MINISTÈRE
DE L'ENSEIGNEMENT SUPÉRIEUR,
DE LA RECHERCHE
ET DE L'INNOVATION

Liberté • Égalité • Fraternité
RÉPUBLIQUE FRANÇAISE

ÉCOLE DOCTORALE 52
PHAST
PHYSIQUE ET ASTROPHYSIQUE
UNIVERSITÉ DE LYON

UNIVERSITÉ DE LYON
Lyon 1

Recherche d'un boson de Higgs de haute masse se désintégrant en paire de taus dans l'expérience CMS au LHC

Thèse de doctorat

Lucas TORTEROTOT

Institut de Physique des deux Infinis – Lyon

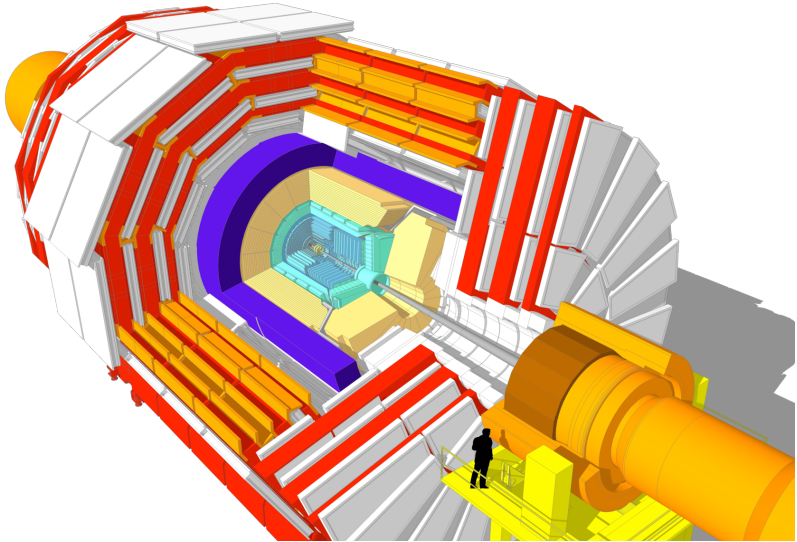
XX xxxx 2021

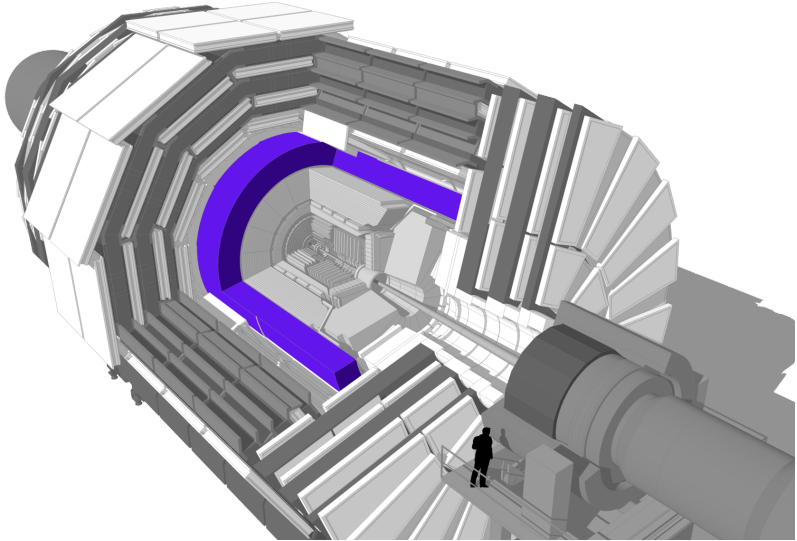
cnrs IN2P3 Les deux infinis

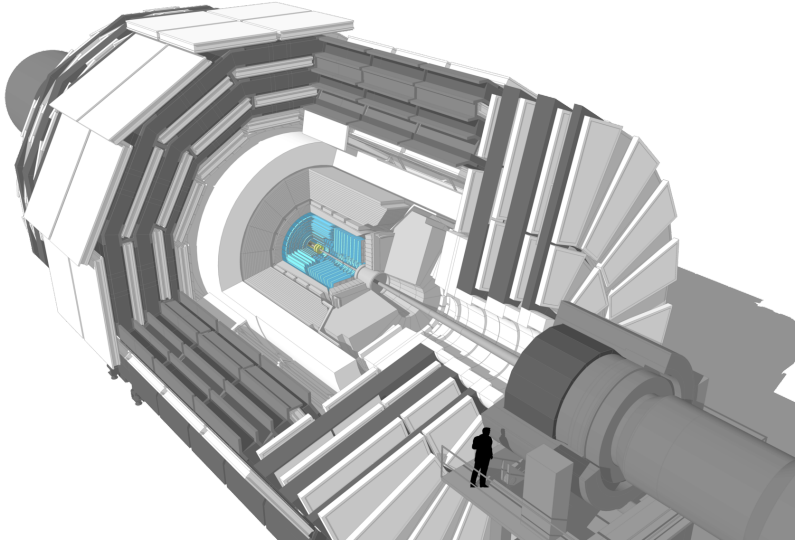
CERN

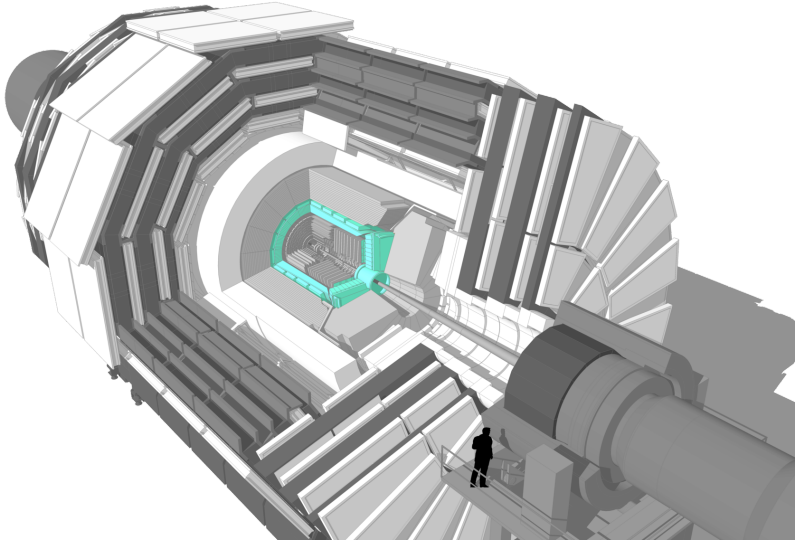
CMS

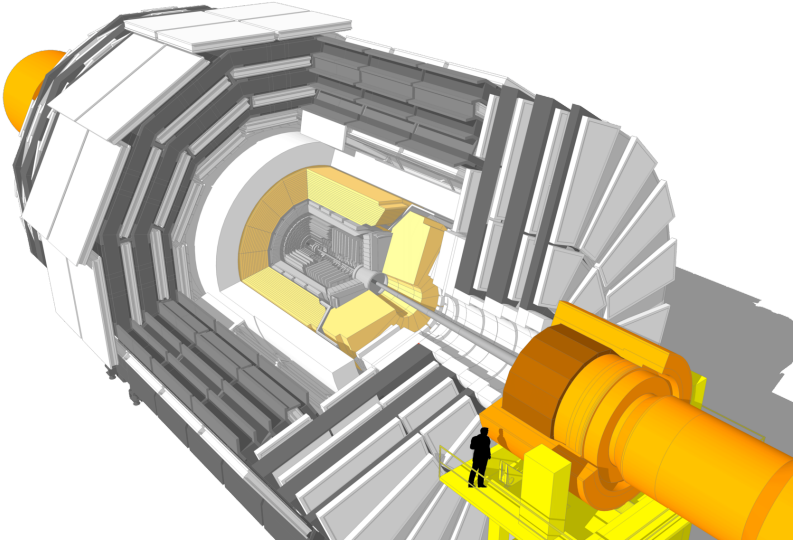
iP2I LES 2 INFINIS LYON

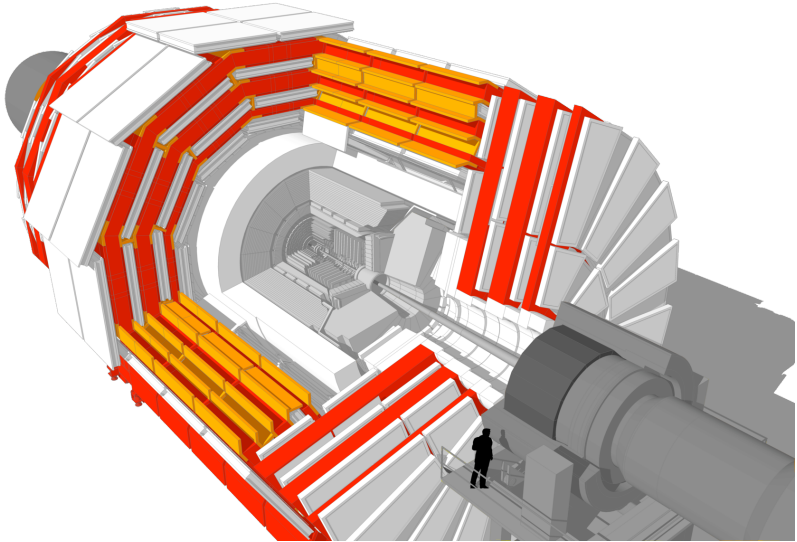


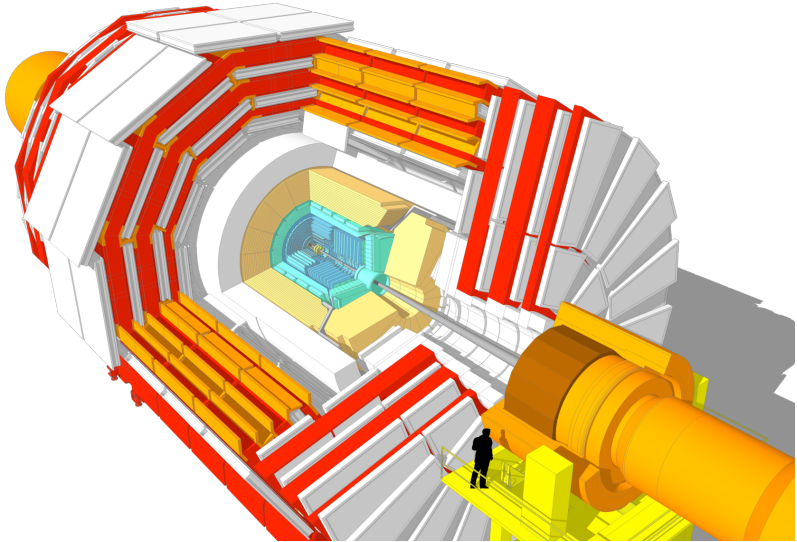










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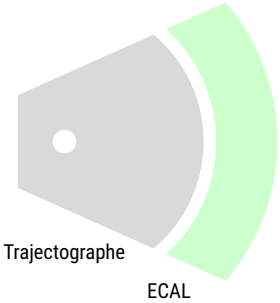
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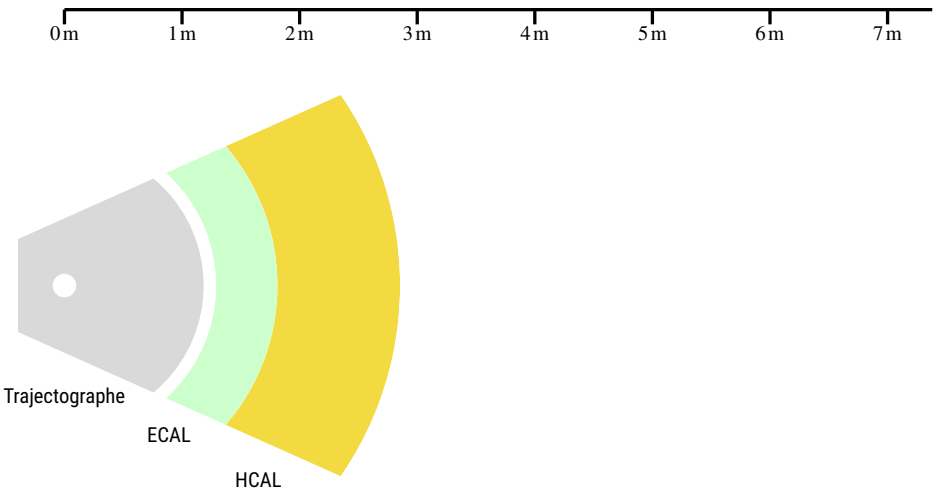
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ECAL
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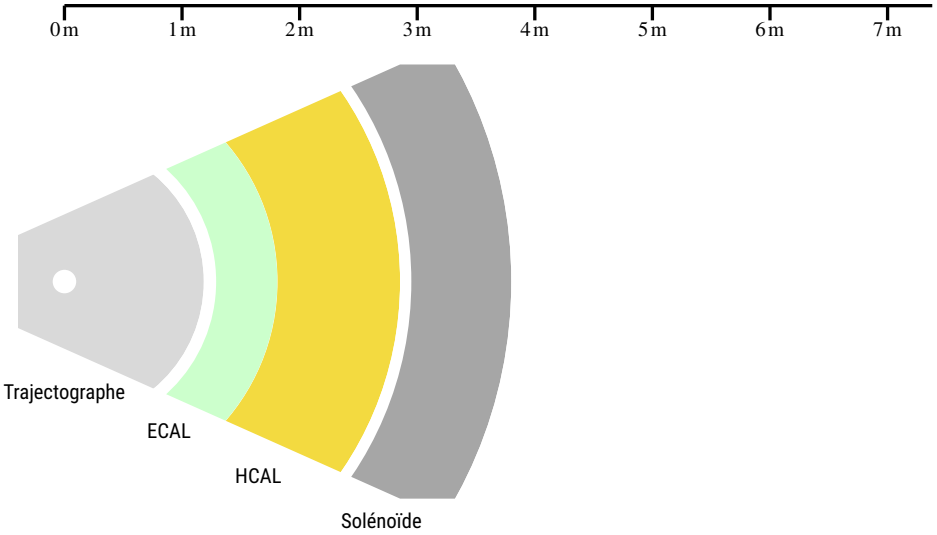
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Trajectographe
ECAL
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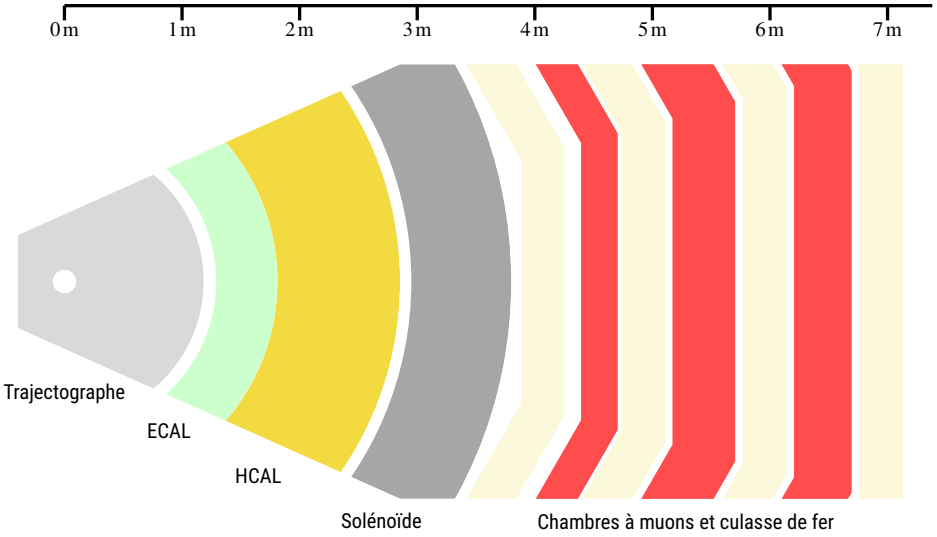
Solénoïde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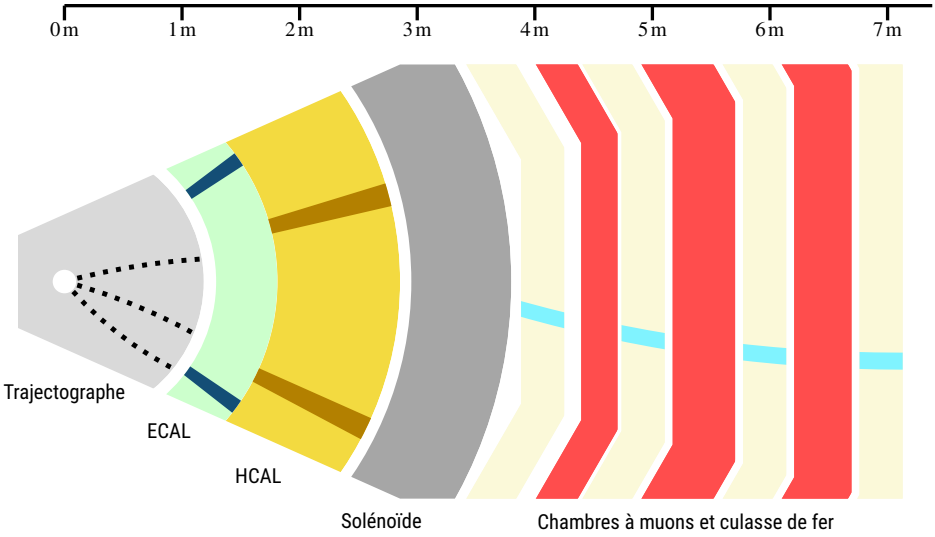
Trajectographe
ECAL
HCAL
Solénoïde
Chambres à muons et culasse de fer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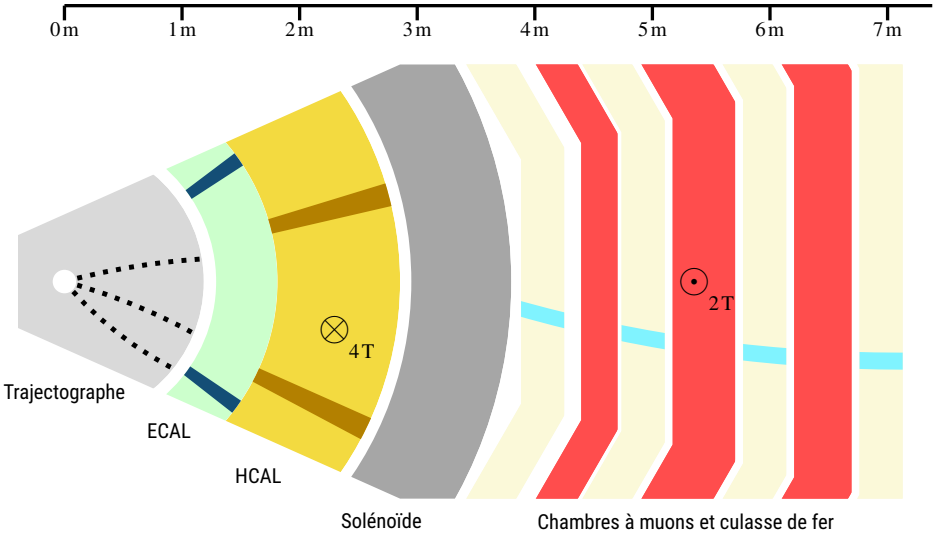
Chambres à muons et culasse de fer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Trajectographe
ECAL
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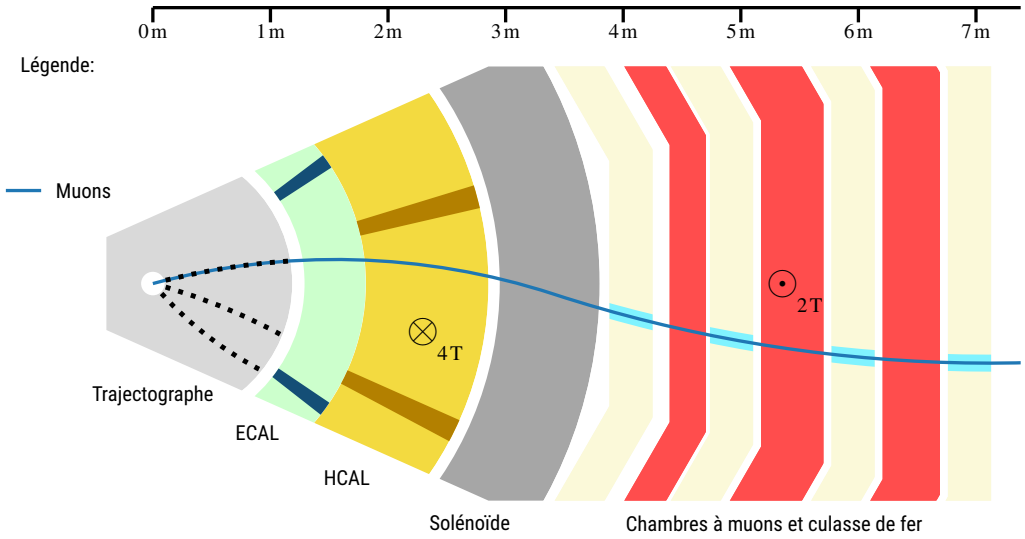
Solénoïde
Chambres à muons et culasse de fer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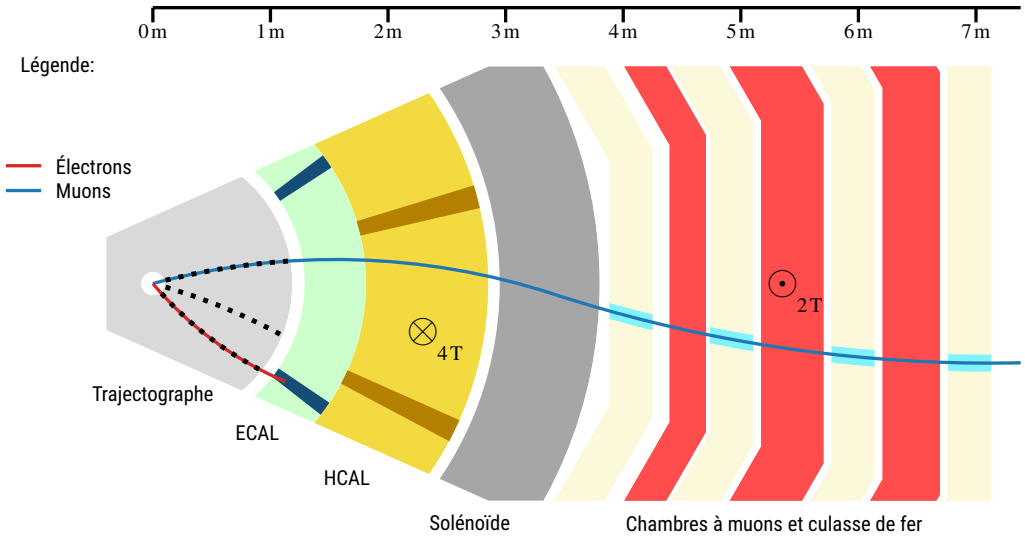
ECAL
HCAL
Solénoïde
Chambres à muons et culasse de fer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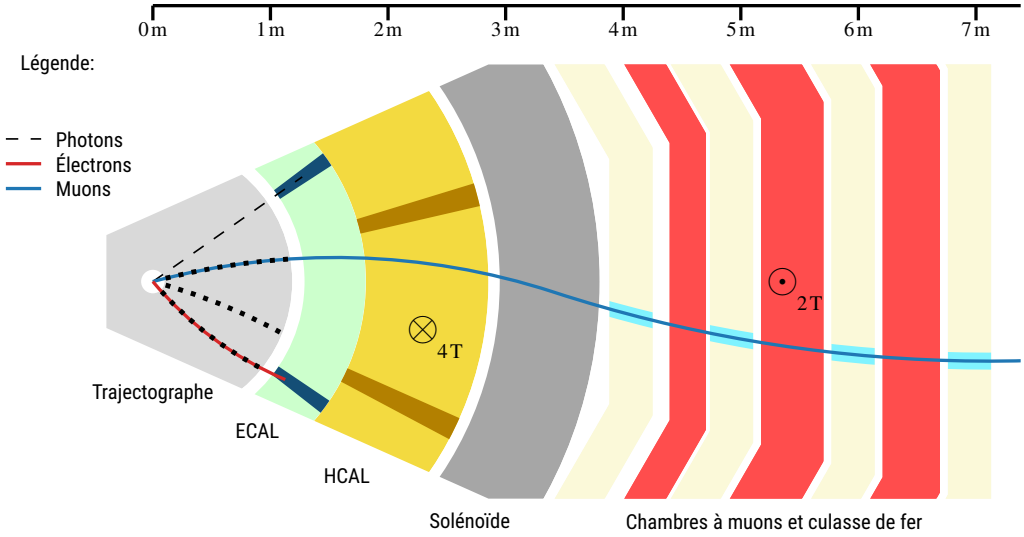
Solénoïde
Chambres à muons et culasse de fer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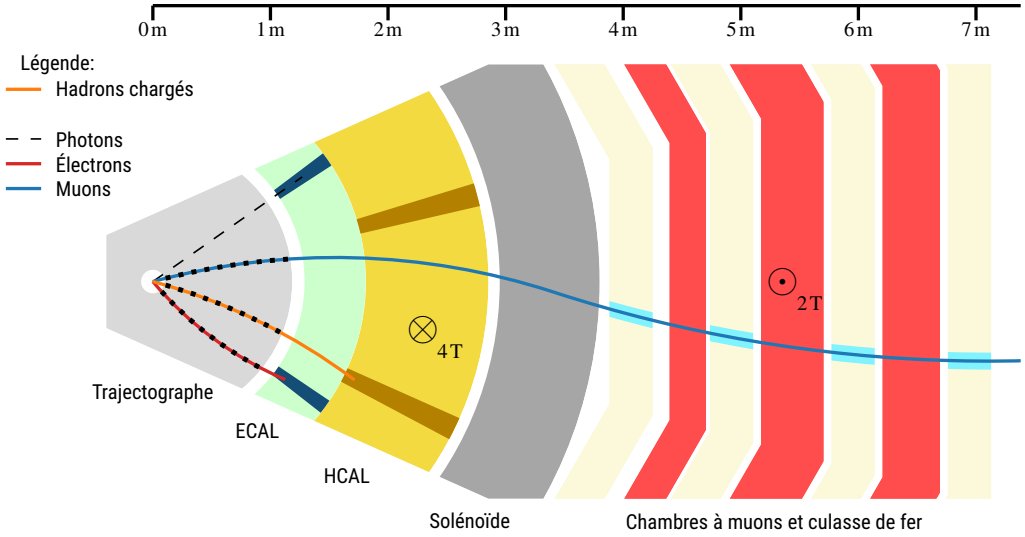
HCAL
Solénoïde
Chambres à muons et culasse de fer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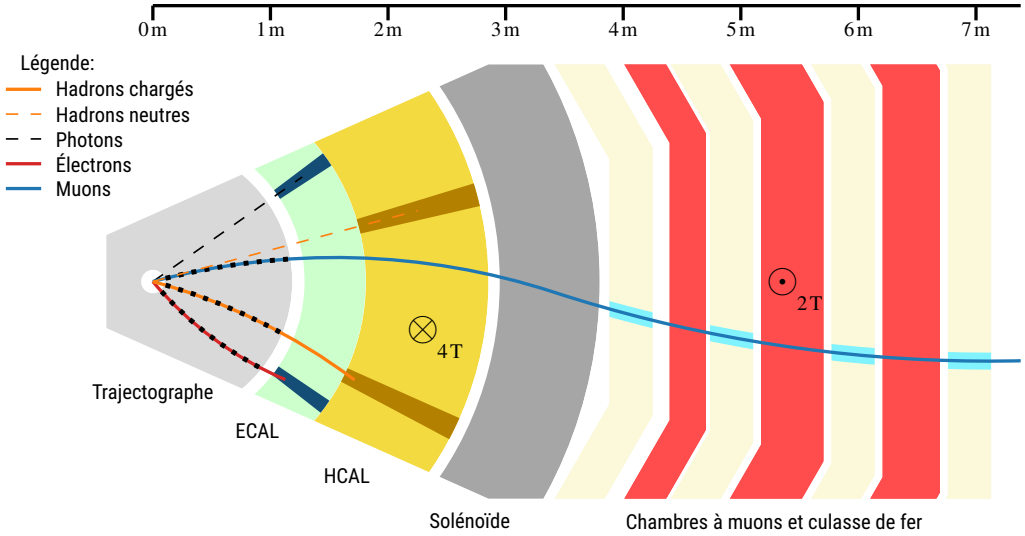
Solénoïde
Chambres à muons et culasse de fer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Électrons
Muons
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Trajectographe
ECAL
HCAL
Solénoïde
Chambres à muons et culasse de fer

- Niveaux de connaissance

particule	(ptcl)
reconstruit	(reco)
corrigé	(corr)

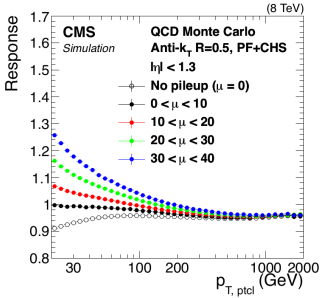
- Niveaux de connaissance

particule	(ptcl)
reconstruit	(reco)
corrigé	(corr)

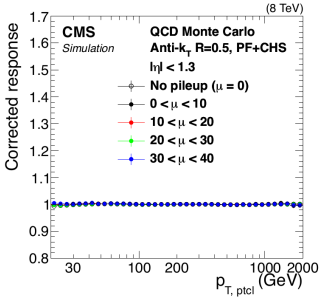
- Réponse d'un jet

$$R = \frac{p_{\mathrm{T}}}{p_{\mathrm{T\,ptcl}}}$$

Jets Reconstruits



Jets Calibrés

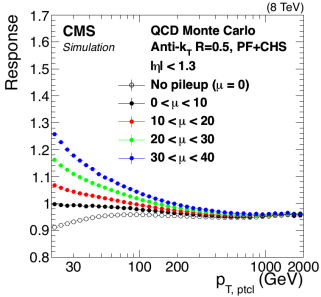


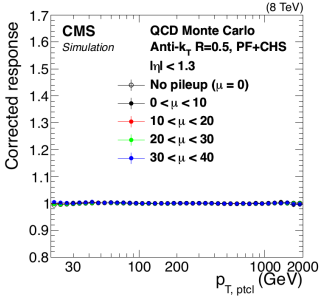
Appliqué aux données →

Jets Reconstruits

Jets Calibrés

Appliqué aux simulations →





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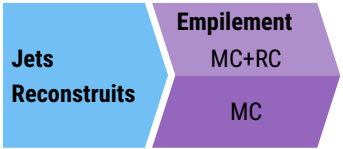
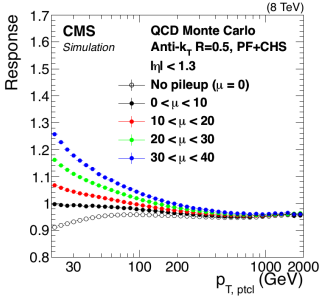
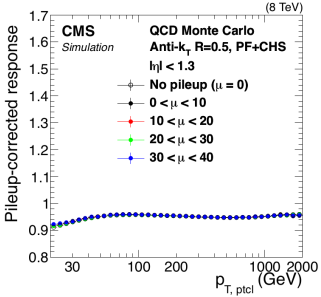
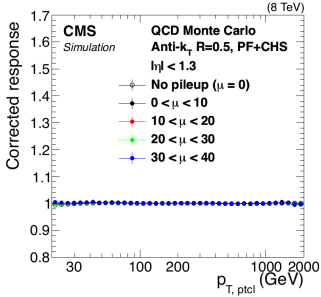


Jets Calibrés

Appliqué aux simulations



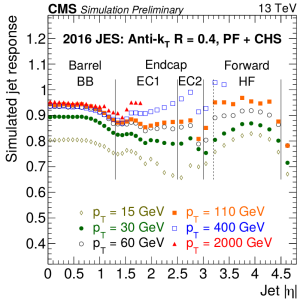


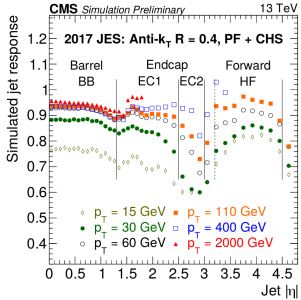


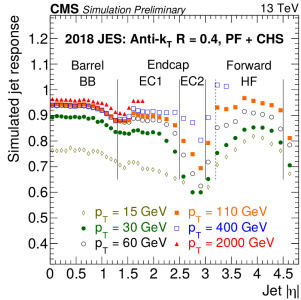
Appliqué aux données

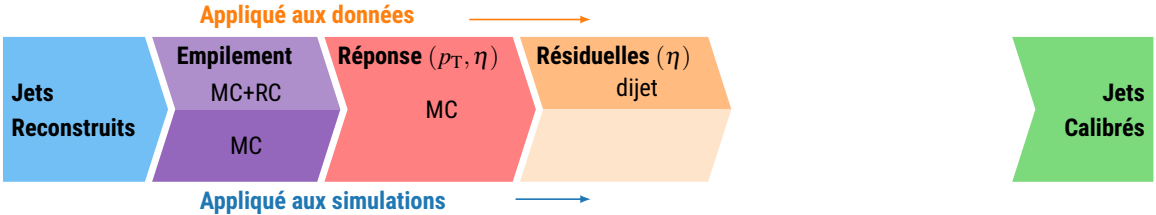
Jets Reconstruits → **Empilement** MC+RC / MC → **Réponse** (p_T, η) MC → **Jets Calibrés**

Appliqué aux simulations

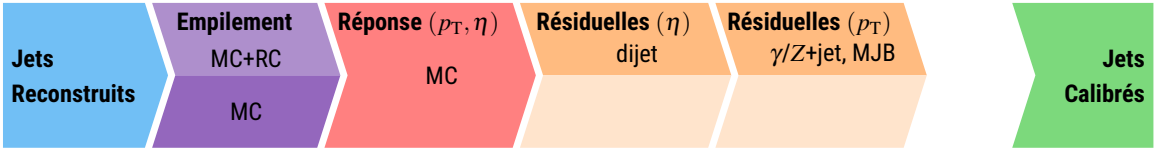







Appliqué aux données
Jets Reconstruits
Empilement
MC+RC
MC
Réponse (p_T, η)
MC
Résiduelles (η)
dijet
Jets Calibrés
Appliqué aux simulations

Appliqué aux données



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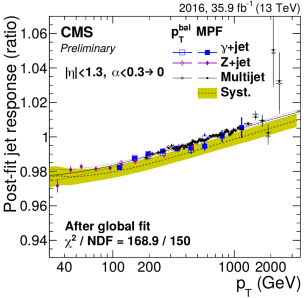

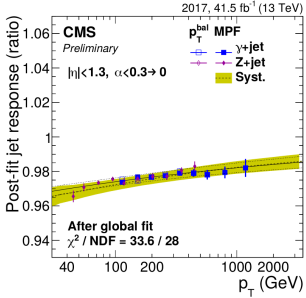

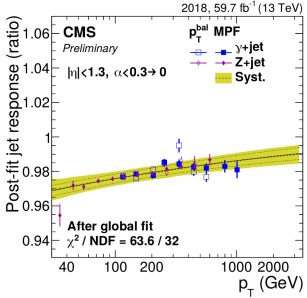

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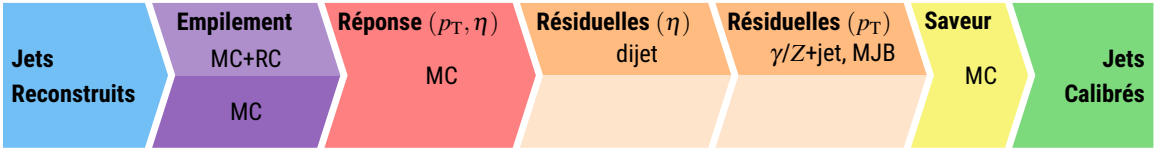

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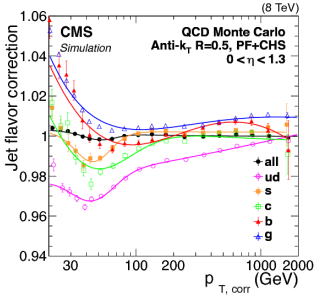

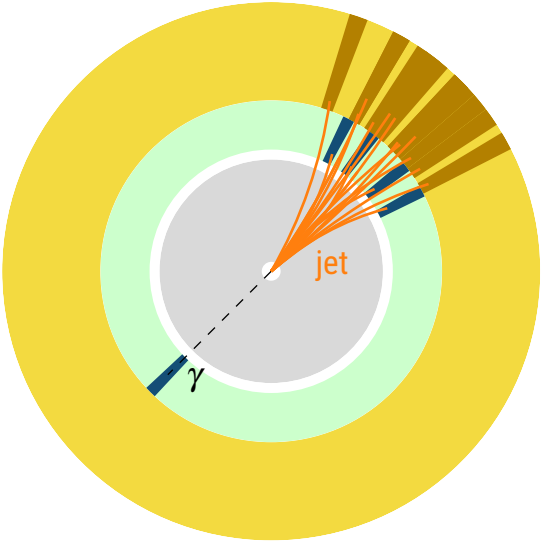
jet
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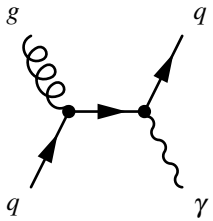
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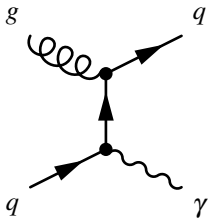
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q
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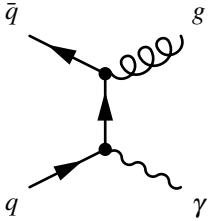
q̄
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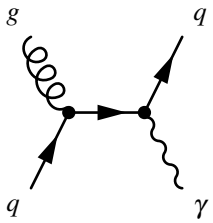
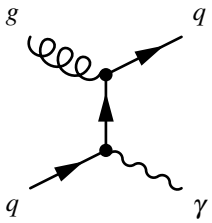
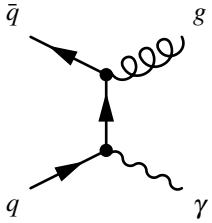
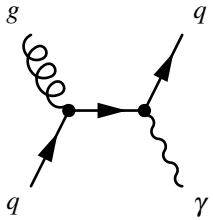
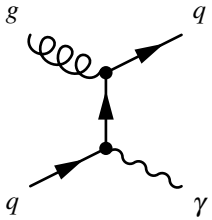


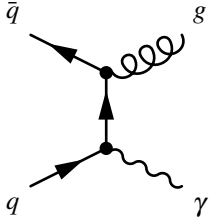




$$\vec{p}_{\mathrm{T}\,\mathrm{ptcl}}^{\,\gamma} + \vec{p}_{\mathrm{T}\,\mathrm{ptcl}}^{\,\mathrm{jet}} = \vec{0} \Rightarrow p_{\mathrm{T}\,\mathrm{ptcl}}^{\,\gamma} = p_{\mathrm{T}\,\mathrm{ptcl}}^{\,\mathrm{jet}}$$

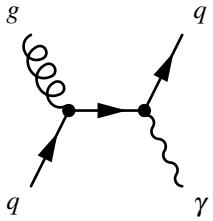


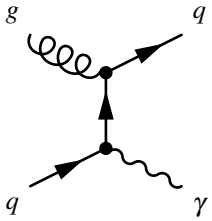


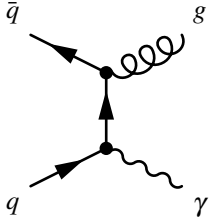


$$\vec{p}_{\mathrm{T}}^{\,\gamma}{}_{\mathrm{ptcl}} + \vec{p}_{\mathrm{T}}^{\,\mathrm{jet}}{}_{\mathrm{ptcl}} = \vec{0} \Rightarrow p_{\mathrm{T}}^{\gamma}{}_{\mathrm{ptcl}} = p_{\mathrm{T}}^{\mathrm{jet}}{}_{\mathrm{ptcl}}$$

$$R = \frac{p_{\mathrm{T}}^{\mathrm{jet}}{}_{\mathrm{reco}}}{p_{\mathrm{T}}^{\mathrm{jet}}{}_{\mathrm{ptcl}}} = \frac{p_{\mathrm{T}}^{\mathrm{jet}}{}_{\mathrm{reco}}}{p_{\mathrm{T}}^{\gamma}{}_{\mathrm{ptcl}}} \simeq \frac{p_{\mathrm{T}}^{\mathrm{jet}}{}_{\mathrm{reco}}}{p_{\mathrm{T}}^{\gamma}{}_{\mathrm{reco}}}$$



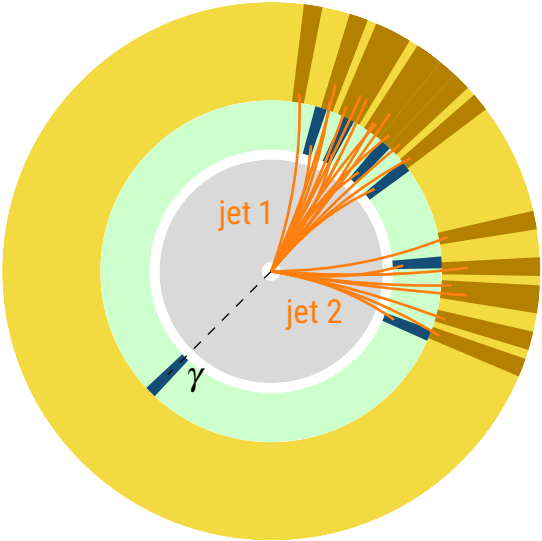


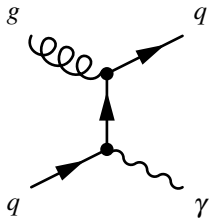


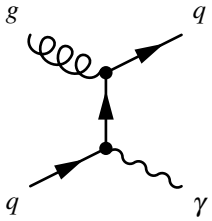
$$\vec{p}_{\mathrm{T}}{}^{\gamma}_{\mathrm{ptcl}} + \vec{p}_{\mathrm{T}}{}^{\mathrm{jet}}_{\mathrm{ptcl}} = \vec{0} \Rightarrow p_{\mathrm{T}}{}^{\gamma}_{\mathrm{ptcl}} = p_{\mathrm{T}}{}^{\mathrm{jet}}_{\mathrm{ptcl}}$$

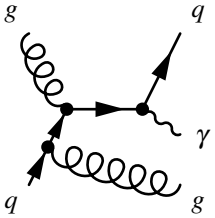
$$R = \frac{p_{\mathrm{T}}{}^{\mathrm{jet}}_{\mathrm{reco}}}{p_{\mathrm{T}}{}^{\mathrm{jet}}_{\mathrm{ptcl}}} = \frac{p_{\mathrm{T}}{}^{\mathrm{jet}}_{\mathrm{reco}}}{p_{\mathrm{T}}{}^{\gamma}_{\mathrm{ptcl}}} \simeq \frac{p_{\mathrm{T}}{}^{\mathrm{jet}}_{\mathrm{reco}}}{p_{\mathrm{T}}{}^{\gamma}_{\mathrm{reco}}}$$

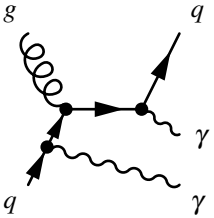
$$R_{bal} = \frac{p_{\mathrm{T}}{}^{\mathrm{jet}}_{\mathrm{reco}}}{p_{\mathrm{T}}{}^{\gamma}}$$

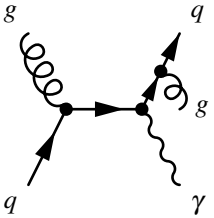

jet 1
jet 2
γ

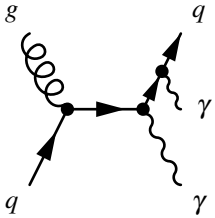

g
q
q
γ


g
q
q
γ


g
q
γ
q
g


g
q
γ
q
γ


g
q
g
q
γ


g
q
γ
q
γ

$$R_{bal} = \frac{p_{\mathrm{T}}^{\text{jet 1}}_{\text{reco}}}{{p_{\mathrm{T}}}^{\gamma}}$$

$$\alpha = \frac{p_{\mathrm{T}}^{\text{jet 2}}_{\text{reco}}}{{p_{\mathrm{T}}}^{\gamma}}$$

$$\vec{p}_{\mathrm{T}\,\mathrm{ptcl}}^{\,\gamma} + \vec{p}_{\mathrm{T}\,\mathrm{ptcl}}^{\,\mathrm{recul}} = \vec{0}$$

$$\vec{p}_{\mathrm{T}\,\mathrm{ptcl}}^{\,\gamma} + \vec{p}_{\mathrm{T}\,\mathrm{ptcl}}^{\,\mathrm{recul}} = \vec{0}$$

$$\vec{p}_{\mathrm{T}\,\mathrm{reco}}^{\,\gamma} + \underbrace{R_{MPF}\vec{p}_{\mathrm{T}\,\mathrm{ptcl}}^{\,\mathrm{recul}}}_{\vec{p}_{\mathrm{T}\,\mathrm{reco}}^{\,\mathrm{recul}}} = -\vec{E}_{\mathrm{T}}^{\mathrm{miss}} \Rightarrow \boxed{R_{MPF} = 1 + \frac{\vec{p}_{\mathrm{T}}^{\,\gamma} \cdot \vec{E}_{\mathrm{T}}^{\mathrm{miss}}}{|\vec{p}_{\mathrm{T}}^{\,\gamma}|^2}}$$

Jet Energy Resolution

- Remember R_{bal} definition,

$$R_{bal} = \frac{p_{\mathrm{T}}^{1^{\mathrm{st}}\mathrm{jet}}}{p_{\mathrm{T}}^{\gamma}}$$

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Then

$$R_{bal} = \underbrace{\frac{p_{\mathrm{T}\,\mathrm{reco}}^{1^{\mathrm{st}}\mathrm{jet}}}{p_{\mathrm{T}\,\mathrm{ptcl}}^{1^{\mathrm{st}}\mathrm{jet}}}}_{\sigma_{\mathrm{jet}}=\mathrm{JER}} \times \underbrace{\frac{p_{\mathrm{T}\,\mathrm{ptcl}}^{1^{\mathrm{st}}\mathrm{jet}}}{p_{\mathrm{T}\,\mathrm{ptcl}}^{\gamma}}}_{\mathrm{PLI}} \times \underbrace{\frac{p_{\mathrm{T}\,\mathrm{ptcl}}^{\gamma}}{p_{\mathrm{T}\,\mathrm{reco}}^{\gamma}}}_{\sigma_{\gamma}\equiv 1}$$

- PLI: Particle Level Imbalance (pile-up, radiations, neutrinos...), $\to 0$ when $\alpha \to 0$.

Jet Energy Resolution

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$$R_{bal} = \frac{p_{\mathrm{T}\,\mathrm{reco}}^{1^{\mathrm{st}}\mathrm{jet}}}{p_{\mathrm{T}\,\mathrm{reco}}^{\gamma}}$$

Then

$$R_{bal} = \underbrace{\frac{p_{\mathrm{T}\,\mathrm{reco}}^{1^{\mathrm{st}}\mathrm{jet}}}{p_{\mathrm{T}\,\mathrm{ptcl}}^{1^{\mathrm{st}}\mathrm{jet}}}}_{\sigma_{\mathrm{jet}}=\mathrm{JER}} \times \underbrace{\frac{p_{\mathrm{T}\,\mathrm{ptcl}}^{1^{\mathrm{st}}\mathrm{jet}}}{p_{\mathrm{T}\,\mathrm{ptcl}}^{\gamma}}}_{\mathrm{PLI}} \times \underbrace{\frac{p_{\mathrm{T}\,\mathrm{ptcl}}^{\gamma}}{p_{\mathrm{T}\,\mathrm{reco}}^{\gamma}}}_{\sigma_{\gamma}\equiv 1}$$

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$$\boxed{\mathrm{JER} = \sigma_{\mathrm{jet}} = \sqrt{\sigma_{R_{bal}}^2 - \sigma_{\mathrm{PLI}}^2}}$$

Thank you for your attention!