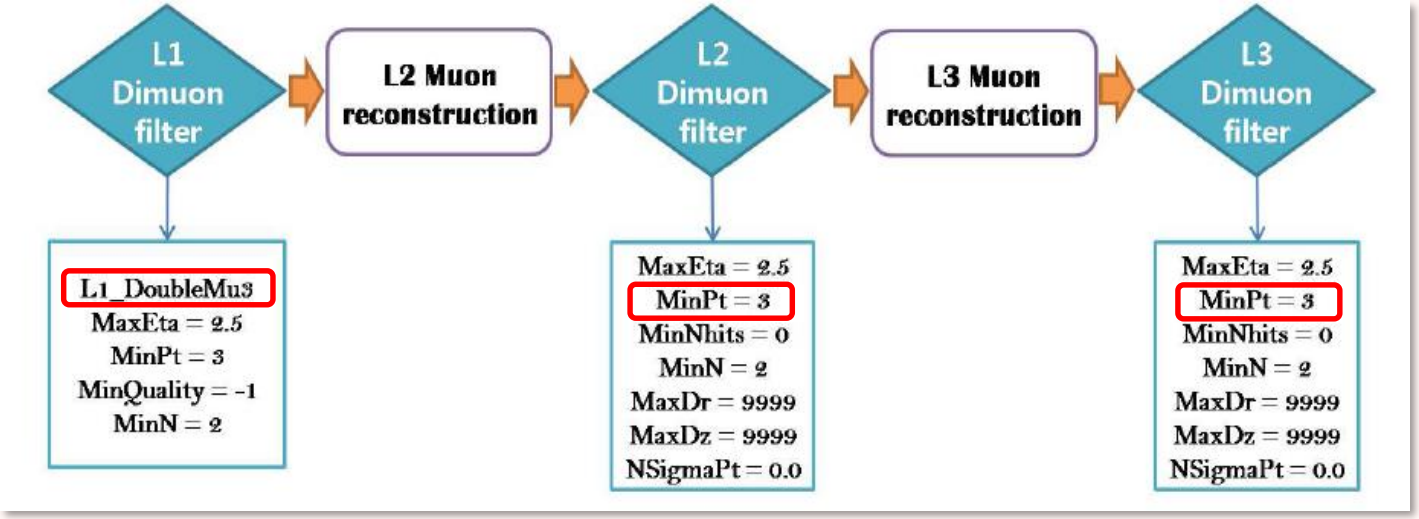
L3 Muon Trigger (GlobalMuon)

- Track reconstruction and matching with track in muon chamber and inner tracker.
- Finding vertex.
- Filter : p_T, invariant mass, etc.



Default Setting of CMS dimuon trigger

- Descriptions of HLT_DoubleMu3 for p+p run
  - **A double muon trigger**, based on the Level 3 (combined muon system and tracker) HLT muon reconstruction.
  - At least **two L1(L2/L3)** muons with **p_T > 3 GeV/c** are required at corre sponding higher trigger level.



Suggestion : Remove p_T cut

- Several reasons to remove the low-p_T cut in CMS default dimuon trigger
  - All measurements “in-medium”(HI) are in comparison with “vacuum”(pp)
  - CMS detector can measure muons down to ~1 GeV/c in the forward region.
  - Shape of p_T distribution is the essential tool to differentiate production models.
  - RHIC measurements are limited at low p_T region.

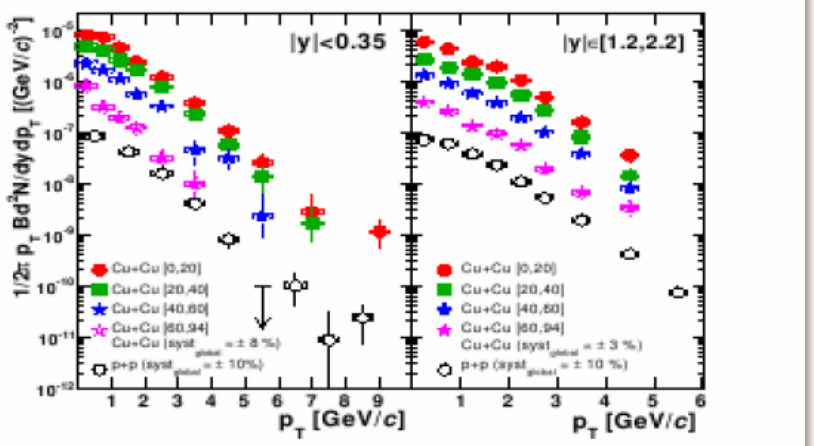


FIG. 1: (color online) J/ψ yield vs p_T at mid (left) and forward (right) rapidity for different Cu+Cu centrality bins and for $p+p$ [15]. Uncertainties are described in the text.

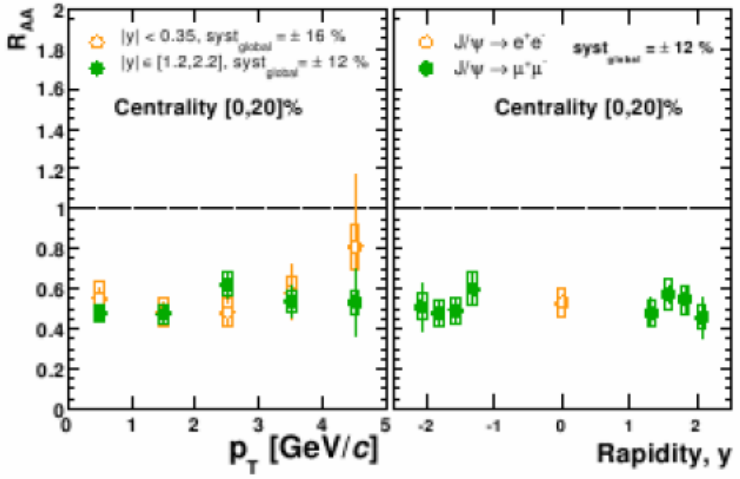
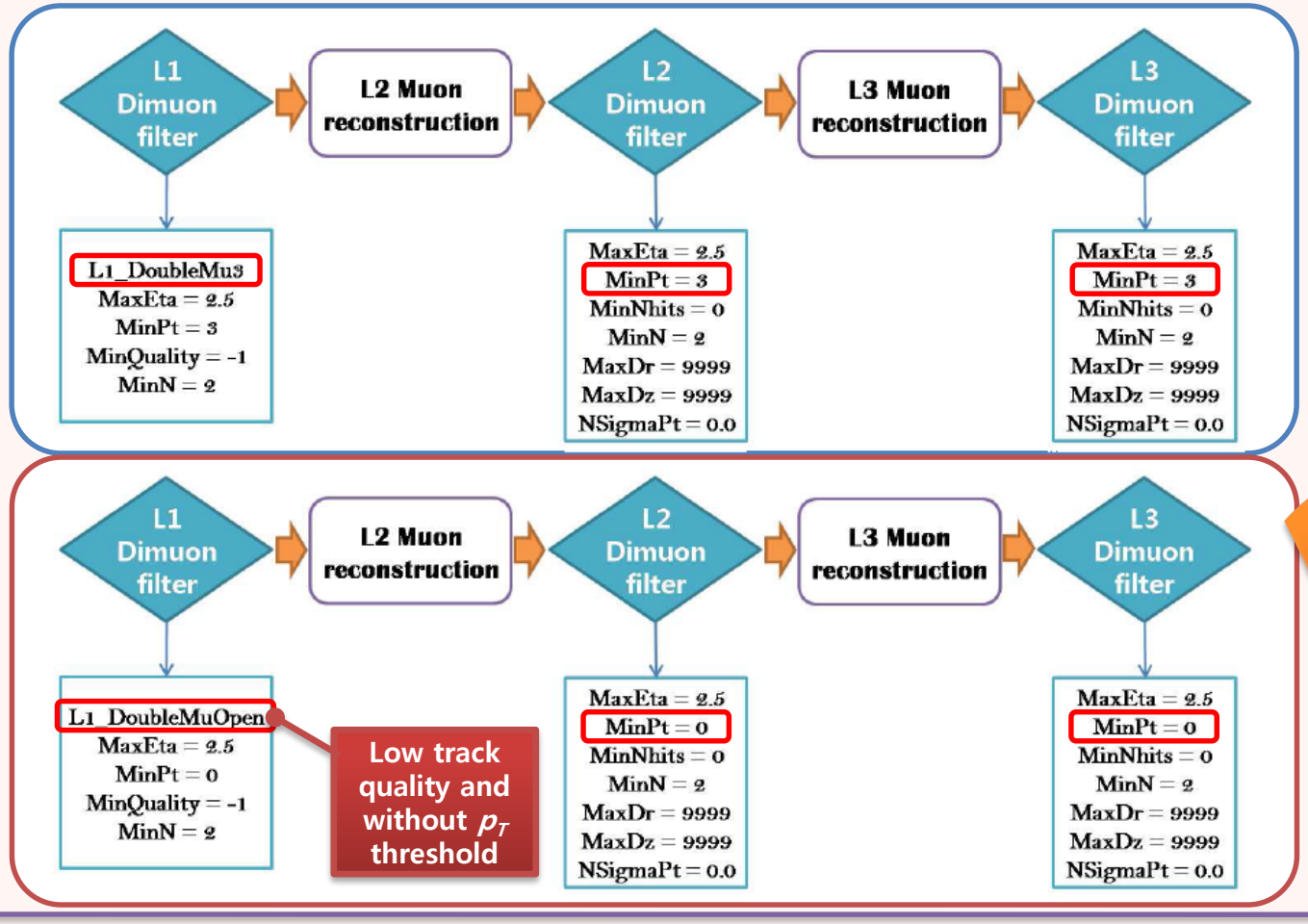


FIG. 3: (color online) R_{AA} vs p_T (left) and y (right) for J/ψ production in the most central Cu+Cu collisions.

CMS Default vs. New setting

- Trigger Structure



HLT_DoubleMu3

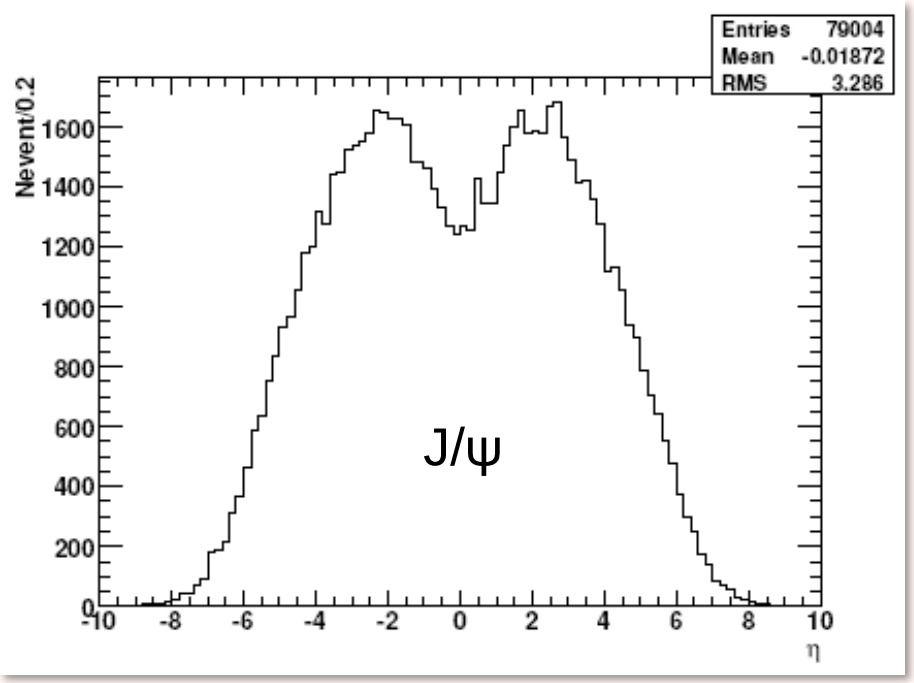
Similar to HI dimuon trigger

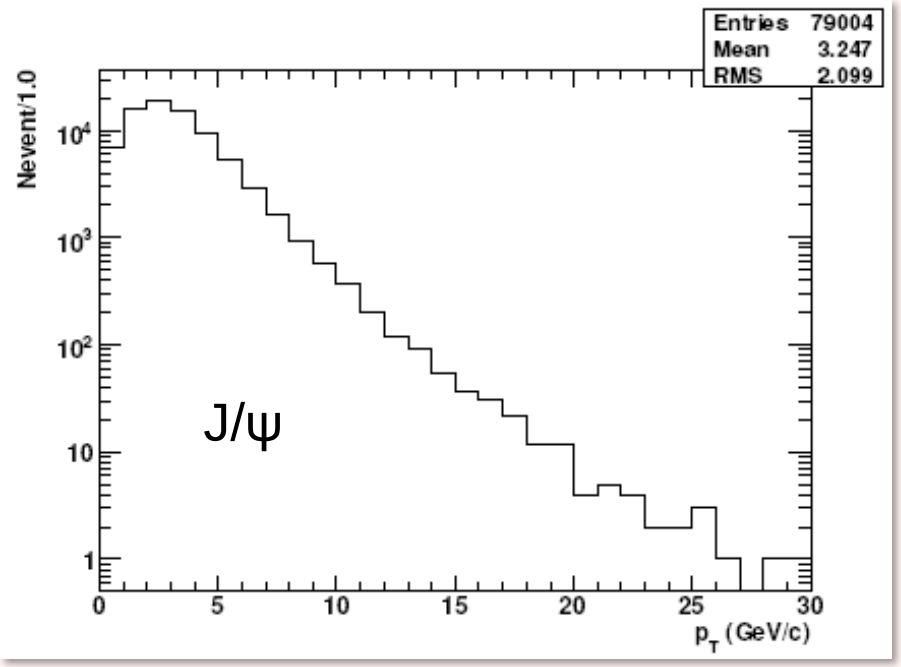
HLT_DoubleMu0

Trigger Study

η & p_T Specra : J/ψ

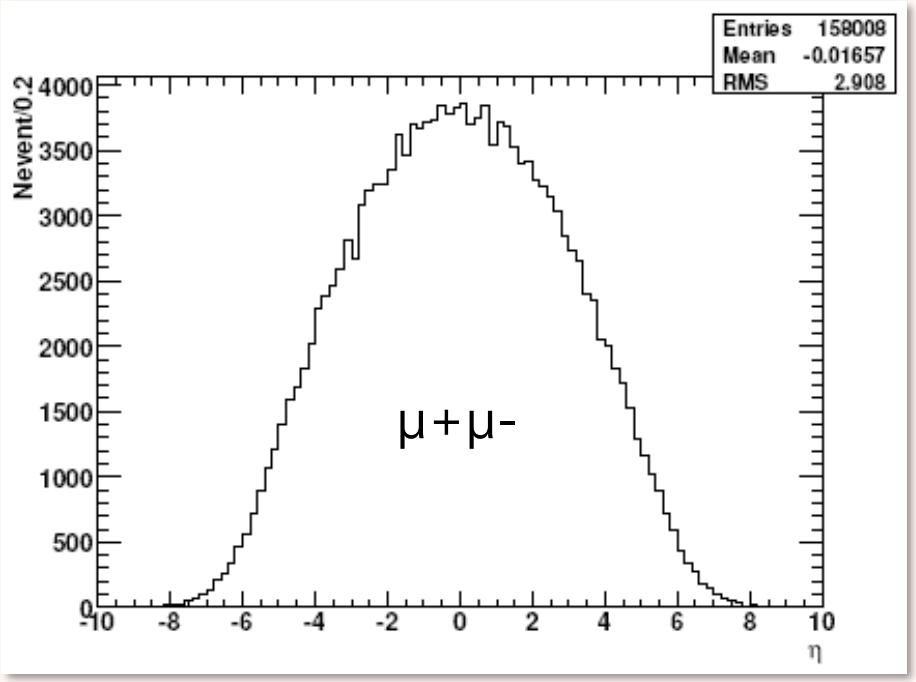
- MC signal sample
  - PYTHIA 6.416, √s = 10 TeV
  - 79,004 J/ψs which are forced to decay to μ+μ-

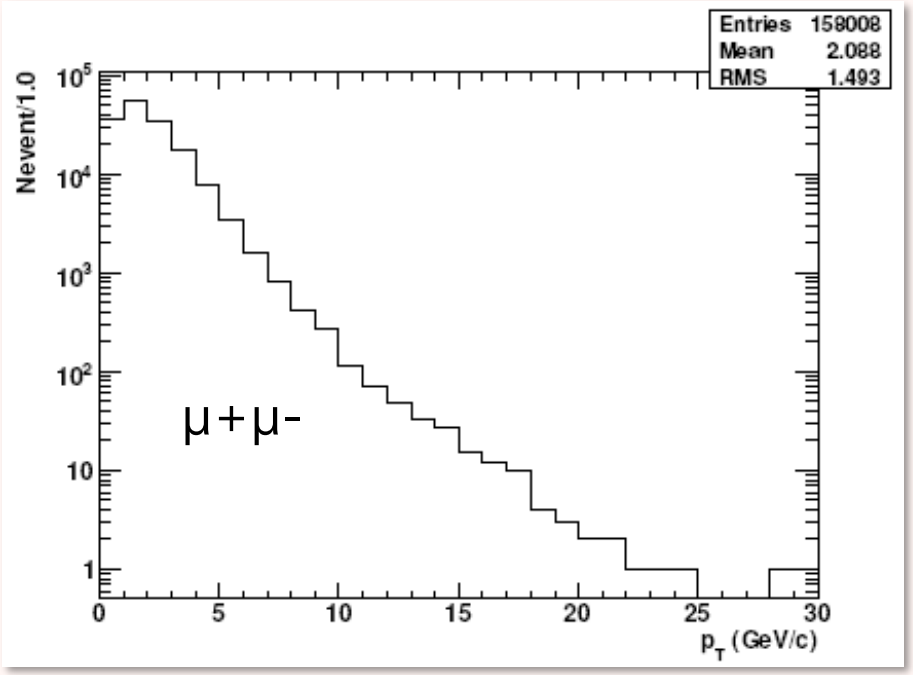




η & p_T Spectra : μ+μ-

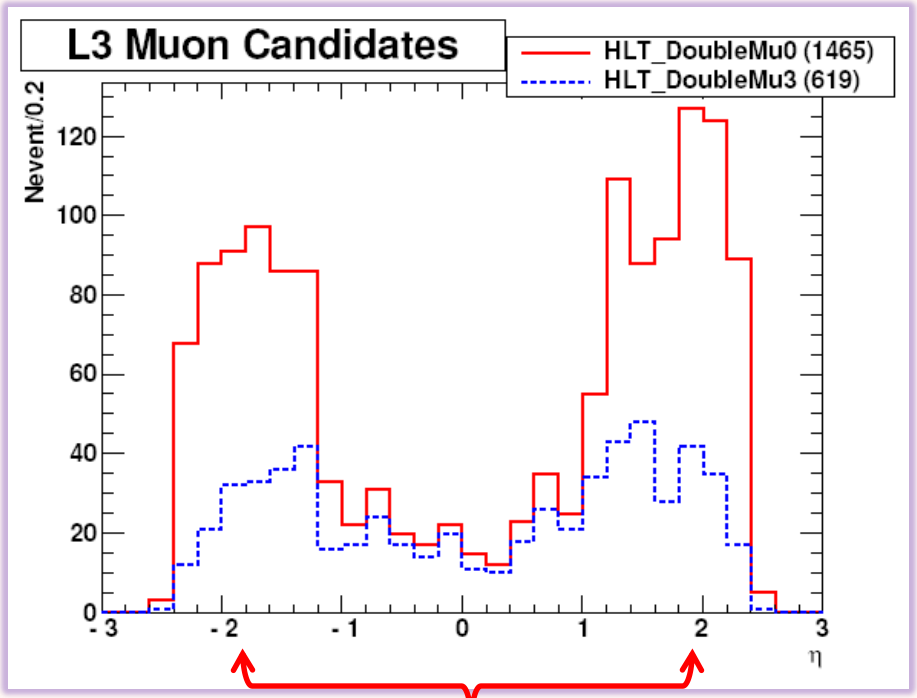
- MC signal sample
  - PYTHIA 6.416, √s = 10 TeV
  - 158,008 muons from J/ψ decay

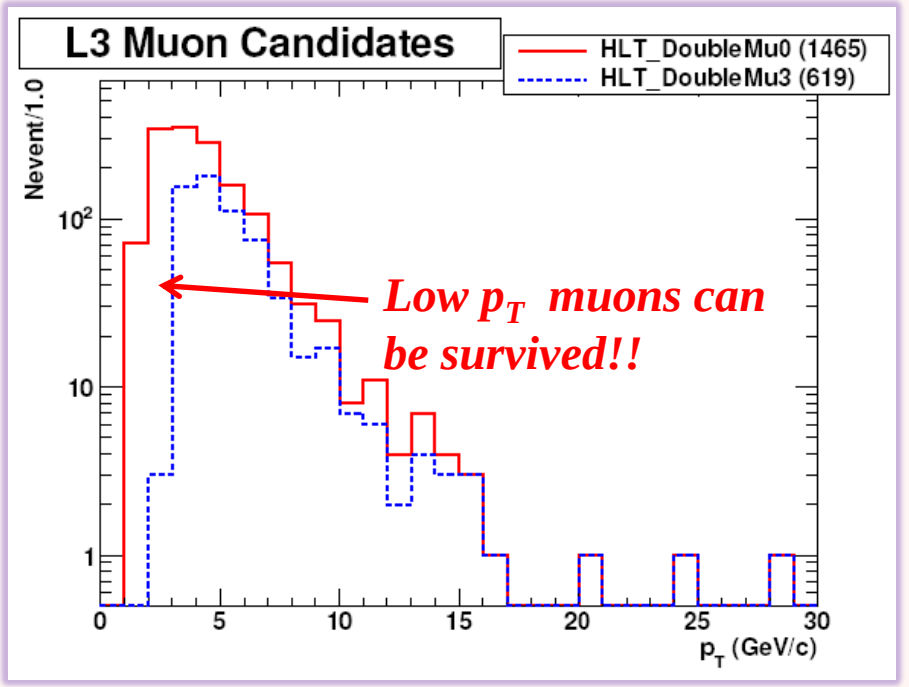




Triggered Muons

- CMS default (HLT_DoubleMu3) vs. new setting (HLT_DoubleMu0)

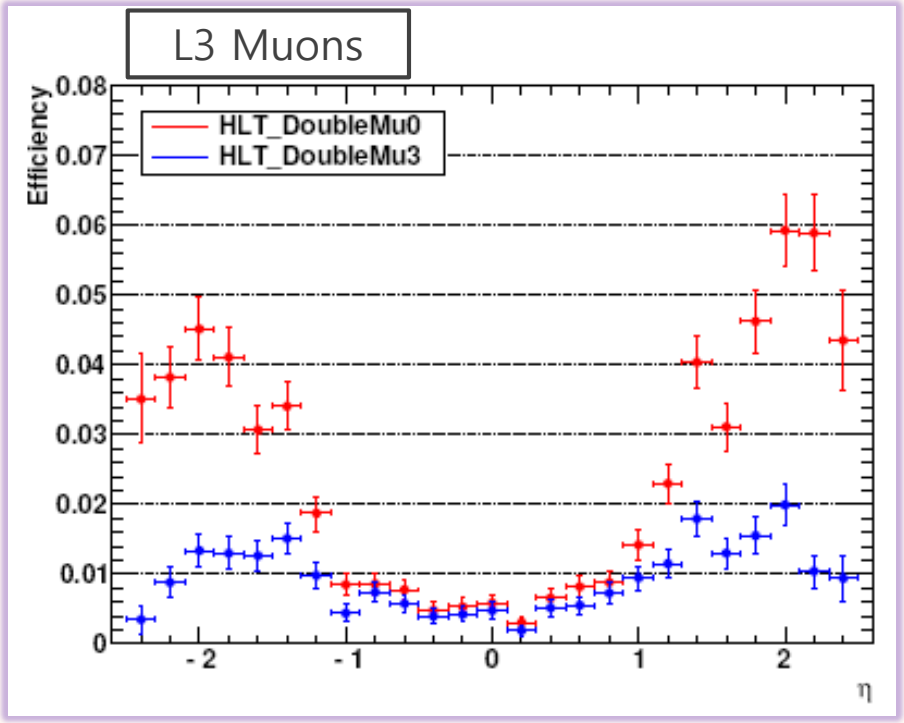


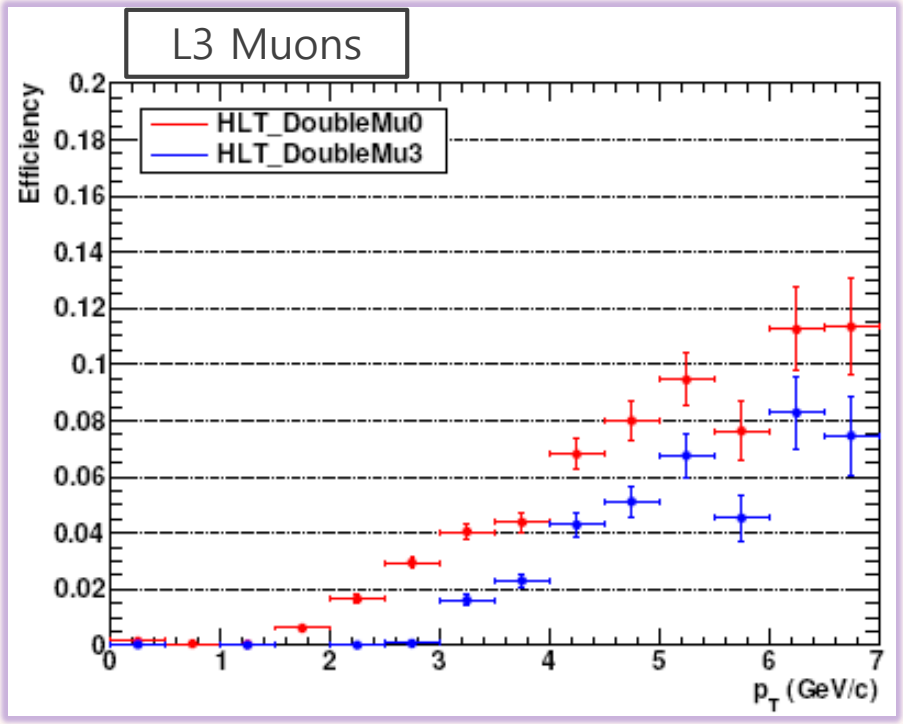


Muons in the forward region can be survived more!!

Trigger Eff. : Muon

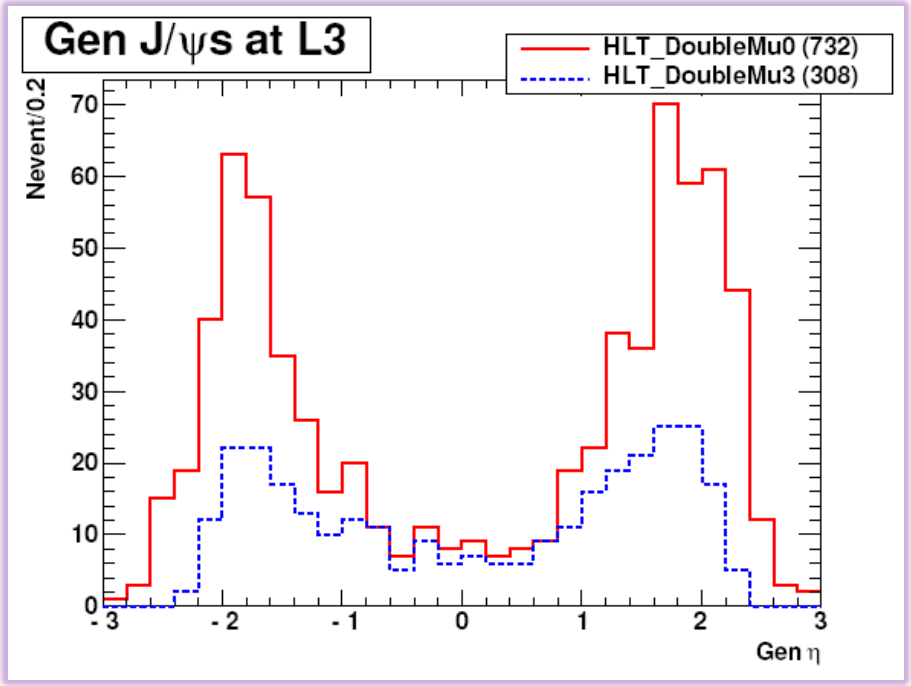
$$\varepsilon_{\mu}^{Trig} = \frac{N_{\mu}^{Trig}}{N_{\mu}^{Gen} \cdot Geometrical\ \ Acceptance}$$

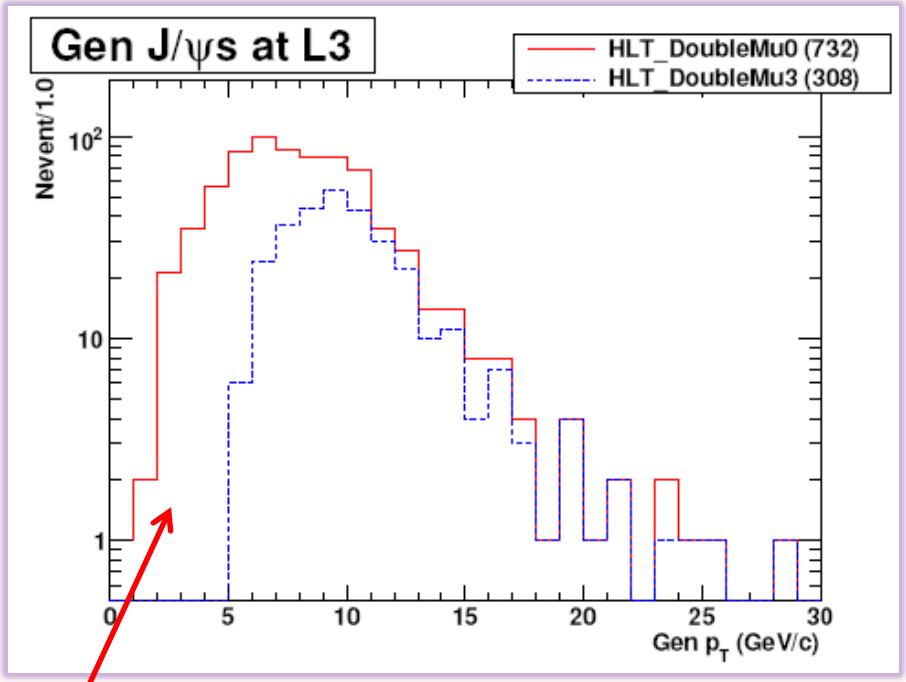




Triggered J/ψs

- CMS default (HLT_DoubleMu3) vs. new setting (HLT_DoubleMu0)

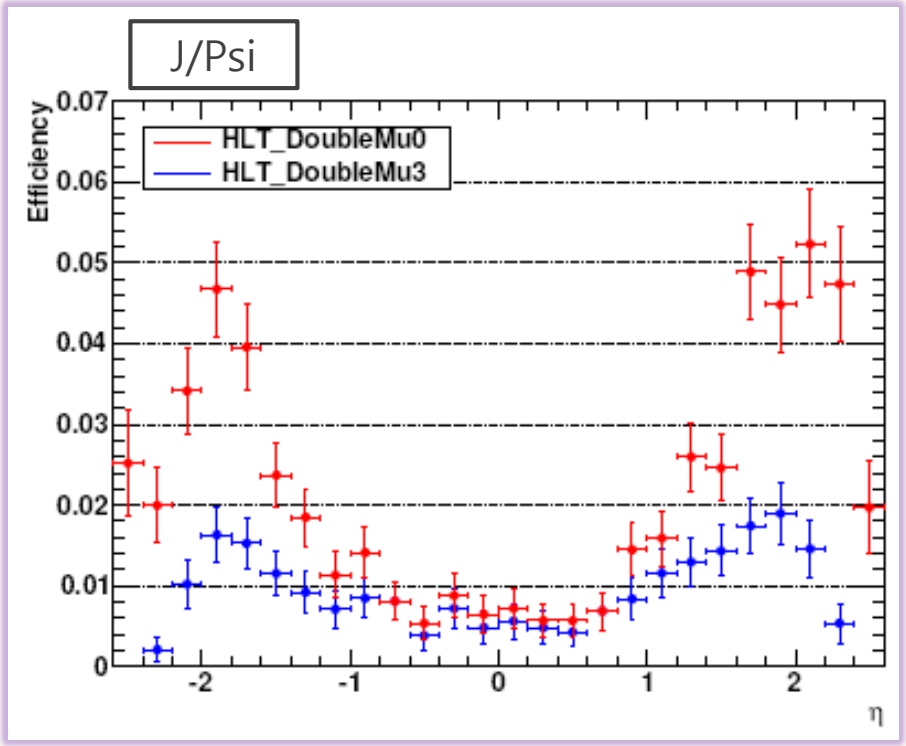


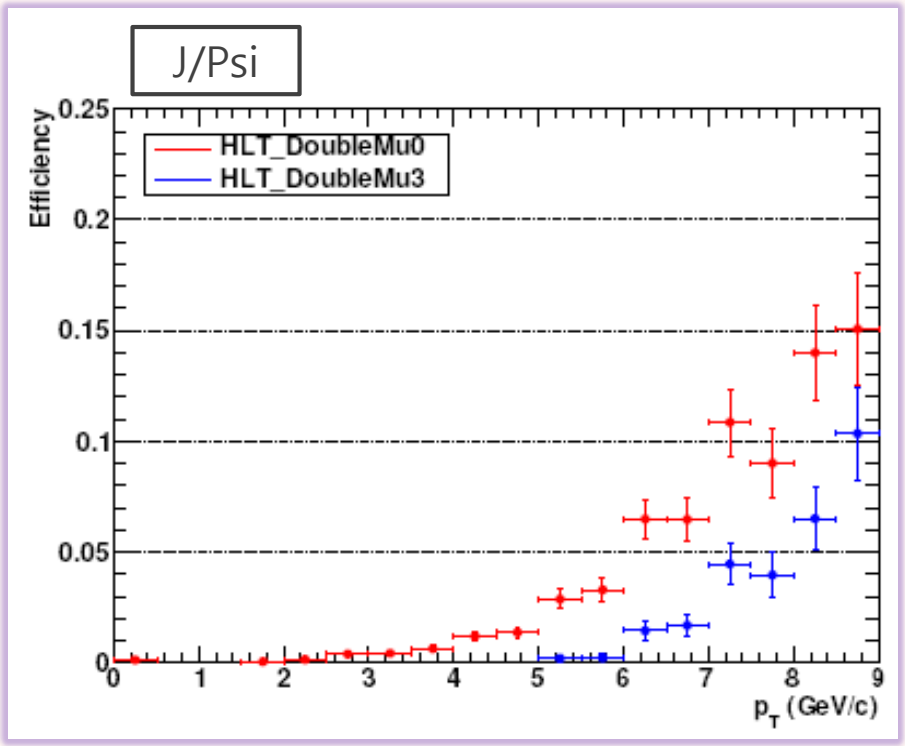


We expect low-p_T J/ψs (< 7 GeV/c) will be triggered by using HLT_DoubleMu0.

Trigger Eff. : J/ψ

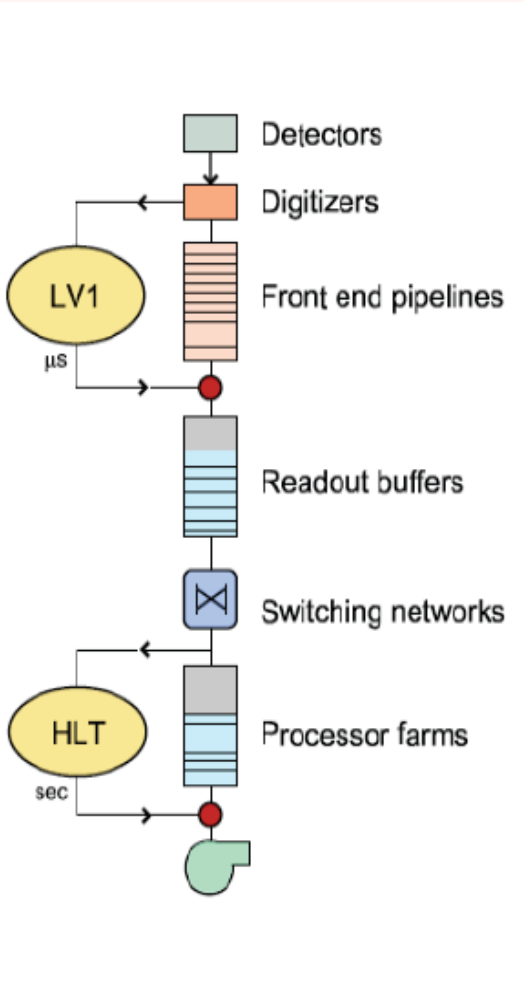
$$\varepsilon_{J/\psi}^{Trig} = \frac{N_{J/\psi}^{Trig}}{N_{J/\psi}^{Gen} \cdot Geometrical\ \ Acceptance}$$





Trigger Rates and Statistics

Pb+Pb vs. p+p Trigger



Level 1 Trigger

- **Uses custom hardware**
- **Muon chamber + calorimeter information**

Level-1	Pb+Pb(5 TeV)	p+p(14 TeV)
Collision rate	3kHz(8kHz peak)	1GHz
Event rate	3kHz(8kHz peak)	40MHz
Output bandwidth	100 GByte/sec	100 GByte/sec
Rejection	none	99.7%

High Level Trigger

- **Full event information available**
- **Run "offline" algorithms**

High Level Trigger	Pb+Pb(5 TeV)	p+p (14 TeV)
Input event rate	3kHz(8kHz peak)	100kHz
Output bandwidth	225 MByte/sec	225 MByte/sec
Output rate	10-100Hz	150Hz
Rejection	97-99.7%	99.85%

Muon Trig. Menu (8E29)

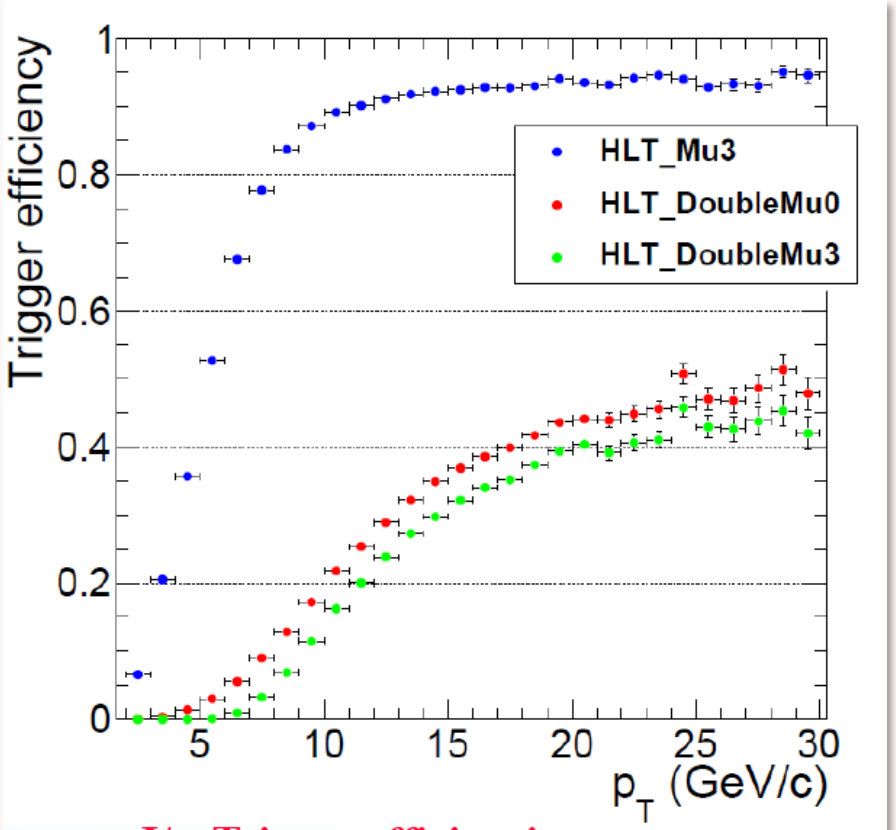
Muons triggers	L1 seeds	L1 prescale	HLT prescale	L1 rate	HLT rate	Cum. rate	Cum. BW	Trigger Type
HLT_L1MuOpen	L1_SingleMuOpen OR L1_SingleMu0	1, 1	10	TBD	10.81 ± 0.26 Hz	51.79 Hz	7.77 MB/s	Monitoring
HLT_L1Mu	L1_SingleMu7 OR L1_DoubleMu3	1, 1	5	TBD	2.19 ± 0.12 Hz	53.72 Hz	8.06 MB/s	Monitoring
HLT_L1Mu20	L1_SingleMu20	1	1	1.17 ± 0.08 Hz	1.17 ± 0.08 Hz	54.52 Hz	8.18 MB/s	Physics
HLT_L2Mu9	L1_SingleMu7	1	1	9.27 ± 0.24 Hz	1.37 ± 0.09 Hz	55.15 Hz	8.27 MB/s	Physics
HLT_L2Mu11	L1_SingleMu7	1	1	9.27 ± 0.24 Hz	0.81 ± 0.07 Hz	55.15 Hz	8.27 MB/s	Backup
HLT_Mu3	L1_SingleMuOpen OR L1_SingleMu0 OR L1_SingleMu3	1, 1, 1	1	TBD	22.83 ± 0.37 Hz	73.32 Hz	11.00 MB/s	Physics
HLT_Mu5	L1_SingleMu3	1	1	36.27 ± 0.47 Hz	7.53 ± 0.21 Hz	73.32 Hz	11.00 MB/s	Backup
HLT_Mu9	L1_SingleMu7	1	1	9.27 ± 0.24 Hz	0.95 ± 0.08 Hz	73.32 Hz	11.00 MB/s	Backup
HLT_DoubleMu0	L1_DoubleMuOpen	1	1	2.59 ± 0.13 Hz	0.43 ± 0.05 Hz	73.35 Hz	11.00 MB/s	Physics
HLT_DoubleMu3	L1_DoubleMu3	1	1	2.16 ± 0.11 Hz	0.17 ± 0.03 Hz	73.35 Hz	11.00 MB/s	Physics

Muon Trig. Menu (1E31)

Muons triggers	L1 seeds	L1 prescale	HLT prescale	L1 rate	HLT rate	Cum. rate	Cum. BW	Trigger Type
HLT_L1MuOpen	L1_SingleMuOpen OR L1_SingleMu0	1, 1	400	TBD	3.85 ± 0.57 Hz	29.87 Hz	4.48 MB/s	Monitoring
HLT_L1Mu	L1_SingleMu7 OR L1_DoubleMu3	1, 1	100	TBD	1.17 ± 0.31 Hz	31.04 Hz	4.66 MB/s	Monitoring
HLT_L1Mu20HQ	L1_SingleMu20	1	1	14.73 ± 1.11 Hz	1.42 ± 0.34 Hz	32.38 Hz	4.86 MB/s	Physics
HLT_L1Mu30	L1_SingleMu20	1	1	14.73 ± 1.11 Hz	10.21 ± 0.92 Hz	41.41 Hz	6.21 MB/s	Physics
HLT_L2Mu11	L1_SingleMu7	1	1	115.87 ± 3.11 Hz	10.37 ± 0.93 Hz	47.69 Hz	7.15 MB/s	Physics
HLT_Mu5	L1_SingleMu3	20	1	24.10 ± 1.42 Hz	4.27 ± 0.60 Hz	51.71 Hz	7.76 MB/s	Monitoring
HLT_Mu9	L1_SingleMu7	1	1	115.87 ± 3.11 Hz	11.96 ± 1.00 Hz	56.81 Hz	8.52 MB/s	Physics
HLT_Mu11	L1_SingleMu7	1	1	115.87 ± 3.11 Hz	5.86 ± 0.70 Hz	56.81 Hz	8.52 MB/s	Backup
HLT_Mu15	L1_SingleMu10	1	1	60.07 ± 2.24 Hz	1.76 ± 0.38 Hz	56.81 Hz	8.52 MB/s	Backup
HLT_DoubleMu0	L1_DoubleMuOpen	1	1	32.63 ± 1.65 Hz	5.77 ± 0.69 Hz	61.91 Hz	9.29 MB/s	Physics
HLT_DoubleMu3	L1_DoubleMu3	1	1	27.02 ± 1.50 Hz	2.26 ± 0.43 Hz	61.91 Hz	9.29 MB/s	Physics

J/ψ Triggger Efficiency

- HLT_DoubleMu0 is available since CMSSW_3_X_X:
  - Without p_T requirement on muons.
- Comparing to DoubleMu3, DoubleMu0 could highly enlarge the statistics at low-p_T.
- No prescale for 8E29 and 1E31.



J/ψ Trigger efficiencies vs. p_T

Quarkonia Workshop, Sep. 12-13 2009

Expected Statistics in p+p

Month	Comment	Turn around time	Energy [TeV]	Max number bunches	Protons/Bunch	% nom. intensity	Min beta*	Peak Luminosity $cm^{-2}s^{-1}$	Integrated Luminosity
1	Beam commissioning								First collisions
2	Pilot physics, partial squeeze, gentle increase in bunch intensity, avaialbility low	Long	3.5	43	3×10^{10}		4 m	8.6×10^{29}	100 - 200 nb^{-1}
3		5	3.5	43	5×10^{10}		4 m	2.4×10^{30}	~1 pb^{-1}
4		5	3.5	156	5×10^{10}	2.5	2 m	1.7×10^{31}	~9 pb^{-1}
5a	No crossing angle - could at this stage push intensity see 5b	5	3.5	156	7×10^{10}	3.4	2 m	3.4×10^{31}	~18 pb^{-1}
5b	No crossing angle - squeezing to beta* = 1m at this stage would double these lumi numbers (and the pile-up)	5	3.5	156	10×10^{10}	4.8	2 m	6.9×10^{31}	~36 pb^{-1}

Expected yields per pb^{-1} with DoubleMu3 at 10 TeV:

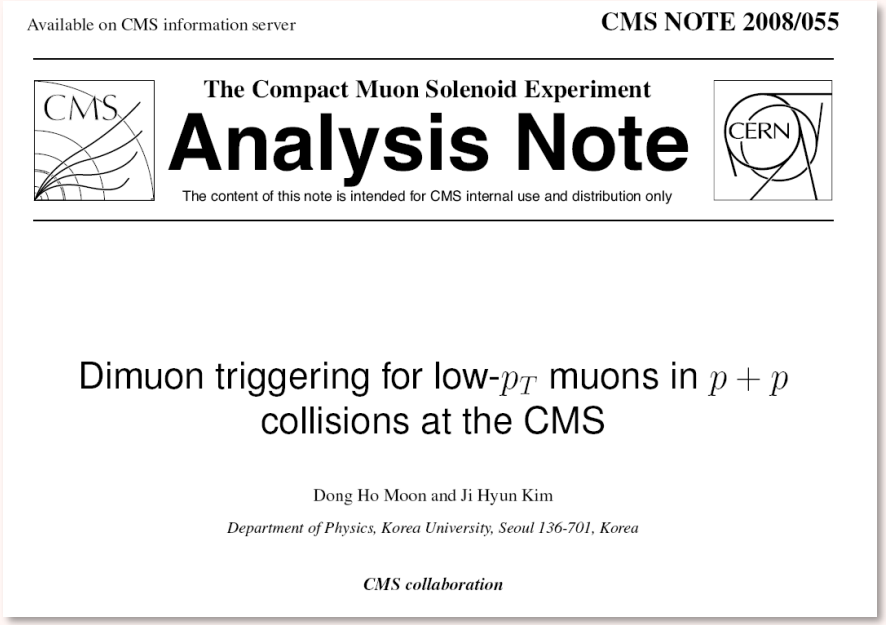
- ~25000 J/ψ
- ~6000 b → J/ψ
- ~10000 Upsilon
- ~175 B → J/ψK
- ~100 B → J/ψK*

"With an instantaneous luminosity of just ~1e30, in one month CMS will trigger and reconstruct tens of thousands of quarkonia events and hundreds of exclusive B decays."

CMS Physics Week, Bologna, Sep. 7-11 2009

Conclusion

- Removing p_T cut certainly shows better performance for triggering low-p_T muons than default dimuon trigger setting .
- New setting of dimuon trigger algorithm was designed for HI collisions, but will be also used in p+p.
- Estimated trigger rate is acceptable level for p+p startup run.


Available on CMS information server

CMS NOTE 2008/055

The Compact Muon Solenoid Experiment

Analysis Note

The content of this note is intended for CMS internal use and distribution only

Dimuon triggering for low-p_T muons in $p + p$ collisions at the CMS

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CMS collaboration

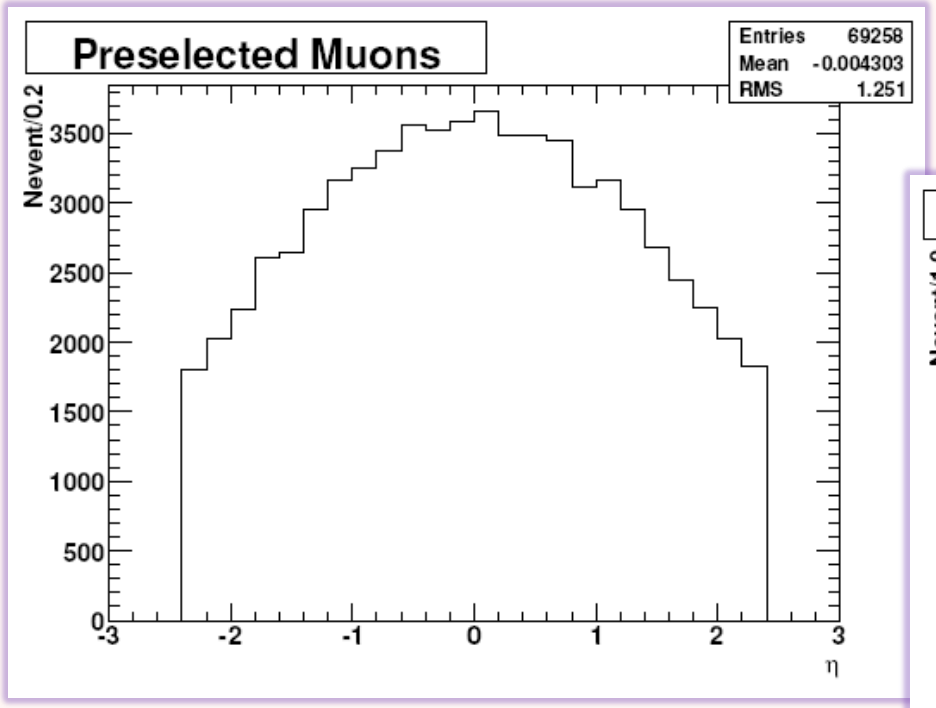
Backup Slides

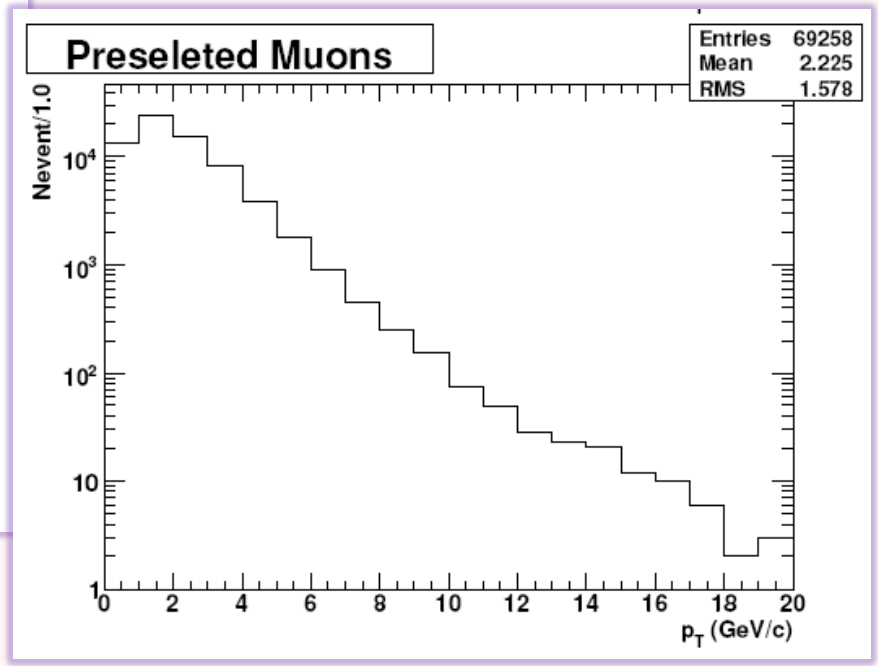
PYTHIA Conditions : J/ψ

- Version : 6.416
- $\sqrt{s}$ = 10 TeV
- Some essential parameters
  - MSEL = 61 : Quarkonium production via color-singlet and color-octet mechanism of NRQCD
  - MSTP(51) = 10042 : PDF CTEQ6L1
  - MSTP(142) = 2 : Quarkonia cross section damping for reweighting
  - PARP(82) = 1.8387 : p_T cutoff for multiparton interactions
  - PARP(141) ~ PARP(150) : Tuning NRQCD matrix elements from the CDF data
  - BRAT(859) = 1.000 : J/psi->mu+mu-

Dimuon η Acceptance

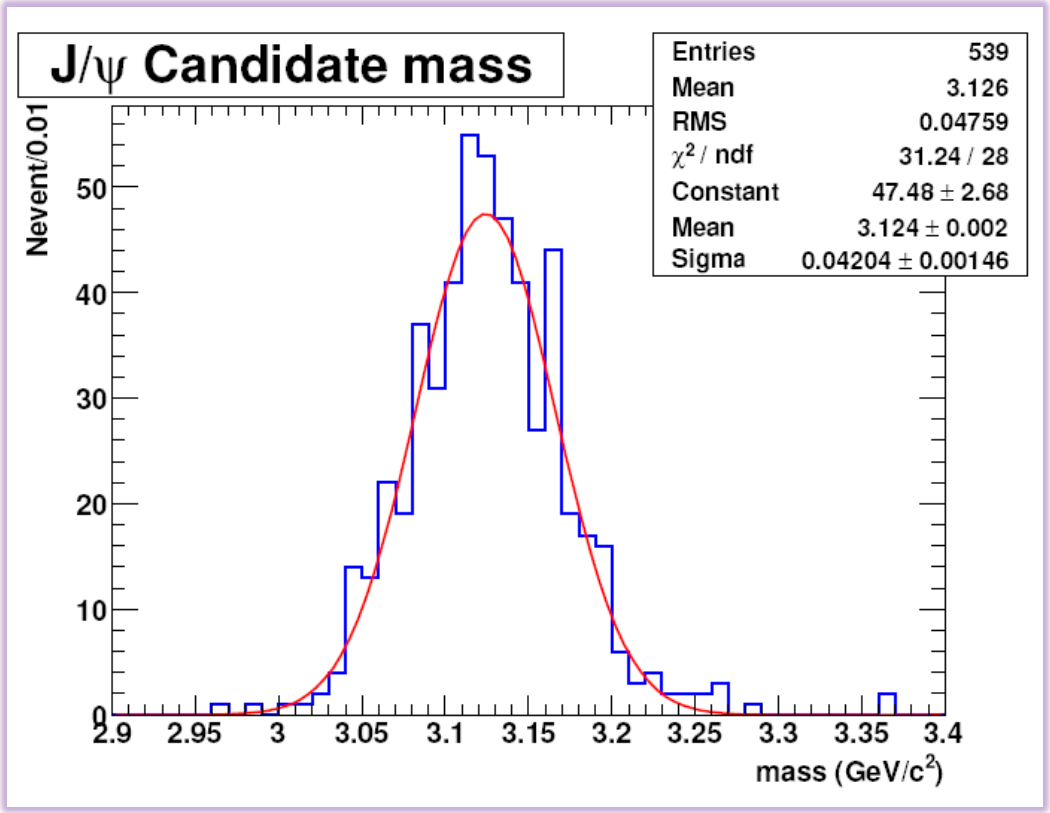
- Preselected μ+μ- from J/ψ decay ($|\eta^{\mu}| < 2.4$)





$$\eta \ Acceptance = \frac{34629}{79004} = 0.44$$

Dimuon Mass Spectrum



- By using MuonTrackAssociatorbyHits.
- Matching muon SimTrack and RecTrack with Purity = 1.
- Ensuring 2 reconstructed muons have decayed from the same vertex.

$$Purity = \frac{N_{SharedHitsBetweenSim\&Rec}}{N_{ValidHitsOfRec}}$$