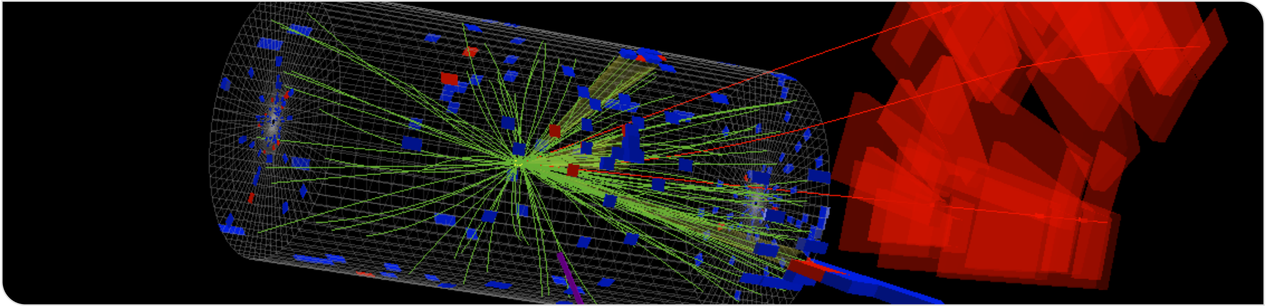
Karlsruher Institut für Technologie

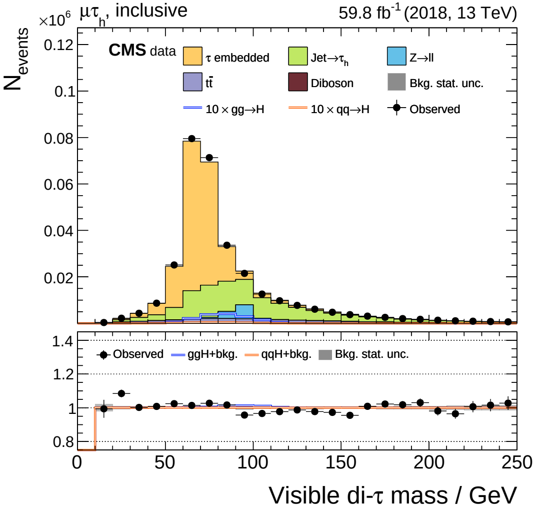
Institute of Experimental Particle Physics

Improvements of the event cleaning step of the τ-embedding procedure

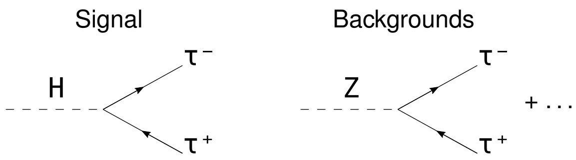
Christian Winter, Sebastian Brommer, Artur Gottmann, Roger Wolf, Günther Quast | 23 March 2023



Why the τ Embedding Method?



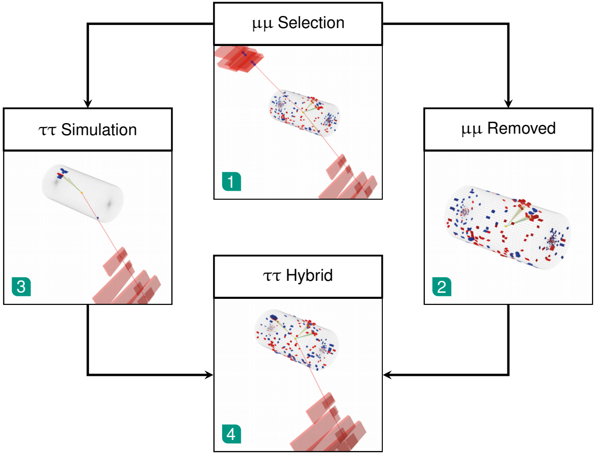
Taken from [Bro22].



τ embedding method

Alternative data driven method to estimate ττ backgrounds.

The τ Embedding Method

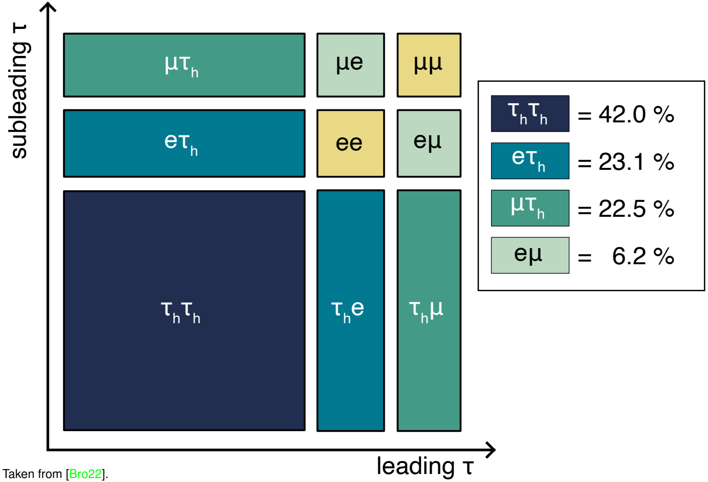


Adapted from [CMS19].

Replace muons in $\mu\mu$ events with simulated $\tau\tau$ decays

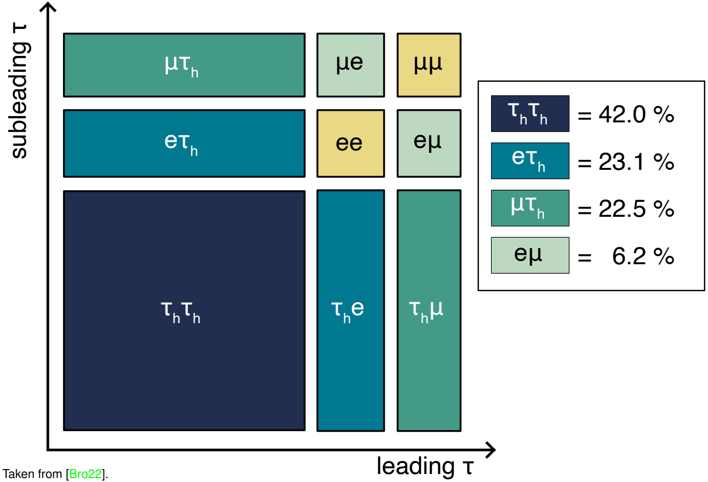
1. **Selection** of well-defined $\mu\mu$ pair events
2. **Remove** μ energy deposits from the event record
3. **Simulation** of the τ-leptons with the same four vector information as for the removed muons
4. **Merging** the simulated $\tau\tau$ decays into the cleaned event

Simulation Step



Taken from [Bro22].

Simulation Step



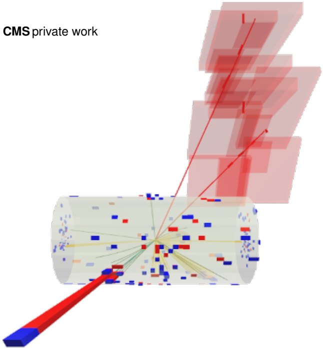
Taken from [Bro22].

To validate or calculate of scale factors

- $\mu \rightarrow \mu$ embedding
- $\mu \rightarrow$ e embedding

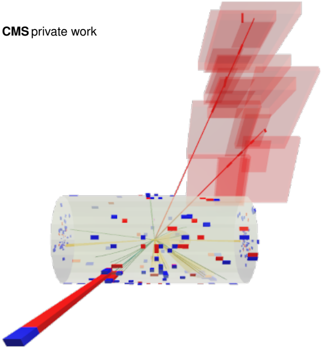
Validation using $\mu \to \mu$ Embedding

Original event



p_T [GeV]	η	ϕ
431.7	0.653	0.780
32.0	0.438	1.457

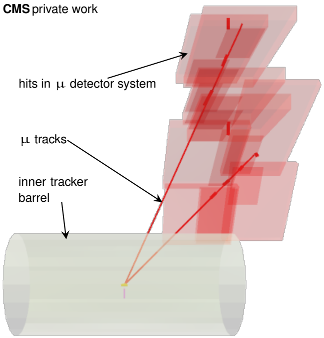
Good $\mu \to \mu$ embedded event



p_T [GeV]	η	ϕ
423.4	0.653	0.780
31.3	0.437	1.457

Validation using $\mu \to \mu$ Embedding

Original event



p_T [GeV]	η	ϕ
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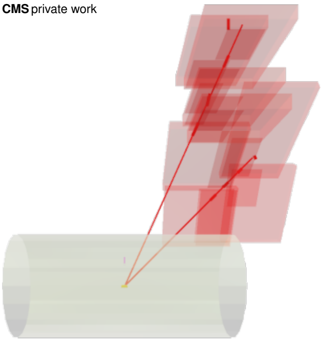
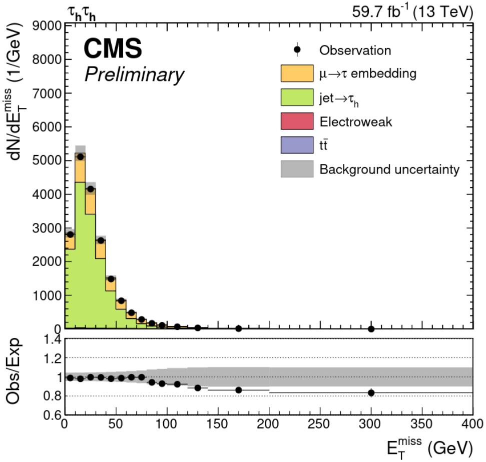
Good $\mu \to \mu$ embedded event



p_T [GeV]	η	ϕ
423.4	0.653	0.780
31.3	0.437	1.457

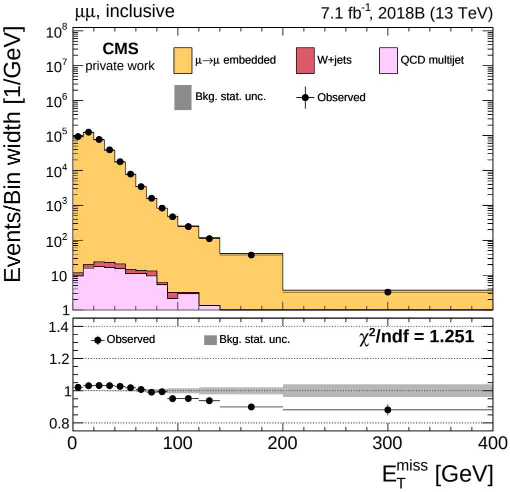
Discrepancy in the high E_T^{miss} Region

Observed during review of HIG-21-001



From HIG-21-001 Analysis Note

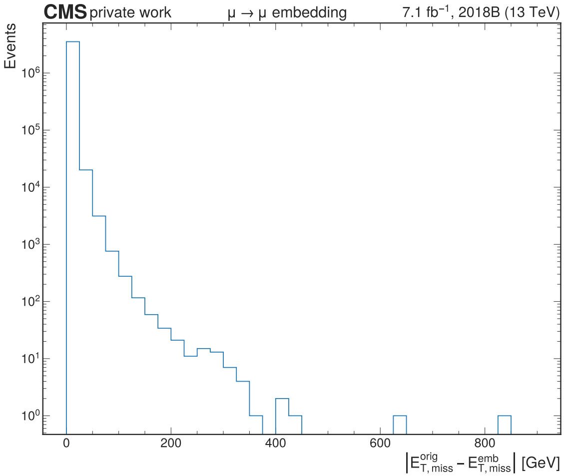
Discrepancy also in the $\mu \rightarrow \mu$ channel (UL Run2018B)



Difference in $E_{\mathrm{T}}^{\mathrm{miss}}$

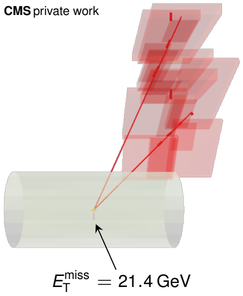
$$\Delta E_{\mathrm{T}}^{\mathrm{miss}} = \left| E_{\mathrm{T,\,miss}}^{orig} - E_{\mathrm{T,\,miss}}^{emb} \right|$$

- $E_{\mathrm{T}}^{\mathrm{miss}} \equiv$ PUPPI MET no corrections
- Huge amounts of MET created during embedding procedure
- 2.01 % events have $\Delta E_{\mathrm{T}}^{\mathrm{miss}} > 15\,\mathrm{GeV}$, but some analyses are sensitive



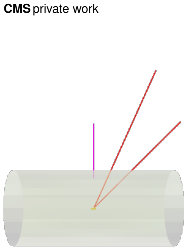
Example how high E_T^{miss} can emerge from insufficient event cleaning

Original event



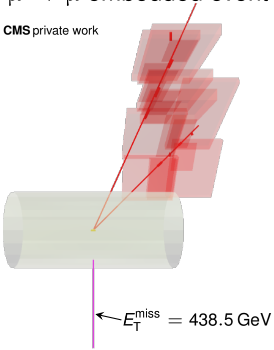
p_T [GeV]	η	ϕ
431.7	0.653	0.780
32.0	0.438	1.457

Removed event



p_T [GeV]	η	ϕ
422.8	0.654	0.780
34.4	0.437	1.467

$\mu \rightarrow \mu$ embedded event

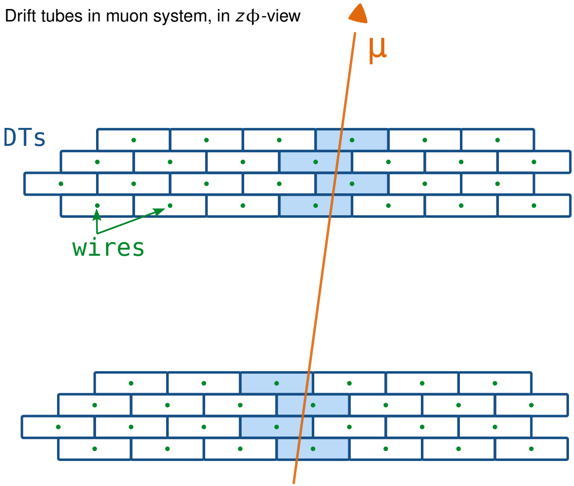


p_T [GeV]	η	ϕ
473.6	0.653	0.780
422.8	0.654	0.780
34.4	0.437	1.467
31.0	0.437	1.457

Improvements in the Removal of μ

- Removal of μ energy deposits in μ detector system completely rewritten

Drift tubes in muon system, in $z\phi$-view

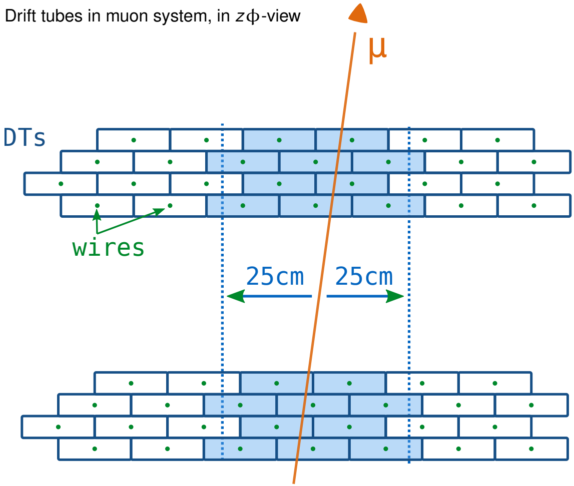


Adapted from [Bat19].

Improvements in the Removal of μ

- Removal of μ energy deposits in μ detector system completely rewritten
- Additional removal of hits in wires within a radius of 25 cm
  $\rightarrow$ Bremsstrahlung and em showers, which generate additional widely scattered hits
- 25 cm from study of MUO POG group [Bat19].

Drift tubes in muon system, in $z\phi$-view

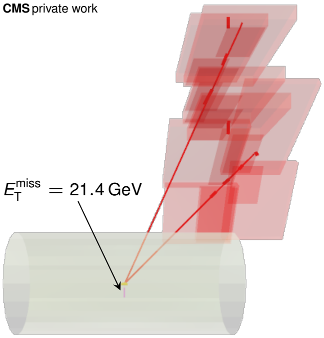


Adapted from [Bat19].

Improvements in the Removal of μ

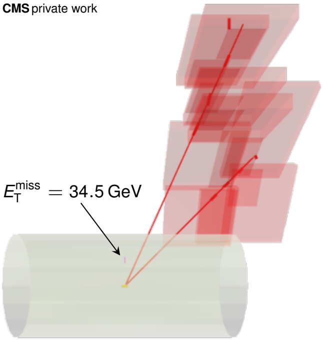
- Removal of μ energy deposits in μ detector system completely rewritten
- Additional removal of hits in wires within a radius of 25 cm
  $\rightarrow$ Bremsstrahlung and em showers, which generate additional widely scattered hits
- 25 cm from study of MUO POG group [Bat19].
- Fixes the issues in the previously shown example.

original



p_T [GeV]	η	ϕ
431.7	0.653	0.780
32.0	0.438	1.457

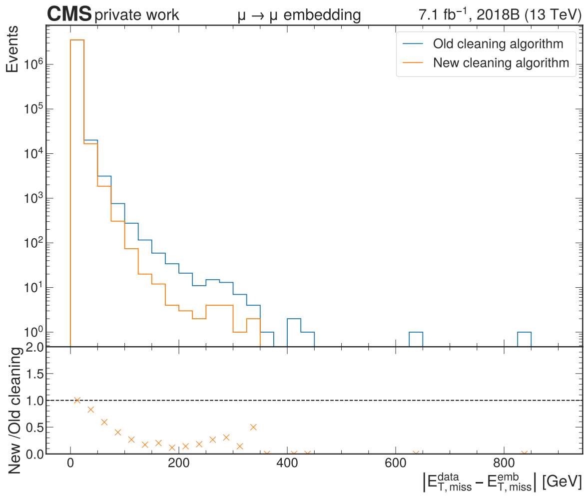
$\mu \rightarrow \mu$ embedded



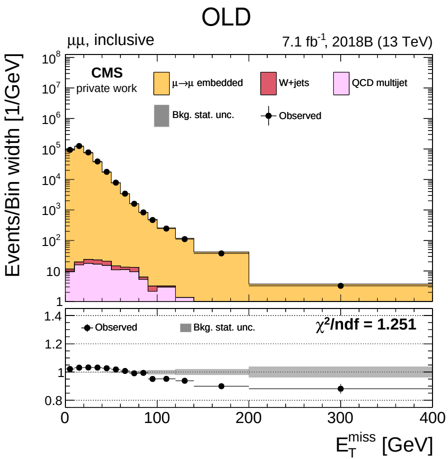
p_T [GeV]	η	ϕ
423.4	0.653	0.780
31.3	0.437	1.457

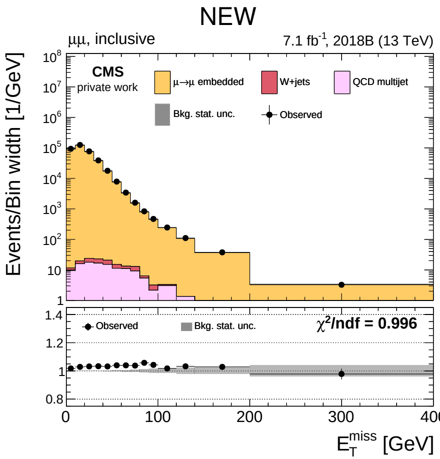
Improvement of $E_{\mathrm{T}}^{\mathrm{miss}}$ distribution

- Improved removing of μ energy deposits in μ detector system in new cleaning algorithm
  - Including additional collections
  - Including additional cleaning in a 25 cm radius in the muon detector system
- Less missing p_{T} is created in embedding
  - $\Delta E_{\mathrm{T}}^{\mathrm{miss}} > 15\,\mathrm{GeV}$:
    - Old 2.01 %
    - New 1.79 %
- Ratio to correction weights



Visible improvement of E_T^{miss} description with new algorithm

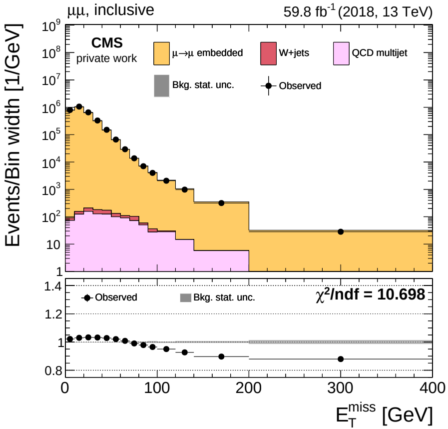




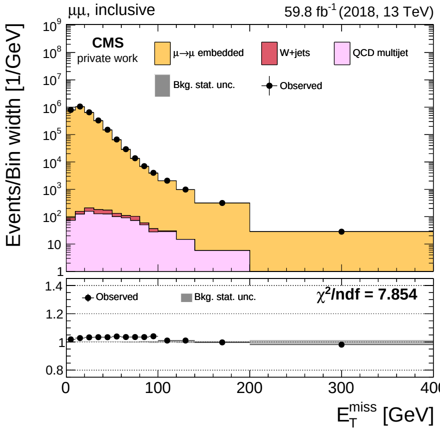
Only statistical uncertainty considered here!

Using weights on whole 2018

OLD



NEW



Only statistical uncertainty considered here!

Conclusion

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- Found main cause for high E_T^{miss} difference and fixed it.
- Improved E_T^{miss} agreement in $\mu \rightarrow \mu$ emb.
- Tested weights on $\mu \rightarrow \mu$ emb.
- Tested in $\mu\tau_H$ channel, but there the agreement is good event without fix.

Next steps:

- Test the $\tau_H\tau_H$ channel
- Include the Improvements in the main CMSSW repo
- Continue Artur Gottmanns work: Makeing the τ-embedding fit for Run 3

References

[1] Carlo Battilana. *Shower studies with detector digi information*. 24. Jan. 2019. URL: https://indico.cern.ch/event/791906/contributions/3290123/attachments/1784568/2904915/Showers_with_digi_method.pdf (besucht am 09. 03. 2023).

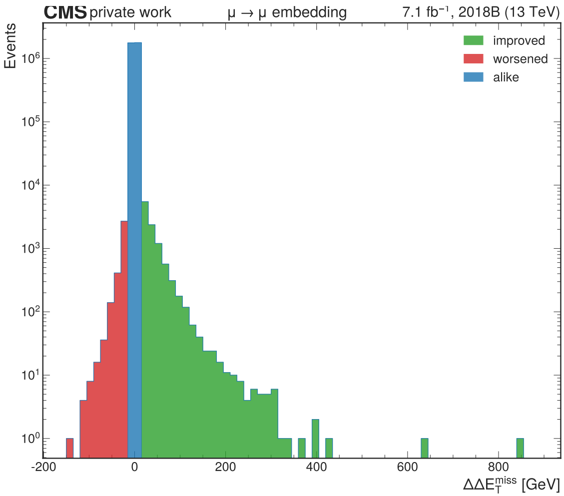
[2] Sebastian Brommer. „A data-driven method for Higgs boson analyses in di-τ final states for the LHC Run II and beyond“. Diss. Karlsruhe Institute of Technology (KIT), 2022. DOI: 10.5445/IR/1000155107.

[3] The CMS collaboration. „An embedding technique to determine $\tau\tau$ backgrounds in proton-proton collision data“. In: *Journal of Instrumentation* 14.06 (Juni 2019), P06032–P06032. DOI: 10.1088/1748-0221/14/06/p06032.

Difference of the Missing p_T difference

$$\Delta\Delta E_T^{miss} = \Delta E_{T,old}^{miss} - \Delta E_{T,new}^{miss}.$$

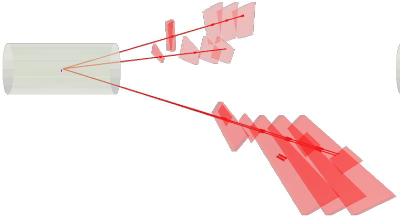
- $\Delta\Delta E_T^{miss} < -15\,\text{GeV}$: 0.093 %
- $\left|\Delta\Delta E_T^{miss}\right| \leq 15\,\text{GeV}$: 99.61 %
- $\Delta\Delta E_T^{miss} > 15\,\text{GeV}$: 0.29 %



Literatur

Mostly worsened event

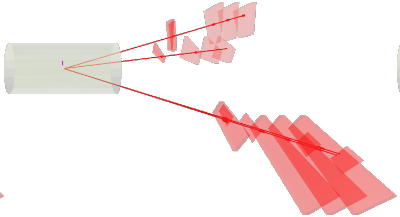
ORIGINAL



$E_T^{miss} = 13.3\,\mathrm{GeV}$

p_T [GeV]	η	ϕ
153.9	1.476	−2.434
145.1	2.171	0.563
113.0	1.480	−2.437
74.9	1.930	1.444

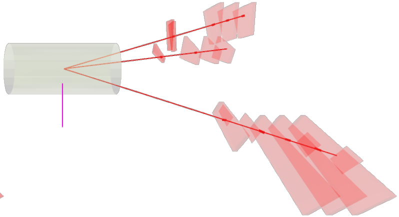
$\mu \to \mu$ EMB. OLD



$E_T^{miss} = 14.9\,\mathrm{GeV}$

p_T [GeV]	η	ϕ
156.2	1.475	−2.434
151.9	2.172	0.563
113.1	1.480	−2.437
74.9	1.930	1.444

$\mu \to \mu$ EMB. NEW



$E_T^{miss} = 156.5\,\mathrm{GeV}$

p_T [GeV]	η	ϕ
146.4	2.171	0.564
117.0	1.479	−2.436
74.9	1.930	1.444

Literatur