Inclusive J/ψ production

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Introduction

- Analysis already done - "*Measurement of the production cross-section of J/ψ and ψ(2S) mesons at high transverse momentum in pp collisions at $\sqrt{s}$=13TeV with the ATLAS detector*"*, main analyzer - Bakar Chargeishvili.
  - J/ψ and ψ(2S) cross-sections were measured;
  - Prompt and non-prompt contributions were separated;
  - Analysis was performed in high-pT bins, starting from 60 GeV reaching 360 GeV region for J/ψ.
- We continue to study inclusive onia production at lower pT range (8 < pT < 60 GeV).
- Low pt dimuon trigger is used: HLT_2mu4_bJpsimumu_noL2

* CONF Note approved in Autumn, 2019: https://cds.cern.ch/record/2693955

Inclusive J/ψ production studies at low pt

- Used data: 2015 13 TeV data samples;
- Trigger: HLT_2mu4_bJpsimumu_noL2 (available unprescaled for 2015 data);
  - Integrated Luminosity about 2.6 fb^{-1}, but can reach the lowest J/ψ pT;
  - Sample extends up to ~150 GeV, but with low statistics;
- Acceptance cut: (pT1>4 && pT2>4);
- Use unweighted events for yield determination, with average per-bin efficiency and acceptance corrections applied at the next step.

Fit function modification

The fit model is described by a sum of the following terms:

$$PDF(m,\tau) = \sum_{i=1}^{7} \kappa_i f_i(m) \cdot (h_i(\tau) \otimes R(\tau)) \cdot C_i(m,\tau). \qquad (4)$$

where m is the dimuon invariant mass, while τ is the pseudo-proper lifetime of the dimuon. $R(\tau)$ in eq. (4) is the function describing the experimental resolution in pseudo-proper lifetime. It is parameterised as a weighted sum of three Gaussians, with $\sigma_2 = 2\sigma_1$ and $\sigma_3 = 3\sigma_1$, where the relative weights and σ_1 are free parameters.

i	Type	P/NP	$f_i(m)$	$h_i(\tau)$	$C_i(m,\tau)$
1	J/ψ	P	$\omega G_1(m) + (1-\omega)CB_1(m)$	$\delta(\tau)$	$BV(m,\tau,\rho)$
2	J/ψ	NP	$\omega G_1(m) + (1-\omega)CB_1(m)$	$E_1(\tau)$	1
3	$\psi(2S)$	P	$\omega G_2(m) + (1-\omega)CB_2(m)$	$\delta(\tau)$	1
4	$\psi(2S)$	NP	$\omega G_2(m) + (1-\omega)CB_2(m)$	$E_2(\tau)$	1
5	Bkg	P	B	$\delta(\tau)$	1
6	Bkg	NP	$E_4(m)$	$E_5(\tau)$	1
7	Bkg	NP	$E_6(m)$	$E_7(\|\tau\|)$	1

Notation	Function
G	Gaussian
CB	Crystal Ball
E	Exponential
B	Bernstein polynomials
BV	Correlation term of the bivariate Gaussian dist.

Table 1: Parameterisation of the fit model. Notation is explained in the text and in the table on the right.

$\omega * CB_1(S_1 * \sigma_1) + (1-\omega) * G_2(S_2 * \sigma_1)$

ω and S_2 are fit parameters – determined using MC fits

$\omega * E(\tau 1) + (1-\omega) * E(A * \tau 1)$

A – free fit parameter

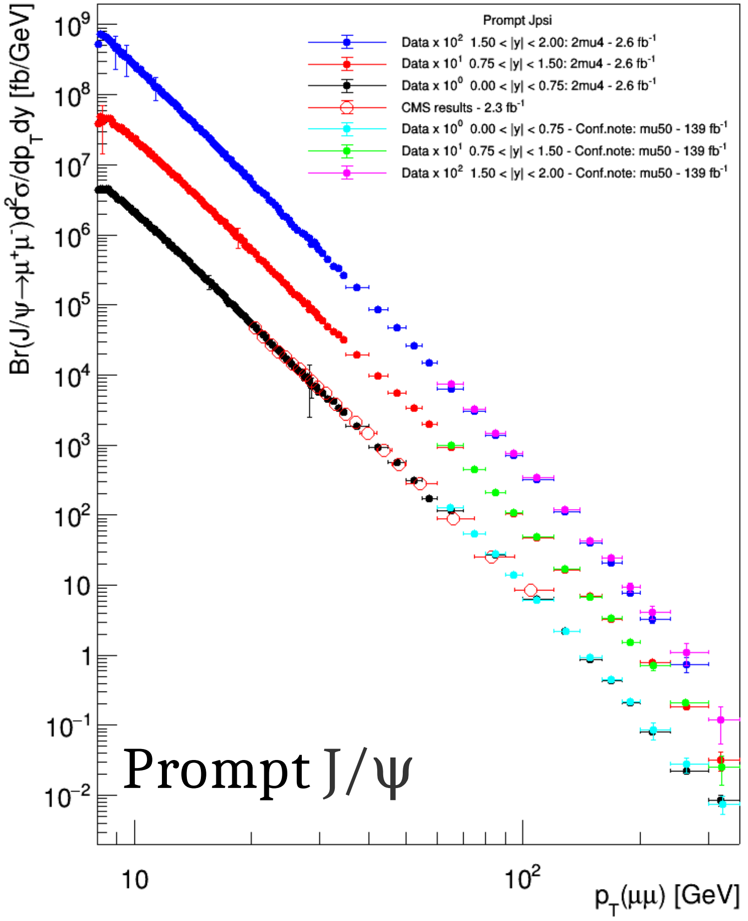
- Fit yields are corrected with acceptance, trigger efficiency and reconstruction weights.

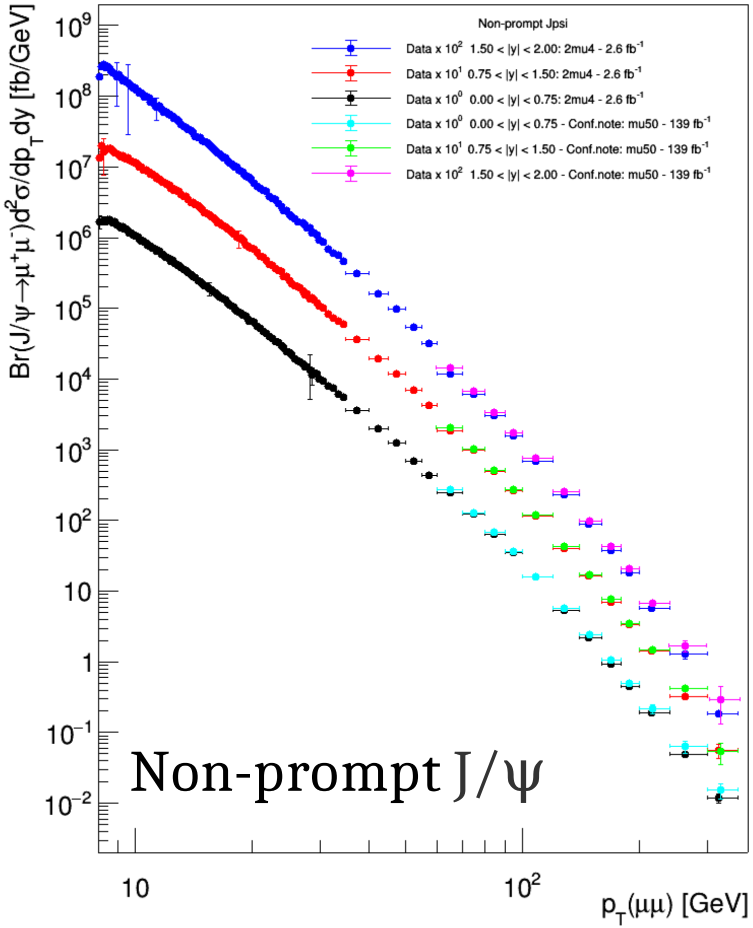
From yields to cross-section

For low pt:

- σ = yield / (E_{trig} * E_{trigSF} * E_{acc} * E_{reco} * Δp_T * ΔY * L)
- $E_{trig} = N_{trig}/N_{reco}$
- $E_{reco} = N_{reco}/N_{truth}$
- E_{acc} = Mean acceptance efficiency for the specific bin
- E_{trigSF} = trigger SF for each trigger muon.

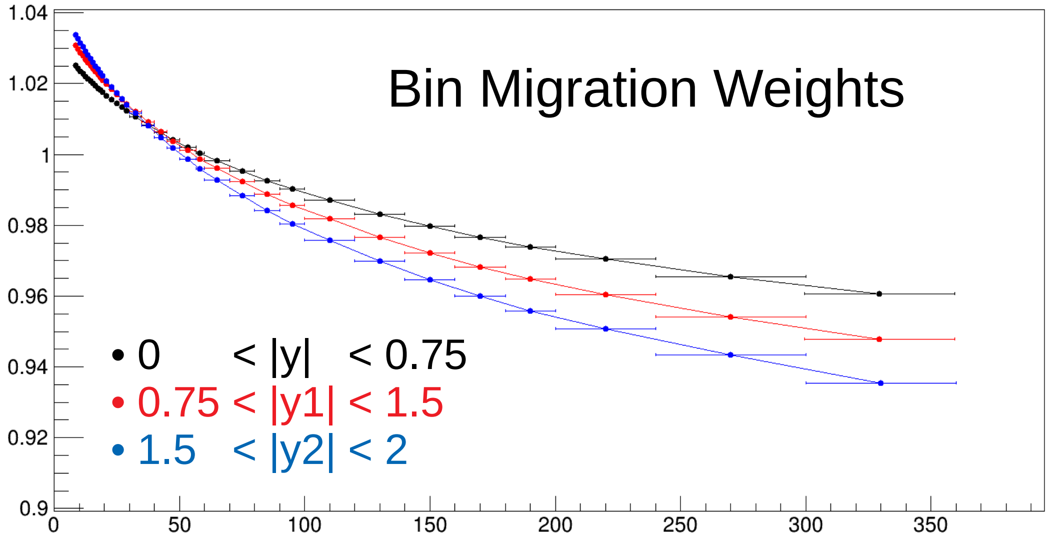
J/ψ cross-section





Bin migration correction factors

- Depending on the definition of the efficiency we may need bin migration correction factors.
- The finite resolution of the detector causes the bin migration effect and appropriate correction should be applied on the cross-section.
- The procedure was developed for the preliminary ConfNote in python and now was re-implemented in c++, with obtaining the same results.



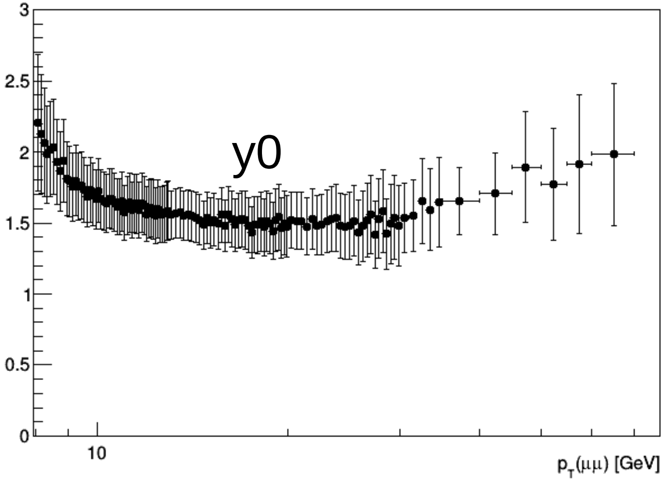
Next few steps:

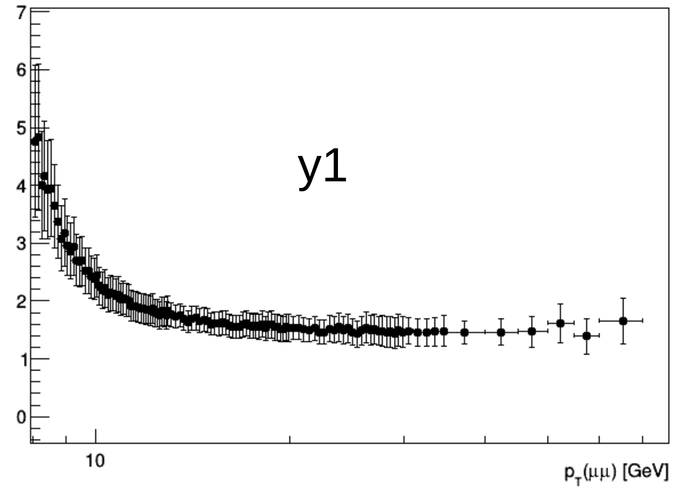
- Fits need attention in the first few p_T bins;
- Determine the trigger and reconstruction efficiency weights for $\psi(2S)$;
- Study systematics.

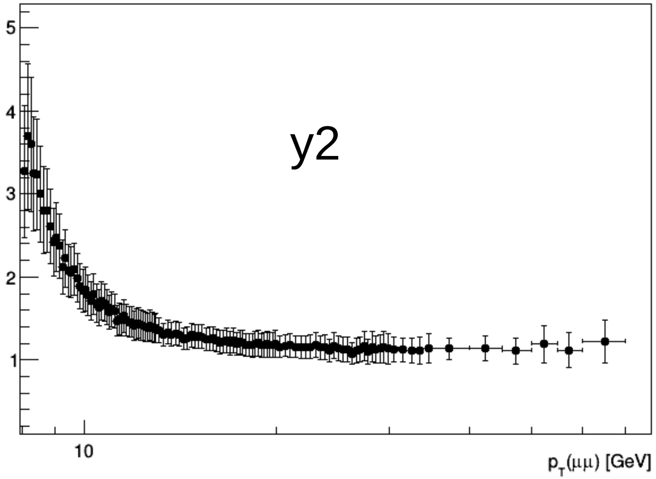
Thank you!

Backup

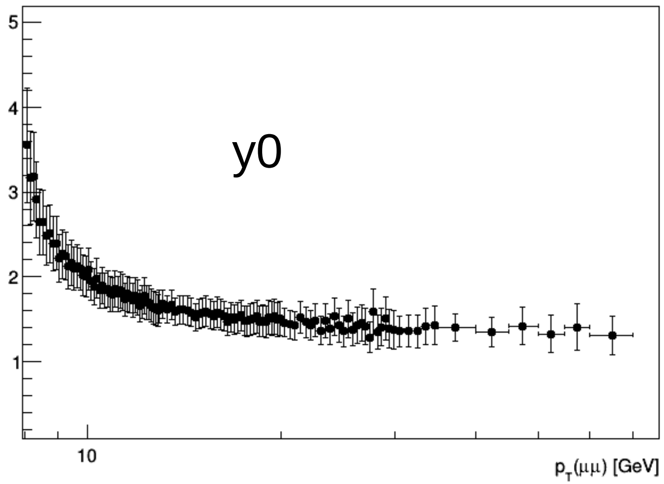
1/E_trig


y0
3
2.5
2
1.5
1
0.5
0
10
pT(μμ) [GeV]

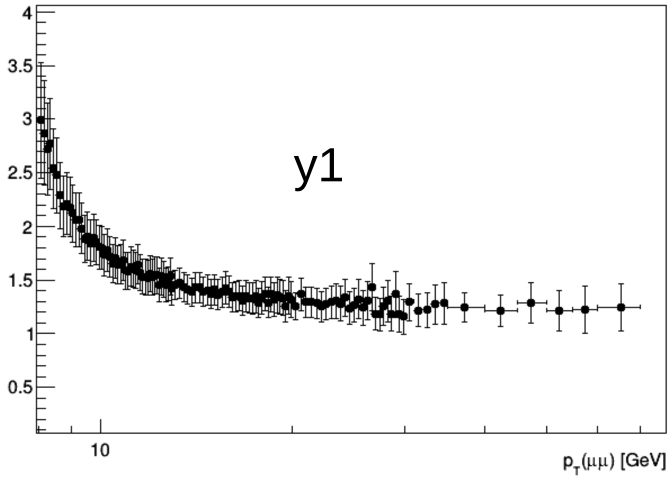

y1
7
6
5
4
3
2
1
0
10
pT(μμ) [GeV]


y2
5
4
3
2
1
10
pT(μμ) [GeV]

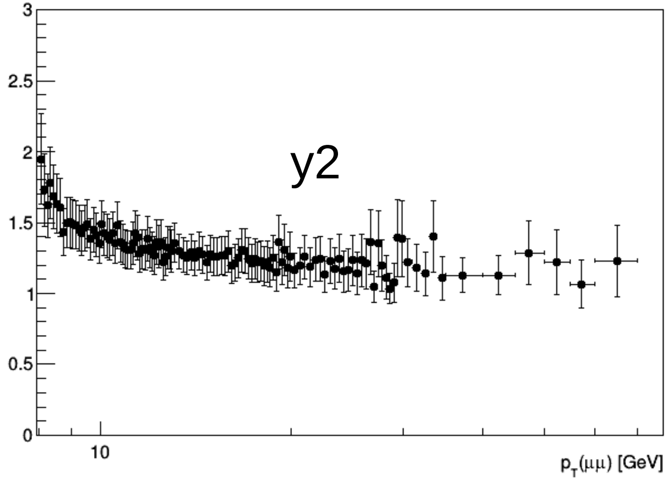
1/E_reco



y0
5
4
3
2
1
10
$p_T(\mu\mu)$ [GeV]

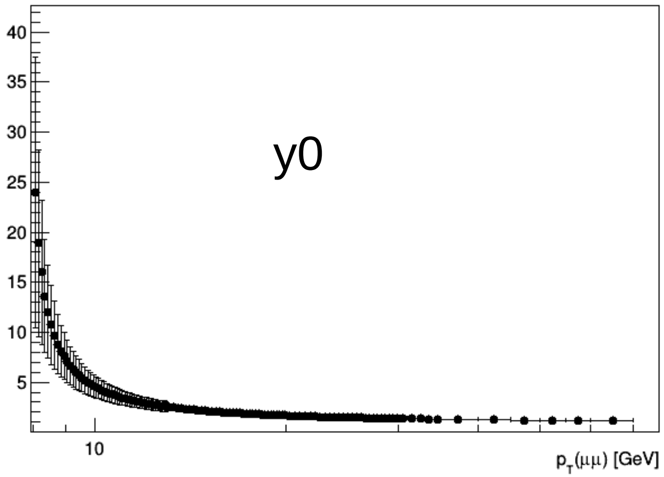


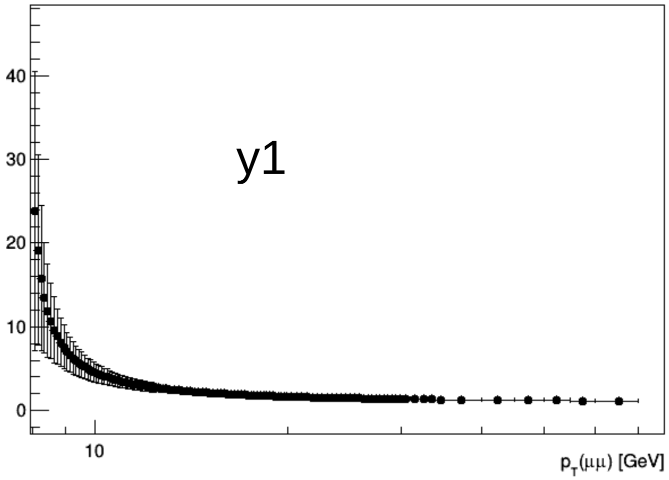
y1
4
3.5
3
2.5
2
1.5
1
0.5
10
$p_T(\mu\mu)$ [GeV]

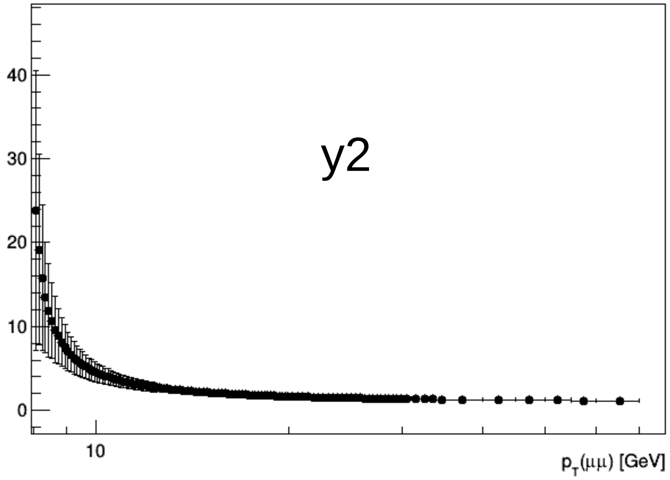


y2
3
2.5
2
1.5
1
0.5
0
10
$p_T(\mu\mu)$ [GeV]

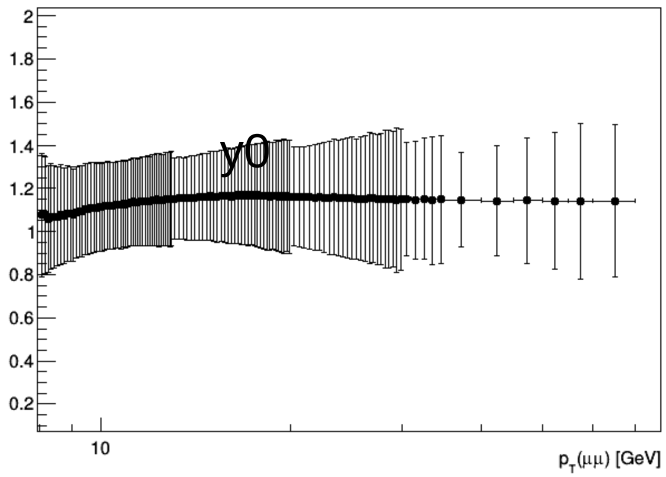
1/E_acc

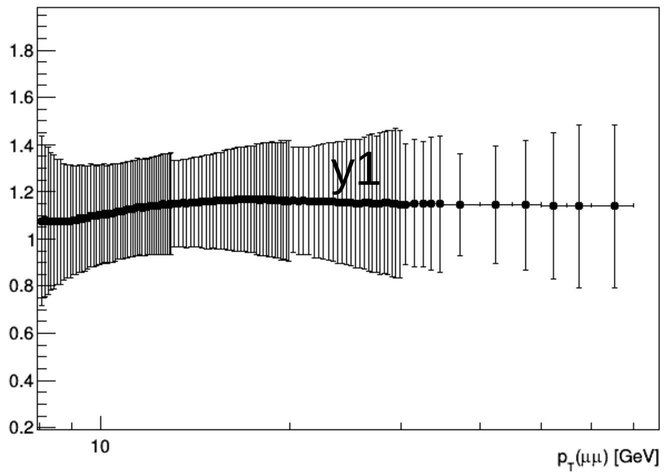

y0
40
35
30
25
20
15
10
5
10
p_T(μμ) [GeV]

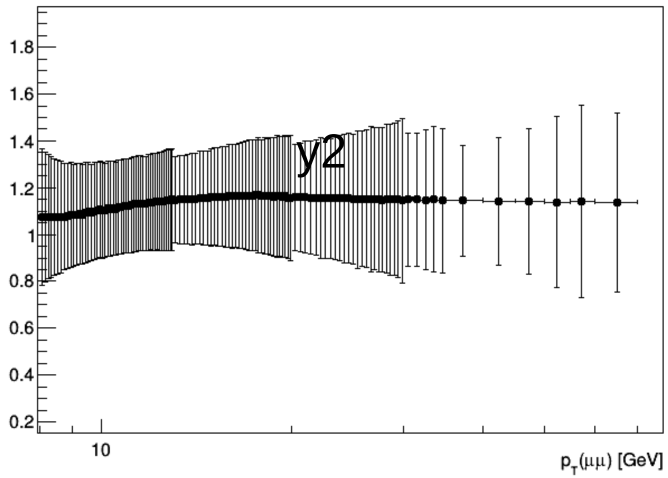

y1
40
30
20
10
0
10
p_T(μμ) [GeV]


y2
40
30
20
10
0
10
p_T(μμ) [GeV]

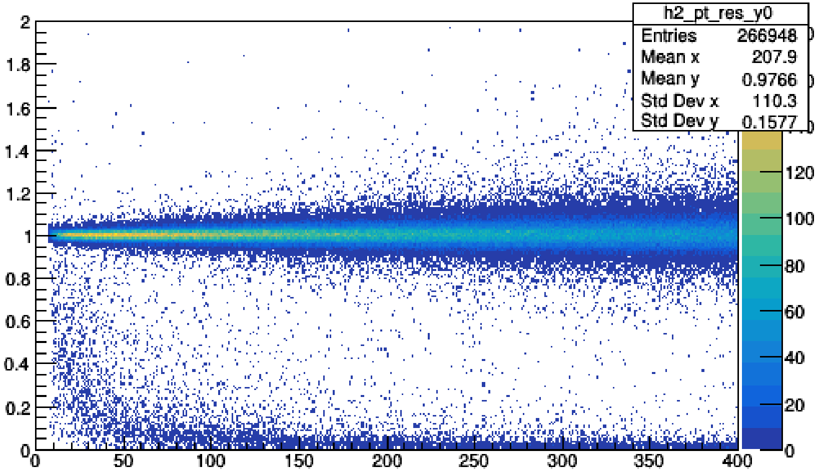
1/E_trigSF


y0
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
10
$p_T(\mu\mu)$ [GeV]

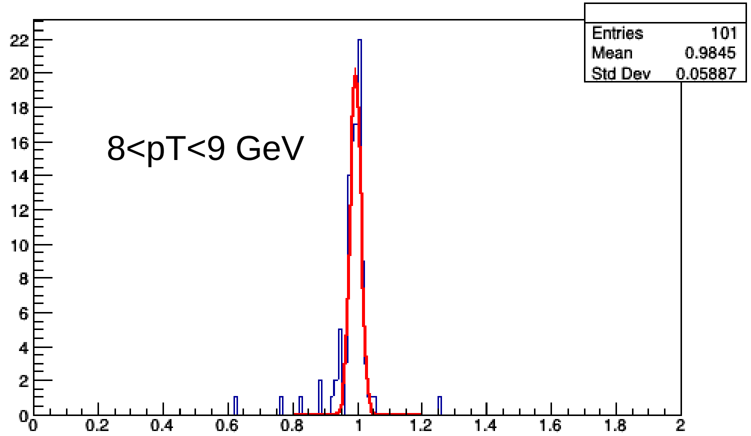

y1
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
10
$p_T(\mu\mu)$ [GeV]

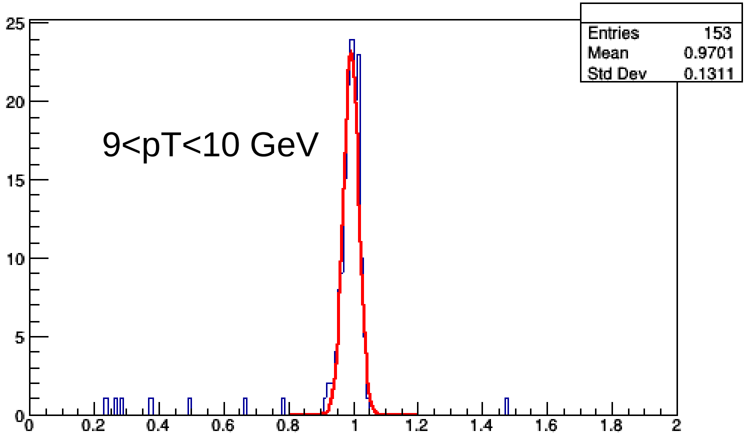

y2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
10
$p_T(\mu\mu)$ [GeV]

pT_reco/pT_truth vs pT_truth



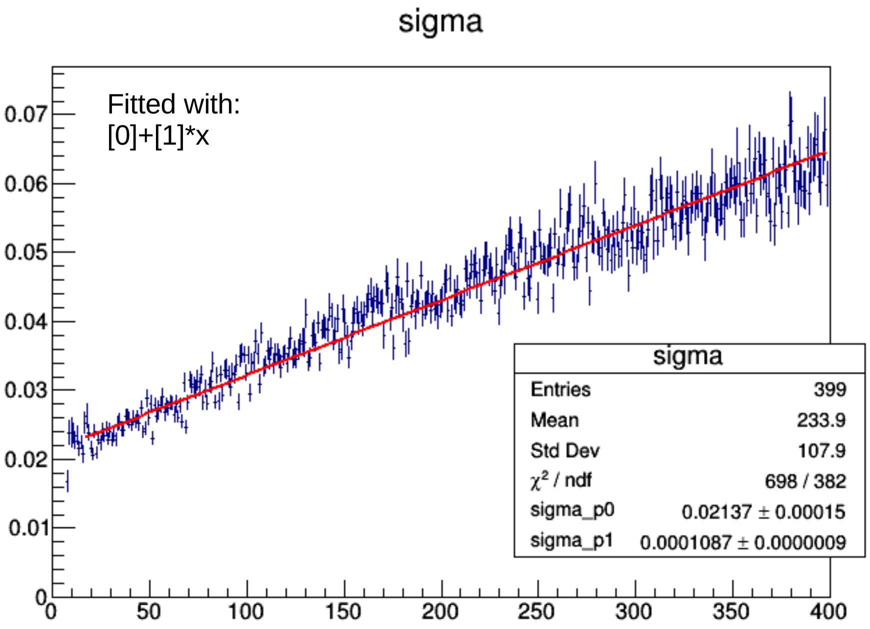
examples of projections

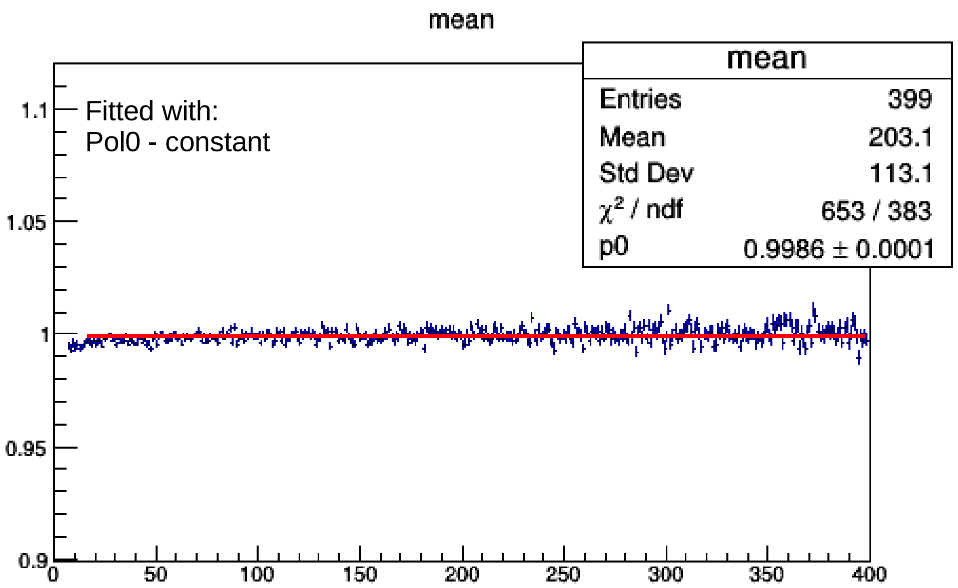




400 1GeV wide projections were produced. These distributions are fitted using Gaussian in the range [0.6−1.4].

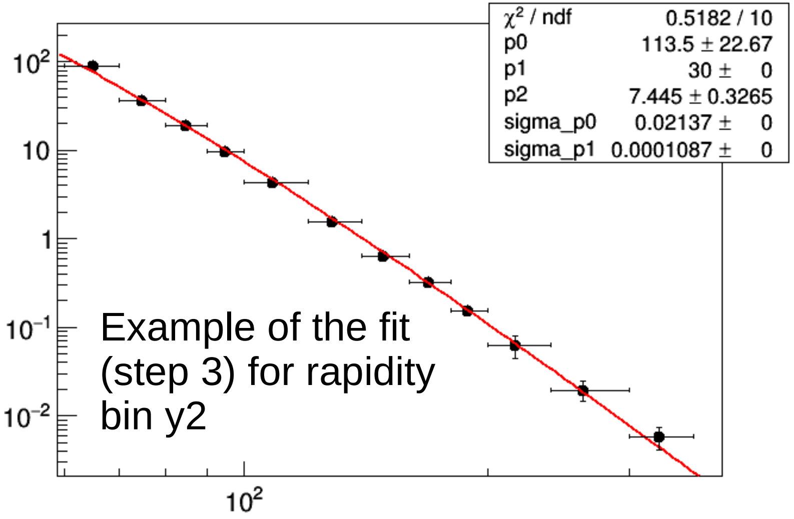
Sigma and mean fits





The extracted distribution of means are fitted using const function (mean=1) and for modeling the sigma-pT dependence the linear approximation is used.

Cross-section fitting



Steps:

1. Fitted with:
TF1("**f0**","[0]*pow((([1]+60) /([1]+x)) ,[2])");

2. Fitted with:
TF1("f1_pre","0.01126*[0]*pow((([1]+60)/([1]+x*(1-2.85696*f_sigma))),[2])+0.22208*[0]*pow((([1]+60)/([1]+x*(1-1.35562*f_sigma))),[2])+0.53332*[0]*pow((([1]+60)/([1]+x)),[2])+ 0.22208*[0]*pow((([1]+60)/([1]+x*(1+1.35562*f_sigma))),[2]) +0.01126*[0]*pow((([1]+60)/([1]+x*(1+2.85696*f_sigma))),[2])");

f_sigma is function obtained for sigma distribution fitting:
f_sigma = TF1("f0","[0]*pow((([1]+60) /([1]+x)) ,[2])");

3. for
TF1("**f1**","[0]*pow((([1]+60)/([1]+x)),[2])");
parameters 0,1,2 are obtained and fixed from previous fit.

4. In chosen pT bins (range), functions f1 (step 3) and f0 (step 1) are integrated and ratio (I2/I1) is the correction factor – BinMigration weight, for a given pT bin.

BPHY1 MC

- Lower p_T range has much higher statistics, and more complex lineshapes.
- Allows moving to narrower binning, but additional shapes in the fit model still necessary.
- Too many parameters make fits unstable In order to fine-tune signal shapes, same fits were applied to signal-only MC distributions (mix of pp and bb)
- Aim to fix some parameters once fits move to data, with parameter varied at systematics stage

MC: *bb*→*J/ψ*->*μμ* DAODs used:

1. mc16_13TeV.300203.Pythia8BPhotospp_A14_CTEQ6L1_bb_Jpsimu3p5mu3p5.deriv.DAOD_BPHY1.e4889_a875_r9364_p3648

MC: *pp*→*J/ψ*->*μμ* DAODs used:

1. mc16_13TeV.300013.Pythia8B_A14_CTEQ6L1_pp_Jpsimu3p5mu3p5.deriv.DAOD_BPHY1.e7703_a875_r9364_p4277
2. mc16_13TeV.300000.Pythia8BPhotospp_A14_CTEQ6L1_pp_Jpsimu2p5mu2p5.deriv.DAOD_BPHY1.e3989_s3126_r9364_p4277

Description of MC produced (*pp*→*J/ψ*):

- Derivation format: BPHY1
- AthDerivation cache used: 21.2.105.0
- Production: unskimmed production