

# Study of $J/\psi$ $R_{AA}$ at $\sqrt{s_{NN}}=5.36$ TeV in PbPb system at LHC using ALICE detector



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# Outline



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- **Physics Motivation**
- **ALICE Detector**
- **Datasets and Analysis procedures**
- **Results**
- **Summary and outlook**

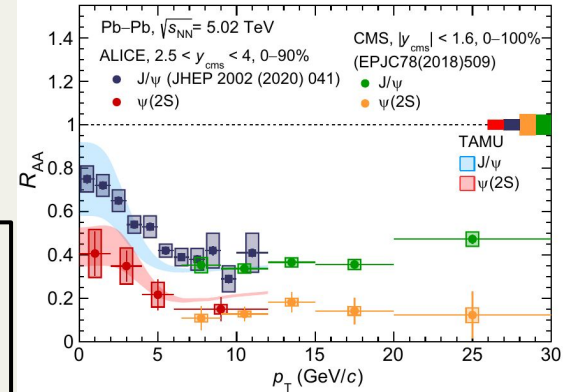
# Physics Motivation

## Properties of $J/\psi$ meson

- Mass =  $3.096 \text{ MeV}/c^2$
- Width =  $93 \text{ KeV}/c^2$
- Lifetime =  $7.2 \times 10^{-21} \text{ sec}$
- Quark content:  $c\bar{c}$
- Spin = 1
- Decay channel = Leptonic ( $J/\psi \rightarrow e^+e^-, \mu^+\mu^-$ ), hadronic

## Advantage to study QGP through $J/\psi$

- Resonance particle of high mass produced at very early stage of heavy ion collision
- Give hints to screening of QCD color charge in deconfined medium like Debye screening in QED
- Thermometer of QGP
- QGP lifetime and dynamics by suppression and regeneration
- $R_{AA}$ , elliptic flow ( $v_2$ ) measures the degree of thermalization and quantifies the transport coefficients



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# What is different from RUN2?

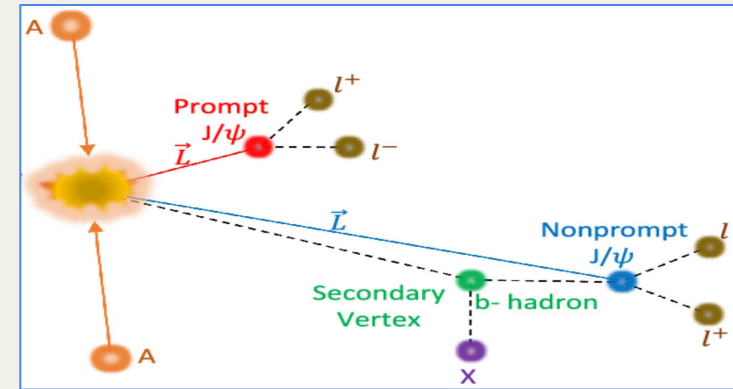
- With upgraded ALICE setup at RUN3, data was taken at energy  $\sqrt{s_{NN}} = 5.36$  TeV at higher luminosity than RUN2
- Muon Forward Tracker(MFT) is introduced in front of the hadron absorber

- **Effect:**

**Prompt and Non-prompt separation:** separation between primary and secondary vertex will be possible. Only the produced system information will be convoluted in the prompt one.

**Improved precision for new physics opportunities:**

High precision measurements over extended kinematic domain can reveal some deviations from the existing model.

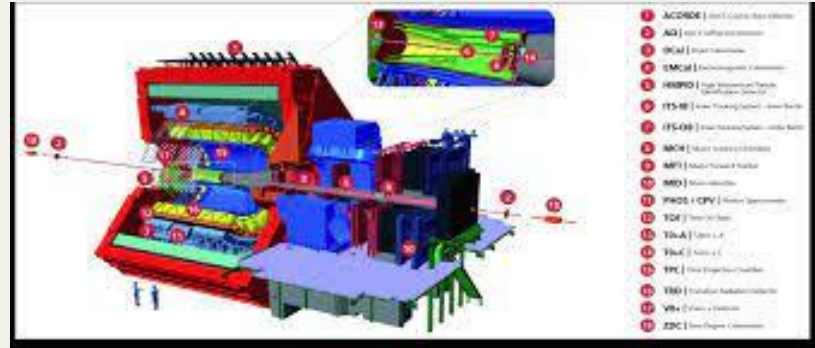




ALICE

# ALICE detector to detect $J/\psi$ :

- In ALICE  $J/\psi$  detected via dilepton  
 $|y| < 0.9$ :  $J/\psi \longrightarrow e^-e^+$  (BR: 6%)  
 $2.5 < y < 4.0$ :  $J/\psi \longrightarrow \mu^-\mu^+$  (BR: 6%)
- For this analysis only three detectors have been used: **ITS, FTO, MUON SPECTROMETER**

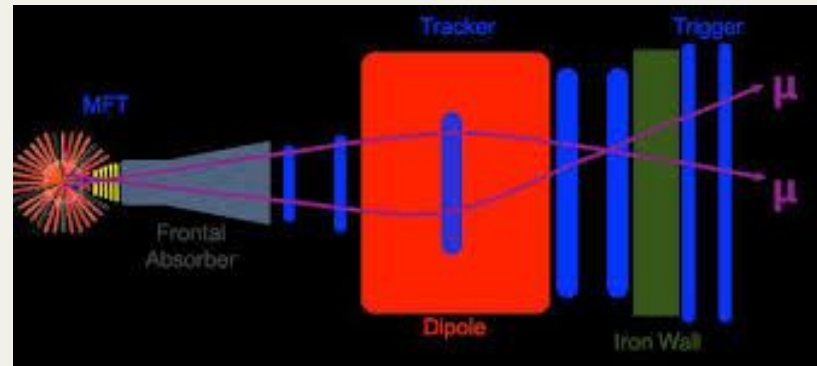


**ITS:** Tracking and vertexing

**FTO:** Centrality estimator

**Muon spectrometer:** oppositely charge muon tracking

- Muon spectrometer has (four+one) components:
- MFT, Hadron absorber, Dipole magnet(0.7 T), tracking chamber(MWPC), trigger system(RPC)

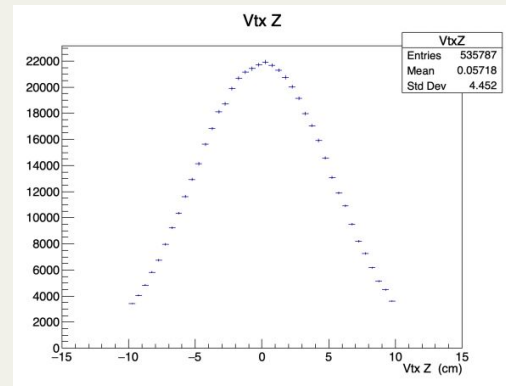


# Datasets

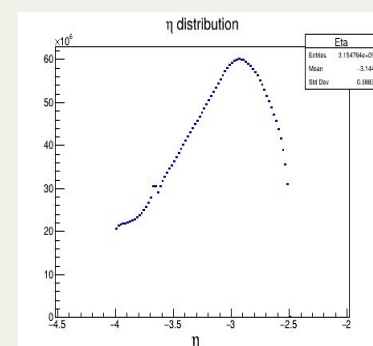
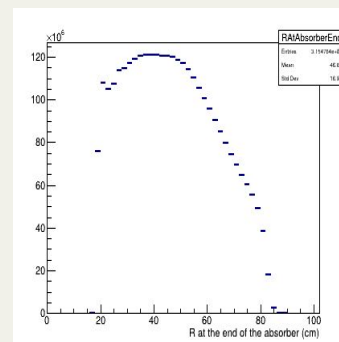
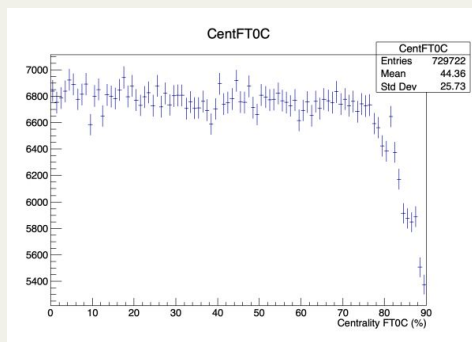


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- Dataset: DQ\_LHC23\_PbPb\_pass4
- The total no of events: ~11 Billion
- Event selection: eventStandardSel8PbPbQuality  
 $|V_z| < 10$  cm
- Centrality estimator: FT0C5, Vtx2
- Track selection cut:
  - single muon  $p_T > 0.7$  GeV
  - $17.6 < \text{RatEndAbs} < 89.5$  cm
  - $-4 < \eta < -2.5$
  - $10\sigma$  pDCA cut
  - $0 < \chi^2_{\text{MchMid}} < 1e^6$



- Dimuon Selection:
  - $2.5 < y < 4$
  - Pair charge equal zero
  - $0 < p_T < 20$  GeV/c



# Analysis procedure

## Analysis goal

$$R_{AA}^i = \frac{N_{J/\psi}^i}{\text{BR}_{J/\psi \rightarrow \mu^+ \mu^-} \times (A \times \epsilon)^i \times N_{\text{MB}}^i \times T_{AA}^i \times \sigma_{J/\psi}^{\text{pp}}}$$

- **Centrality:** [0-20],[20-40],[40-60],[60-90]
- **$p_T$ :** [0-2],[2-4],[4-6],[6-12]
- **Signal extraction:** Invariant mass fit

$$M = \sqrt{(p_{1\mu} + p_{2\mu})^2}$$

- **Background subtraction:** ME method (Depth=5)

$$F = \frac{\int_{m_1}^{m_2} R \sqrt{N_{\text{raw}}^{++} N_{\text{raw}}^{--}} dm}{\int_{m_1}^{m_2} N_{\text{mix}}^{+-} dm}$$

$$R = \frac{N_{\text{Mix}}^{+-}}{2\sqrt{N_{\text{Mix}}^{++} N_{\text{Mix}}^{--}}}$$

- **Fitfunction:** Double crystal ball or NA60(signal)+ Pol4Exp or VWG
- Mass of  $J/\psi$  is kept free

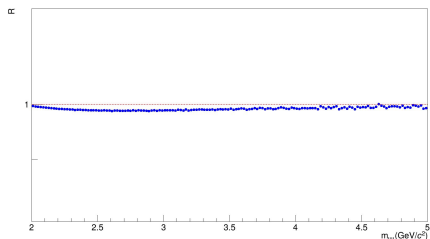
$$M_{\psi(2S)} = M_{J/\psi} + (M_{\psi(2S)}^{\text{pdg}} - M_{J/\psi}^{\text{pdg}})$$

- Systematic uncertainty .....
- Get the cross section of  $J/\psi$  at energy

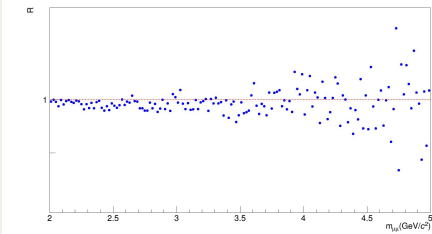
$$\sigma_{\psi(2S)} = \sigma_{J/\psi}^{\text{fit}} \cdot \frac{\sigma_{\psi(2S)}^{\text{MC}}}{\sigma_{J/\psi}^{\text{MC}}}$$

# Mixed event control plot

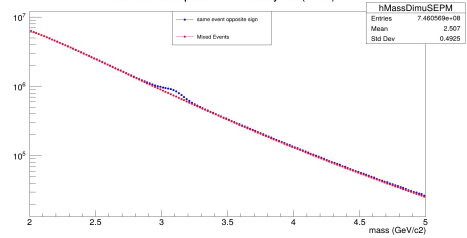
Event Mixing in centrality bin(0-20%)



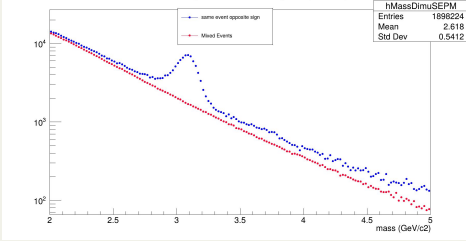
Event Mixing in centrality bin(60-90%)



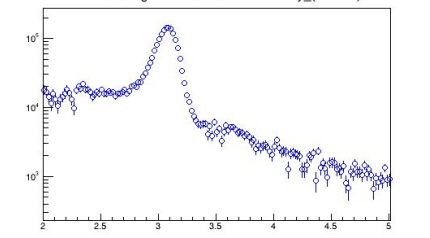
Normalized spectra Centrality bin(0-20%)



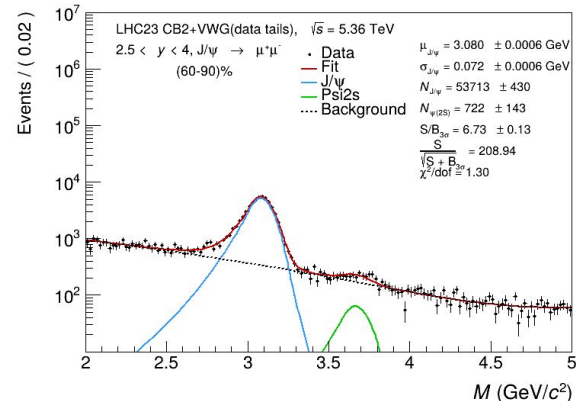
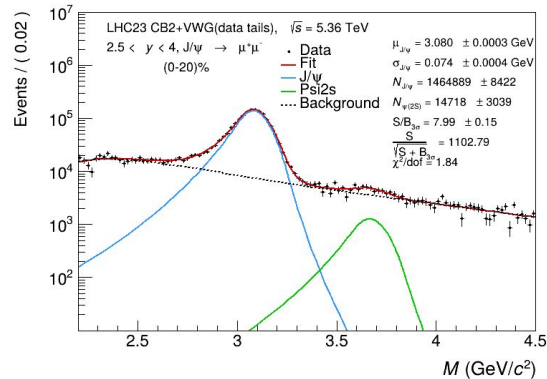
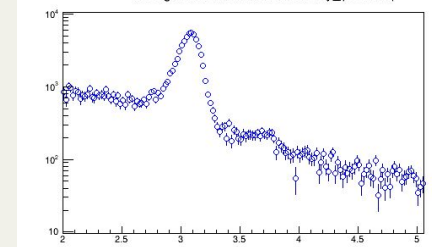
Normalized spectra Centrality bin(60-90%)



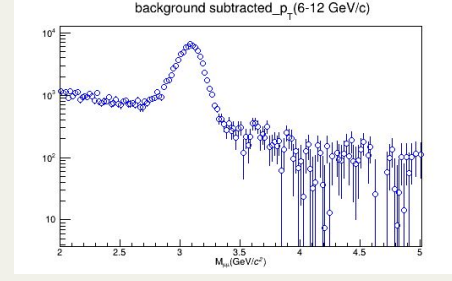
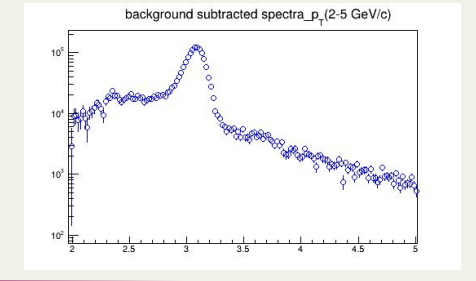
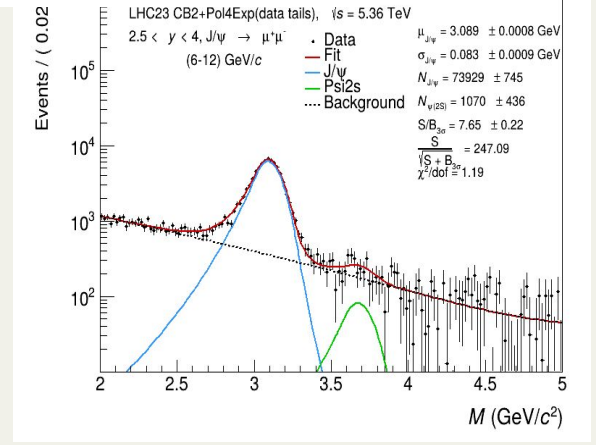
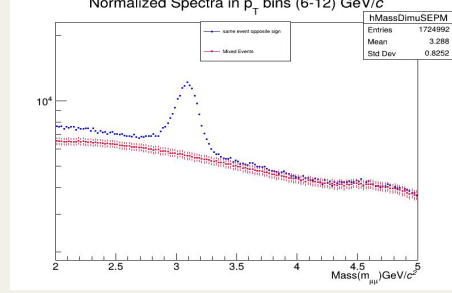
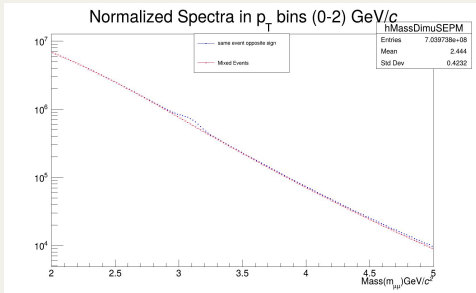
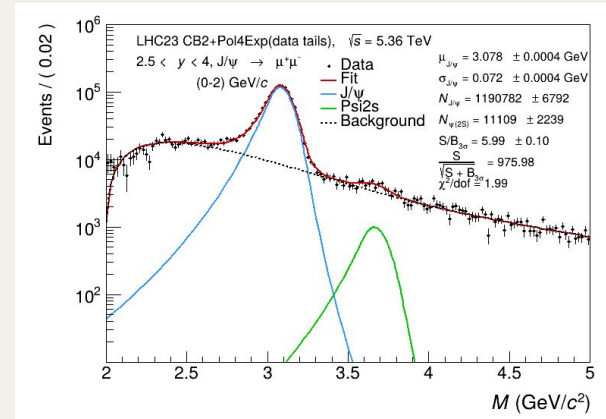
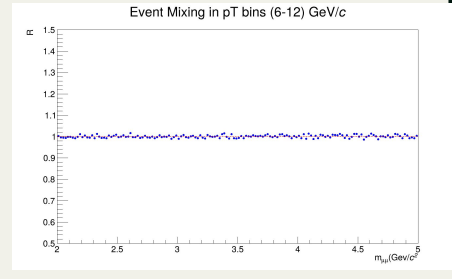
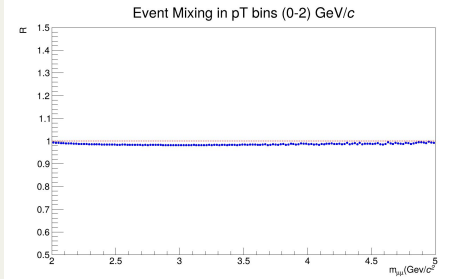
background subtracted Centrality\_(0-20 %)



background subtracted Centrality\_(60-90%)



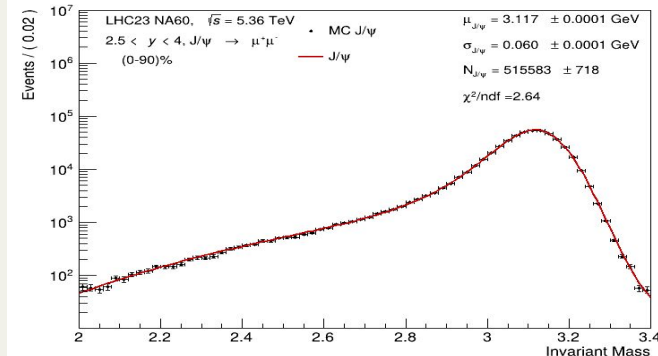
# Mixed event control plot



# Systematics in yield..

• Signal function	Double crystal ball(CB2)
	NA60 function
• Background	Pol4Exp
	VWG
• Tails	Run3 data tune
	MC data tune
• Mix Event range	$m_1=2, m_2=5$
	$m_1=2, m_2=8$
• Fit Range	2 - 5
	2.2 - 4.5
• MC width	1.05
	1.1

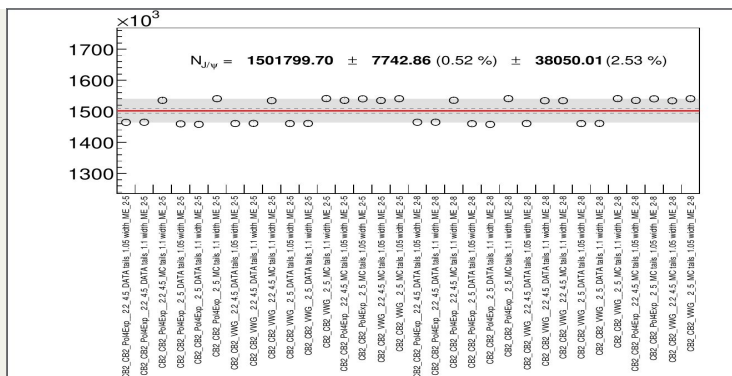
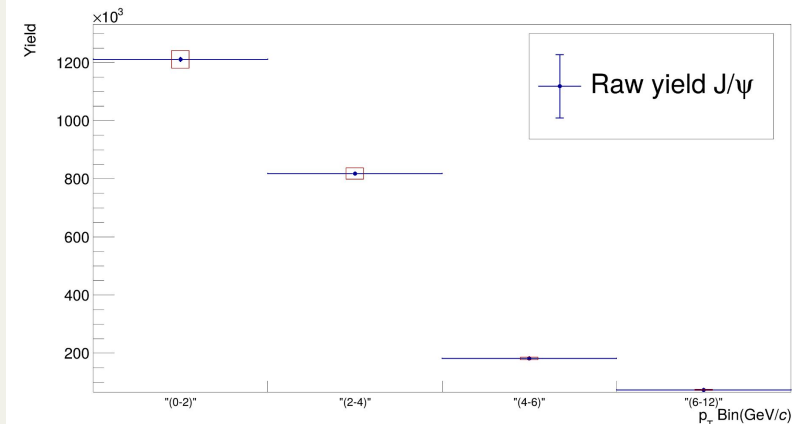
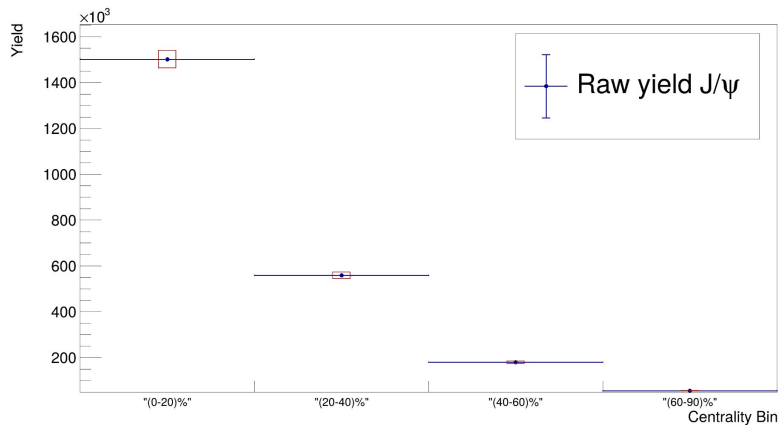
- Total 48 sets of combination would be estimated as a part of systematics for yield extraction in each  $p_T$  and centrality bin
- For the time being I showed here with 32 sets of combination
- NA60 function with MC data tune has been done and would be completed soon.





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# Yield in different centrality and $p_T$ bin





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# Summary & outlook

## Summary

- After tuning the RUN3 data and MC data, tails parameters were extracted
- Raw yields for the  $J/\psi$  and  $\psi(2s)$  are extracted in each centrality and  $p_T$  bin
- Systematics in yield extraction is almost done ....
- MC production had been done recently

## Outlook

- correction in differential yields will be done just after acceptance  $\times$  efficiency correction
- Then analysis will be done using latest pass5 data and LHC24 data will be added
- For the reference of pp , reference run was taken in 2024 and reconstruction is going on centrally
- As soon as the dataset will available  $J/\psi$  cross section will be calculated at the same energy in pp
- $R_{AA}^{ALICE}$  will be calculated and compared with some theoretical model as well as the previous result of ALICE



*Thank You*



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# Backup slide:

crystal ball function:

$$f(x; N, \bar{x}, \sigma, t_1, t_2, p_1, p_2) = N \cdot \begin{cases} A \cdot (B-t)^{-p_1} & , t \leq t_1 \\ \exp\left(-\frac{1}{2}t^2\right) & , t_1 < t < t_2 \\ C \cdot (D+t)^{-p_2} & , t \geq t_2 \end{cases}$$

$$t = \frac{x-\bar{x}}{\sigma}$$
$$A = \left(\frac{p_1}{|t_1|}\right)^{p_1} \cdot \exp\left(-\frac{|t_1|^2}{2}\right)$$
$$B = \frac{p_1}{|t_1|} - |t_1|$$
$$C = \left(\frac{p_2}{|t_2|}\right)^{p_2} \cdot \exp\left(-\frac{|t_2|^2}{2}\right)$$
$$D = \frac{p_2}{|t_2|} - |t_2|$$

Variable width gaussian:

$$f(x; N, \bar{x}, A, B) = N \cdot \exp\left(-\frac{(x-\bar{x})^2}{2\sigma_{VWG}^2}\right),$$

$$\sigma_{VWG} = A + B \cdot \frac{(x-\bar{x})}{\bar{x}}$$

NA60 function

$$f(x; N, \bar{x}, \sigma, t_1, t_2, p_1, \dots, p_6) = N \cdot \exp\left(-\frac{1}{2}\left(\frac{t}{t_0}\right)^2\right),$$

$$t = \frac{x-\bar{x}}{\sigma}$$

$$t_0 = \begin{cases} 1 + (p_1(t_1 - t))^{p_2 - p_3\sqrt{t_1 - t}} & , t \leq t_1 \\ 1 & , t_1 < t < t_2 \\ 1 + (p_4(t - t_2))^{p_5 - p_6\sqrt{t - t_2}} & , t \geq t_2 \end{cases}$$

Pol4Exp

$$f(x; N, p_0, \dots, p_n) = N \cdot \exp(p_0 x) (p_1 + p_2 x + \dots + p_n x^{n-1})$$

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