Summary of the New Muon Over-Smearing

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Outlook

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1. Why we need a new muon over-smearing method?
   - The high p_T tails not reproduced
2. What are the differences with the previous over-smearing method?
   - Double-gaussian
   - Lever arm
   - Momentum scale factor
   - New set of parameters
3. Results and conclusion
   - Over-smearing parameters
   - Conclusion and outlook

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Why we Need a New Muon Over-Smearing Method?

The Selection Used to Study High Pt Muons and the Result

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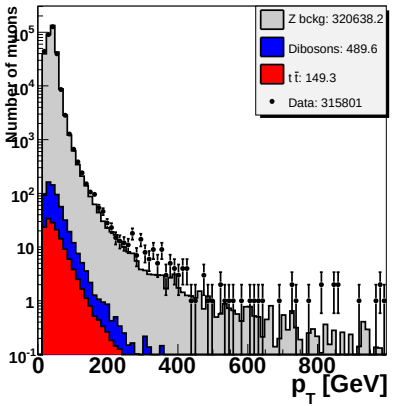
- At least **2** μ:
  - $p_T > 15$ GeV (by default p_T means central p_T)
  - $|\eta| < 2$
  - opposite charges
  - **Loose** quality
  - **Loose** track quality
  - **No** isolation cut
- At least 1 μ with $p_T > 200$ GeV



List of the High Pt Muon Studies

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These parameters has been studied:

- The track χ^2
- The track quality
- The track curvature error

} good track

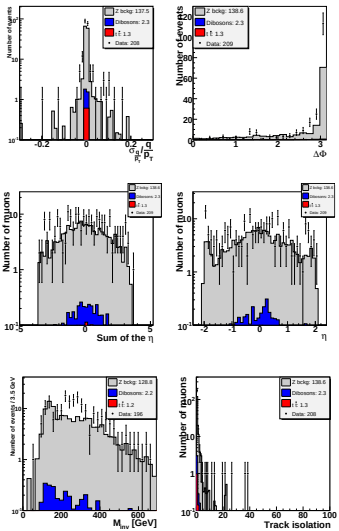
- The track isolation
- The calorimeter isolation

} good isolation

- The $\Delta\phi$
- The η
- The $\sum \eta$

} not cosmic

- The local p_T
- The resolution of the local p_T
- The invariant mass



Conclusion of the High Pt Muon Studies

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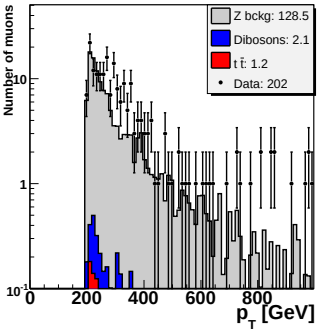
- These high p_T muons are not associated to fake tracks and do not come from cosmics rays
- These high p_T muons seem to come from miss-reconstructed Z muon events
- The tails are not well reproduced
- It has been studied that the resolution has changed with time (Z peak width varies with time)



Thus we need to:

1. reproduce the old smearing (in particular by using Alpgen Z MC) *which means that the oversmearing codes has been updated*
2. improve it by trying to take into account the tails and some effects of the detector (effects of the lever arm in the CFT)

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What Are the Differences With the Previous Over-Smearing Method?

The Previous Over-Smearing Method

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The aim:

smear the MC events in order to reproduce the data (cf. DØ note 5449)

The smearing formula:

$$\frac{q}{p_T} \to \frac{q}{p_T} + \underbrace{AG_1}_{\text{Resolution effect}} + \underbrace{\frac{B\sqrt{\cosh\eta}}{p_T}G_2}_{\text{Muliple scattering effects}}$$

G_1 and G_2 are two independent random numbers distributed according to a *Gaussian function* with a mean value of 0 and a width of 1.

A and B are the smearing parameters to be determined for different μ track types:

1. Both μ have at least one SMT hit and $|\eta_{\text{CFT}}| < 1.6$;
2. Both μ have at least one SMT hit but at least one has $|\eta_{\text{CFT}}| > 1.6$;
3. Only one μ has at least one SMT hit.

The New Parameters and Terms Added to the Over-Smearing Formula

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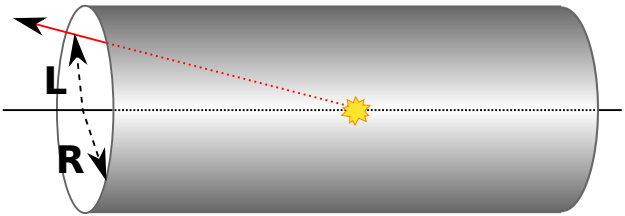
The second gaussian:

In order to fit the tails a second gaussian has been added. Two new over-smearing parameters have then be added: C and D.

Take into account the lever arm:

For tracks with $|\eta_{\text{CFT}}| > 1.6$ the CFT lever arm is lower than its radius. This leads to a track curvature less precise:



Thus the factor $\frac{R^2}{L^2}$ is multiplied to each over-smearing terms to take this effect into account by increasing the smearing of these tracks.

Take Into Account the Shift Between the J/ψ and Z Invariant Mass Mean Value Between Data and MC

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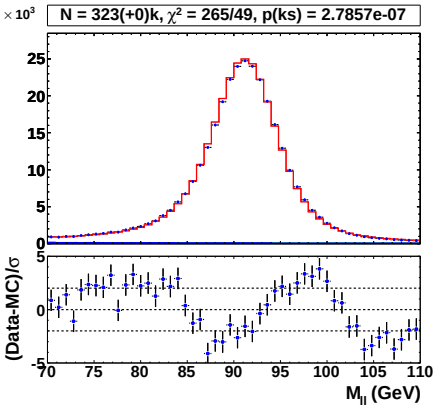

A shift is present between the data and MC mean value of the J/ψ and Z invariant mass peak:

- $\sim$ 12 MeV for J/ψ
- $\sim$ 300 MeV for Z

$\longleftarrow$ *Comparison between data and Monte Carlo from $Z,\gamma^* \rightarrow \mu^+\mu^-$ events by using the previous Monte Carlo corrections*

This shift is corrected by multiplying the curvature of the track by a *momentum scale factor*.

This scale is computed for each type of tracks.

Summary of the New Over-Smearing Method (1/2)

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The new over-smearing formula:

if $rnd > C$:

$$\frac{q}{p_T} \rightarrow (1+S) \times \left\{ \frac{q}{p_T} + \underbrace{AG_1 \times \frac{R^2_{\text{CFT}}}{L^2}}_{\text{Resolution effect}} + \underbrace{\frac{B\sqrt{\cosh\eta}}{p_T} G_2}_{\text{Multiple scattering effects}} \times \frac{R^2_{\text{CFT}}}{L^2} \right\}$$

else:

$$\frac{q}{p_T} \rightarrow (1+S) \times \left\{ \frac{q}{p_T} + DG_3 \times \frac{R^2_{\text{CFT}}}{L^2} + \frac{B\sqrt{\cosh\eta}}{p_T} G_2 \times \frac{R^2_{\text{CFT}}}{L^2} \right\}$$

- L is the radius of the outer layer of the CFT which got the last hit ;
- G_1, G_2 and G_3 are three independent random numbers distributed according to a *Gaussian function* with a mean value of 0 and a width of 1 ;
- rnd is a uniform random number in the range $[0; 1]$;
- A, B, C and D are the over-smearing parameters to be determined for different μ track types ($n_{\text{SMT}} \neq 0$; $n_{\text{SMT}} = 0$).

Summary of the New Over-Smearing Method (2/2)

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Different set of over-smearing parameters are available for:

- Run IIb1 only events (updated with the full Run IIb1 statistics) ;
- Run IIb2 only events (new) ;
- Mixed Run IIb1 – Run IIb2 only events (new) ;
- Single gaussian only (for new physics searches).

and will be available for:

- Run IIa ;
- Latest Monte Carlo version (p20.15).

This study has been done by using Z ALPGEN[1] p20.08.02 Monte Carlo events with higher data and Monte Carlo[2] statistics.

[1] Previously, PYTHIA was used
[2] In particular for the J/ψ Monte Carlo events

Overview of the Systematics Errors

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Systematics errors taken into account are:

- Switching from medium muon selection to *loose* muons ;
- Switching from medium track selection to *new medium* track selection ;
- Switching from medium track selection to *loose* track selection ;
- Using a tight p_T cut on the Z muon events (from 20 GeV to 25 GeV) ;
- Using a tight p_T cut on the J/ψ muon events (from 3 GeV to 3.5 GeV) ;
- Using the J/ψ invariant mass peak to compute the momentum scale factor rather than using the Z invariant mass peak;
- Using a larger invariant mass range around the Z peak on which the χ^2 used to determine the best over-smearing parameters is computed.

Comparison Between the Previous Over-Smearing Method and the New One

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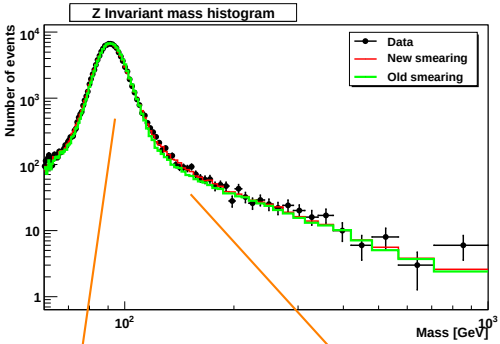

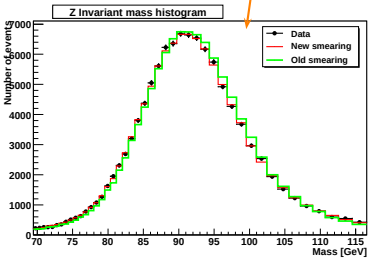

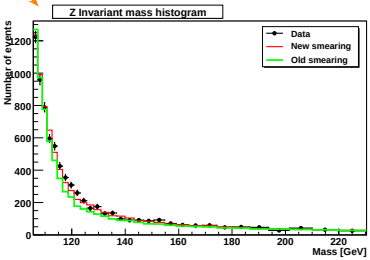

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Results and Conclusion of the New Muon Smearing

Final Results of the Over-Smearing Parameters

		Type	A ($\times 10^{-3}$)	B ($\times 10^{-2}$)	C ($\times 10^{-2}$)	D ($\times 10^{-3}$)	Scale ($\times 10^{-2}$)
Double gauss.	Mixed runs	1 & 2	1.68 ± 0.11	1.2 ± 0.3	4.7 ± 2.6	6.1 ± 1.8	0.32 ± 0.16
		3	2.6 ± 0.5	1.2 ± 1.2	4.7 ± 4.7	6 ± 6	0.1 ± 0.1
	Run IIb 1	1 & 2	1.61 ± 0.13	1.2 ± 0.5	4.3 ± 3.5	6.1 ± 2.1	0.23 ± 0.24
		3	2.1 ± 0.4	1.2 ± 1.2	4.3 ± 4.3	6 ± 6	0.0 ± 1.0
	Run IIb 2	1 & 2	1.72 ± 0.12	1.3 ± 0.4	4.7 ± 4.0	5.9 ± 1.5	0.35 ± 0.12
		3	2.6 ± 0.7	1.3 ± 1.3	4.7 ± 4.5	6 ± 6	0.1 ± 1.1
Single gauss.	Mixed runs	1 & 2	1.82 ± 0.13	1.3 ± 0.5	0	0	0.35 ± 0.14
		3	2.7 ± 0.5	1.3 ± 1.3	0	0	0.0 ± 1.2
	Run IIb 1	1 & 2	1.72 ± 0.11	1.4 ± 0.6	0	0	0.28 ± 0.22
		3	2.0 ± 1.0	1.4 ± 1.4	0	0	0.1 ± 0.7
	Run IIb 2	1 & 2	1.86 ± 0.13	1.4 ± 0.6	0	0	0.39 ± 0.12
		3	3.2 ± 1.0	1.4 ± 1.4	0	0	0.1 ± 0.9

Type 1 & 2: Both μ have at least SMT hits

Type 3: Only one μ has at least SMT hits

Conclusion and Outlook

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- The new over-smearing method has been integrated into Café (by Frédéric);
- It will be released with the next V-Jets version ;
- This new over-smearing procedure is highly tunable depending on your analysis through the VJets configurations (Run period, MC version, New Physics searches ...);
- The tails and the momentum scale factor are now taking into account ;
- Generation of the control plots are in progress (by Slava);
- Over-smearing parameters for the latest Monte Carlo versions (p20.15) and for P17 are ongoing (by Angelo);
- The summary of the momentum task force work will be available in the **DØ note 6031** released in a near future.

$\Longrightarrow$ Don't hesitate to test it and make comments ;-)