Measurement of energy correlators inside Jets and gluon spin interference during parton shower at CMS

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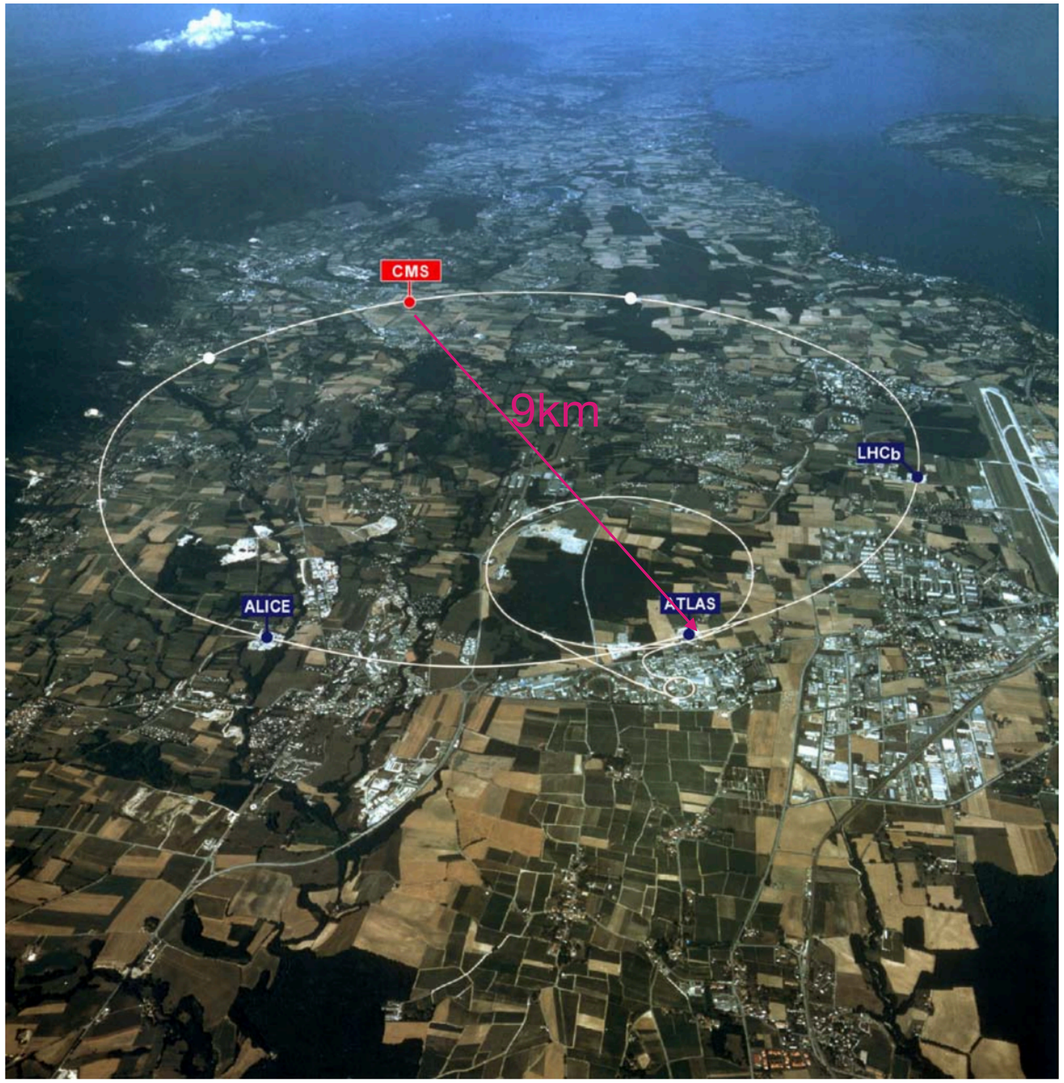
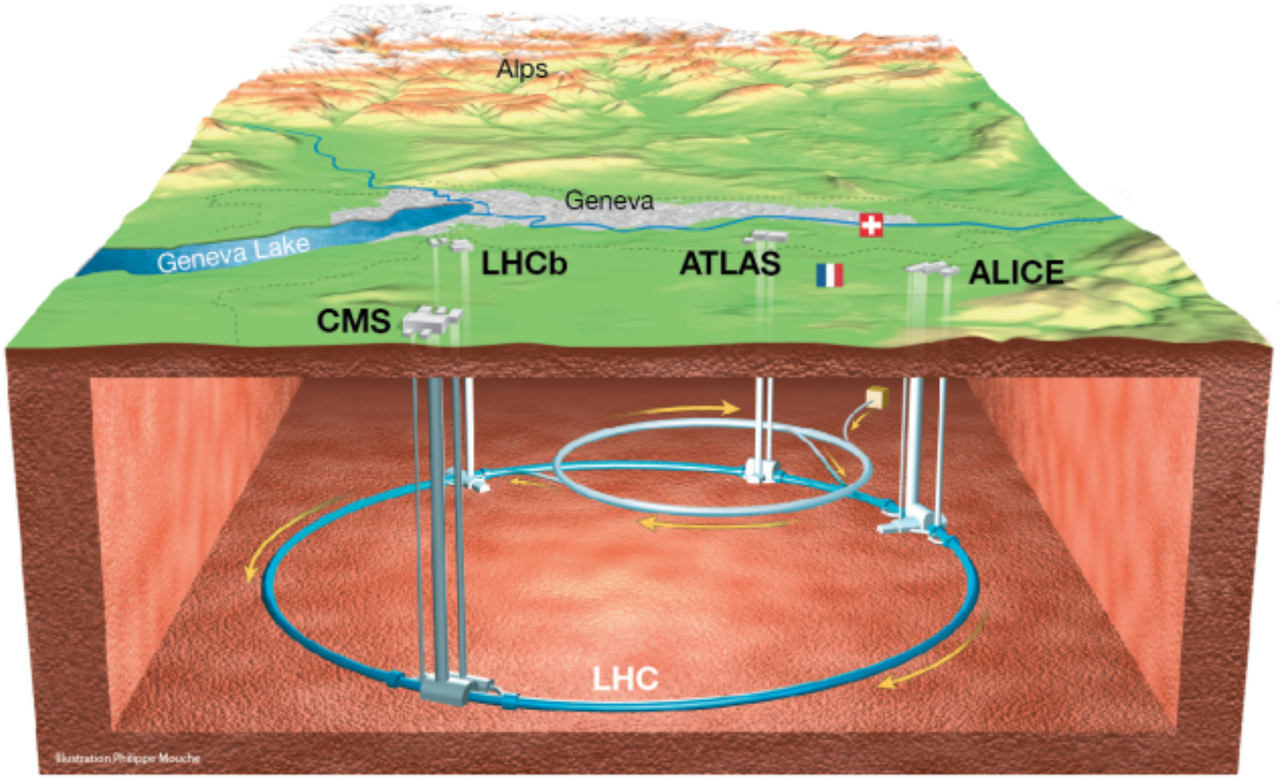
导师：肖朦

LHC: Large Hadron collider



Location of the four LHC experiments around the circumference of the LHC ring



CMS detector

CMS DETECTOR

Total weight : 14,000 tonnes
Overall diameter : 15.0 m
Overall length : 28.7 m
Magnetic field : 3.8 T

STEEL RETURN YOKE
12,500 tonnes

SILICON TRACK
Pixel (100x150 μm) ~1
Microstrips (80x180 μ

Barrel: 250 Drift Tube, 480 Resistive Plate Chambers
Endcaps: 540 Cathode Strip, 576 Resistive Plate Chambers

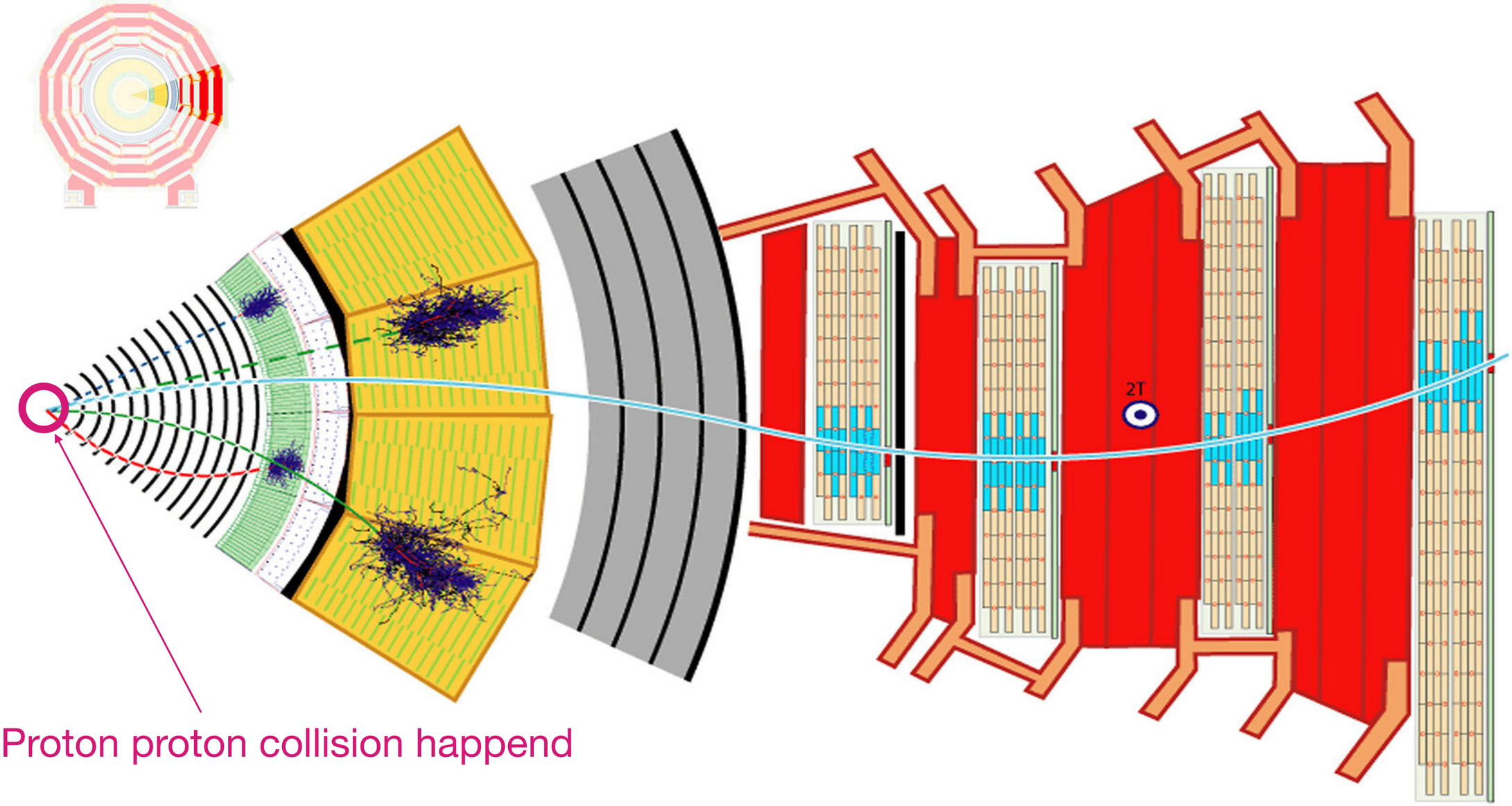
PRESHOWER
Silicon strips ~16m² ~137,000 channels

FORWARD CALORIMETER
Steel + Quartz fibres ~2,000 Channels

CRYSTAL
ELECTROMAGNETIC
CALORIMETER (ECAL)
~76,000 scintillating $PbWO_4$ crystals

HADRON CALORIMETER (HCAL)
Brass + Plastic scintillator ~7,000 channels

CMS detector



Proton proton collision happend

Proton proton collision

Sufficient QCD processes

Hard Scattering

Perturbative QCD

Parton Shower

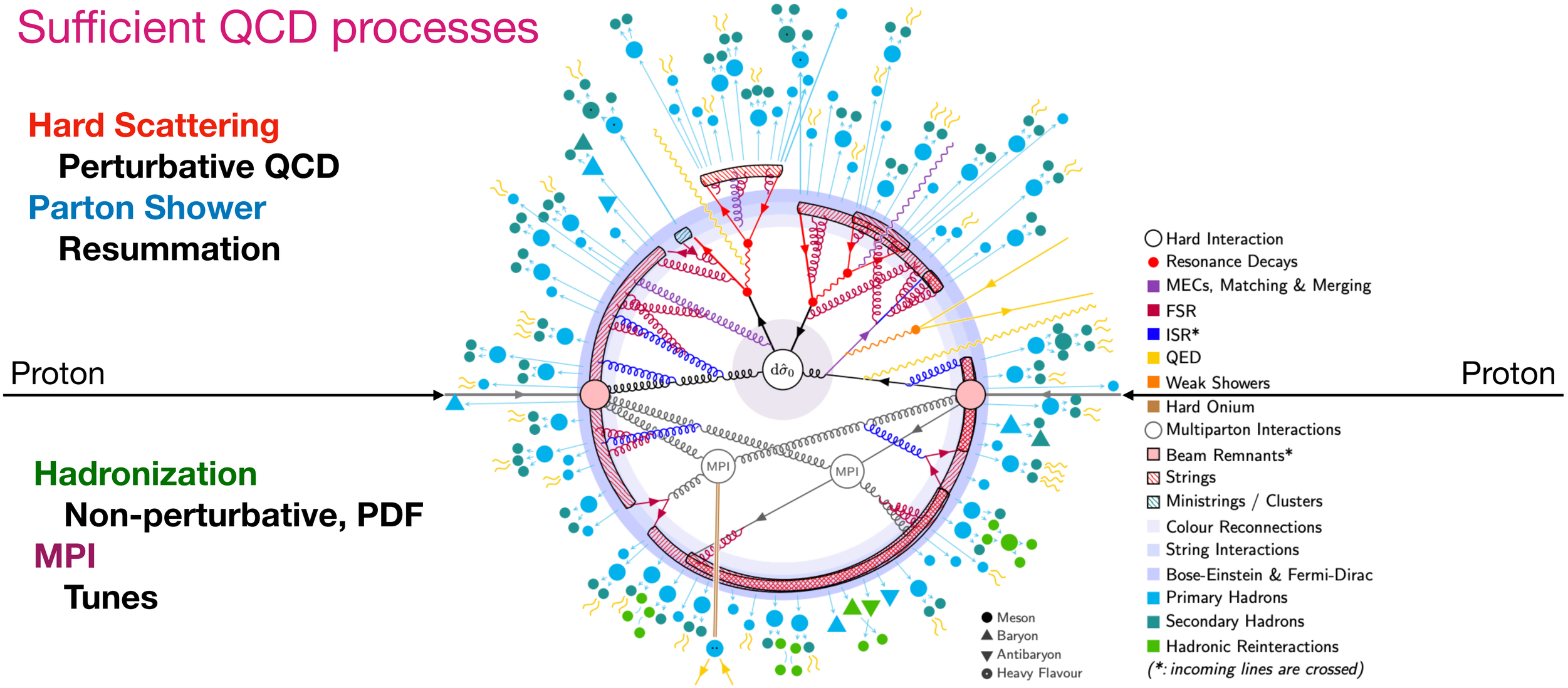
Resummation

Hadronization

Non-perturbative, PDF

MPI

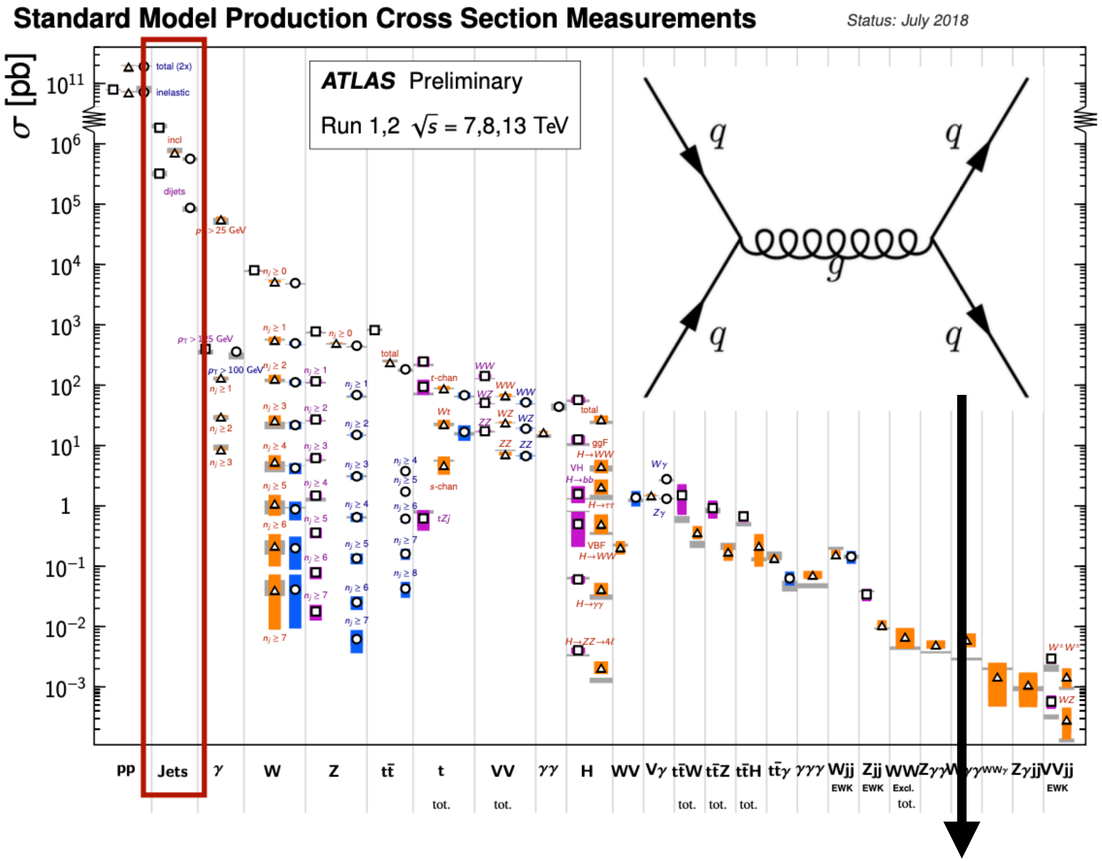
Tunes

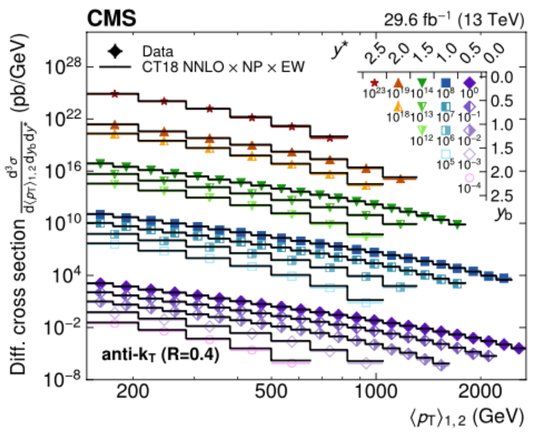


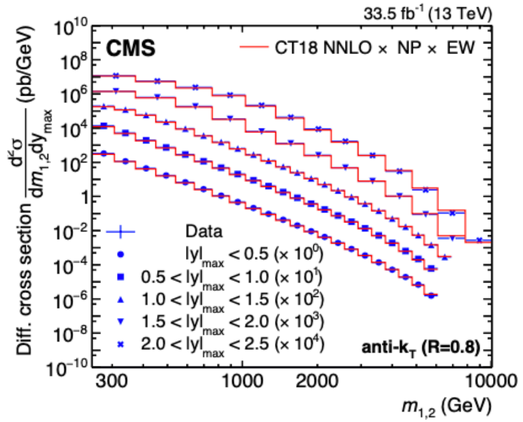
Jet measurements

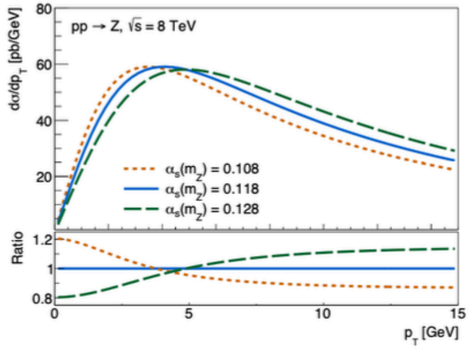
Hard Scattering

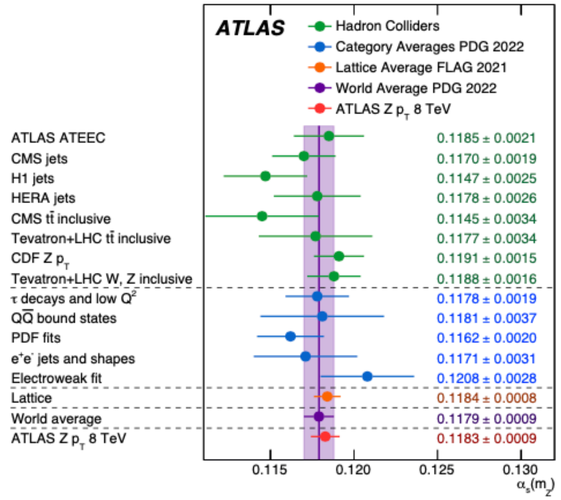
Perturbative QCD











Parton will transfer to jet because of the color confinement

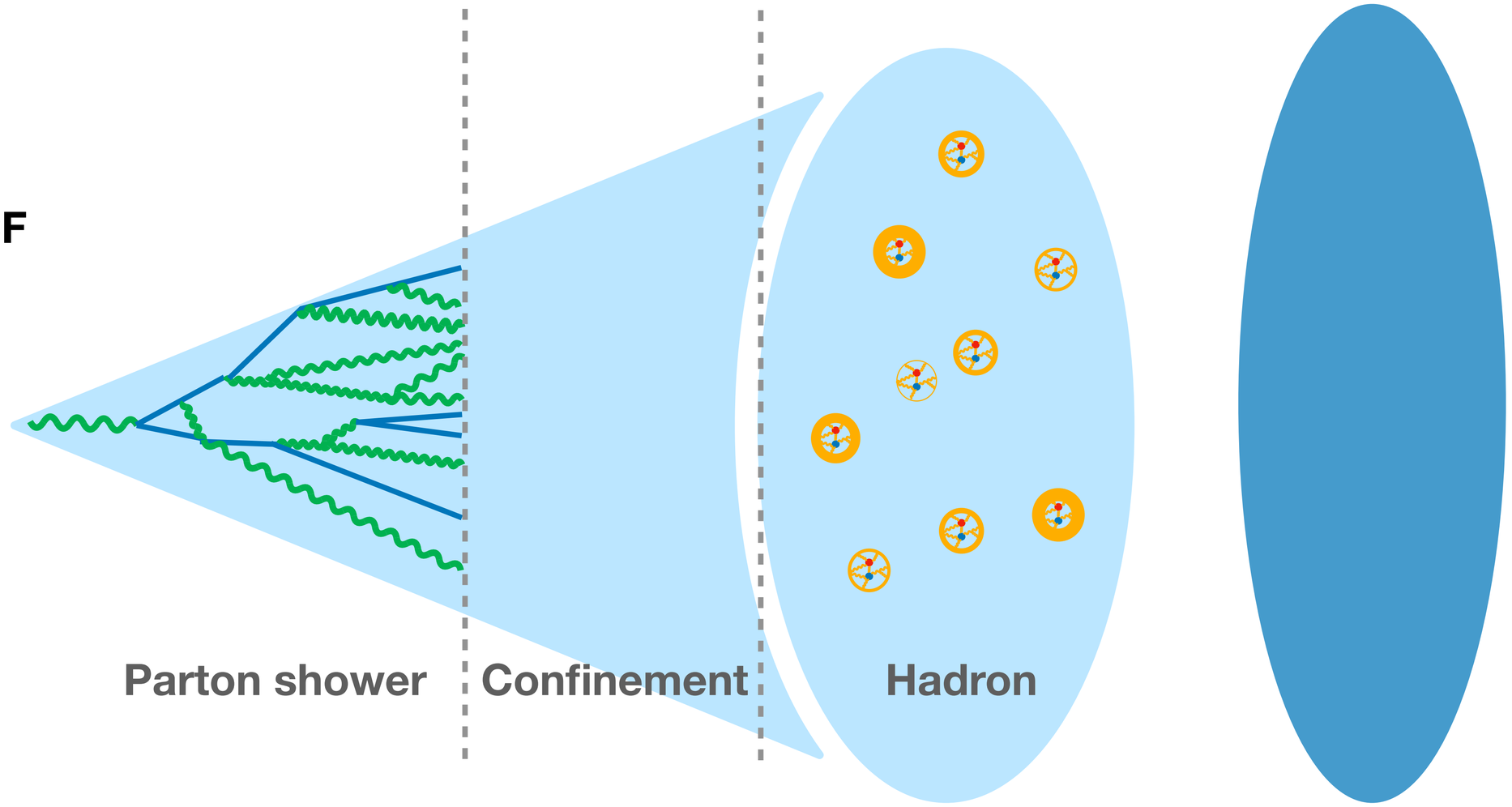
Jet substructure

Parton Shower

Resummation

Hadronization

Non-perturbative, PDF



Jet substructure

Parton Shower

Resummation

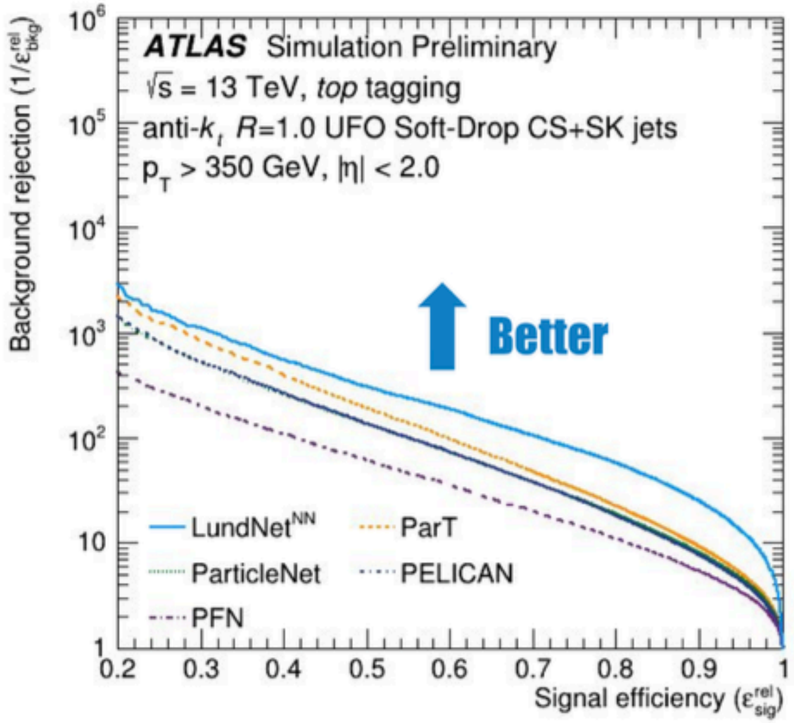
Hadronization

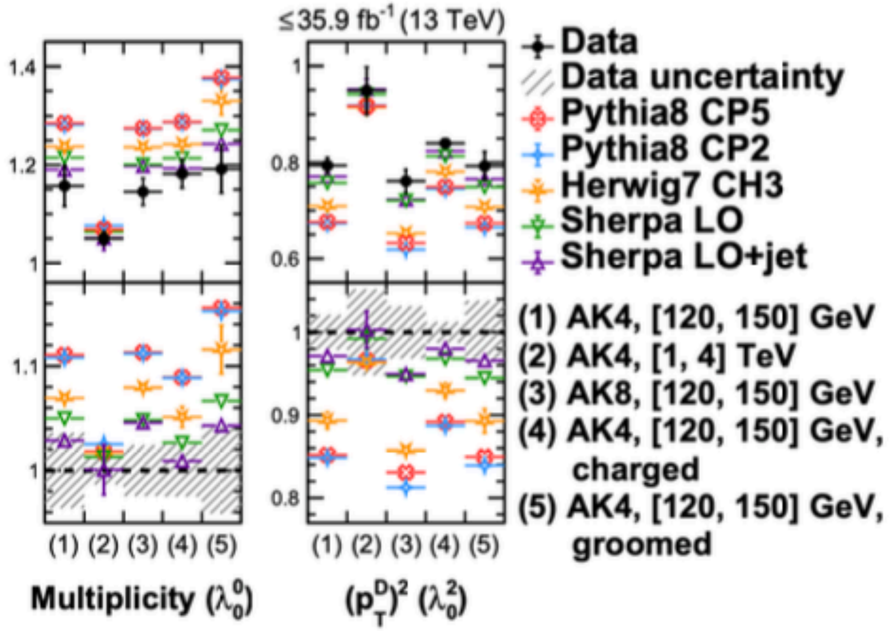
Non-perturbative, PDF

Traditional

Jet substructure

- Jet flavour tagging
- Compare MC to data to improve understanding of PS





Jet substructure

Parton Shower

Resummation

Hadronization

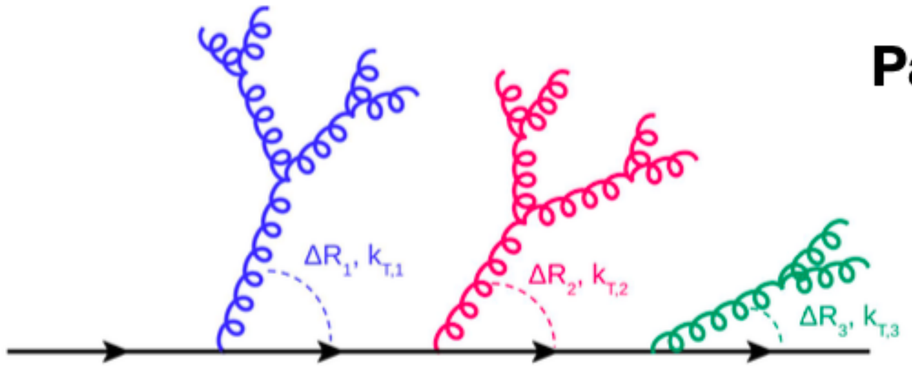
Non-perturbative, PDF

More fundamental

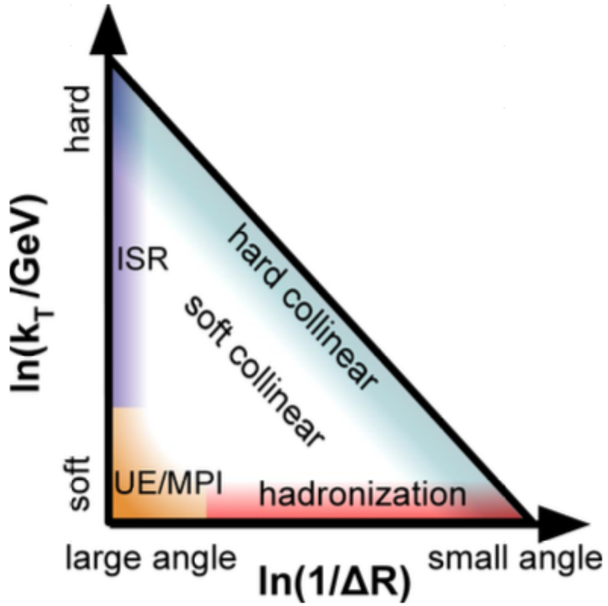
Jet substructure

- Lund plane

Using C/A decluster to restore parton splitting



Parton shower



Lund plane

Jet substructure

$$E2C = \frac{d\sigma^{[2]}}{dx_L} = \sum_{i,j}^{n} \int d\sigma \frac{E_i E_j}{E^2} \delta(x_L - \Delta R_{i,j})$$

Parton Shower

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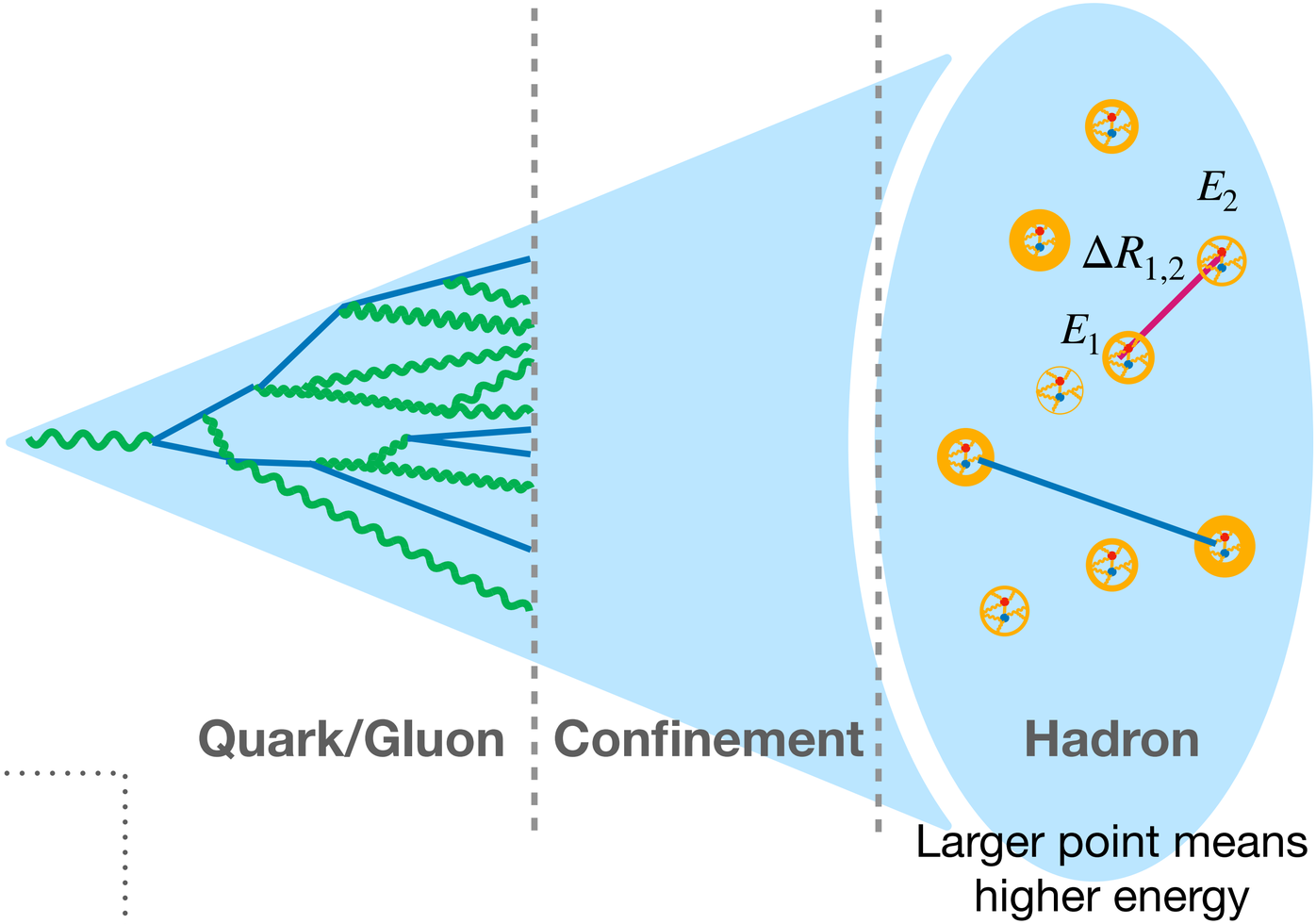
Non-perturbative, PDF



More fundamental

Jet substructure

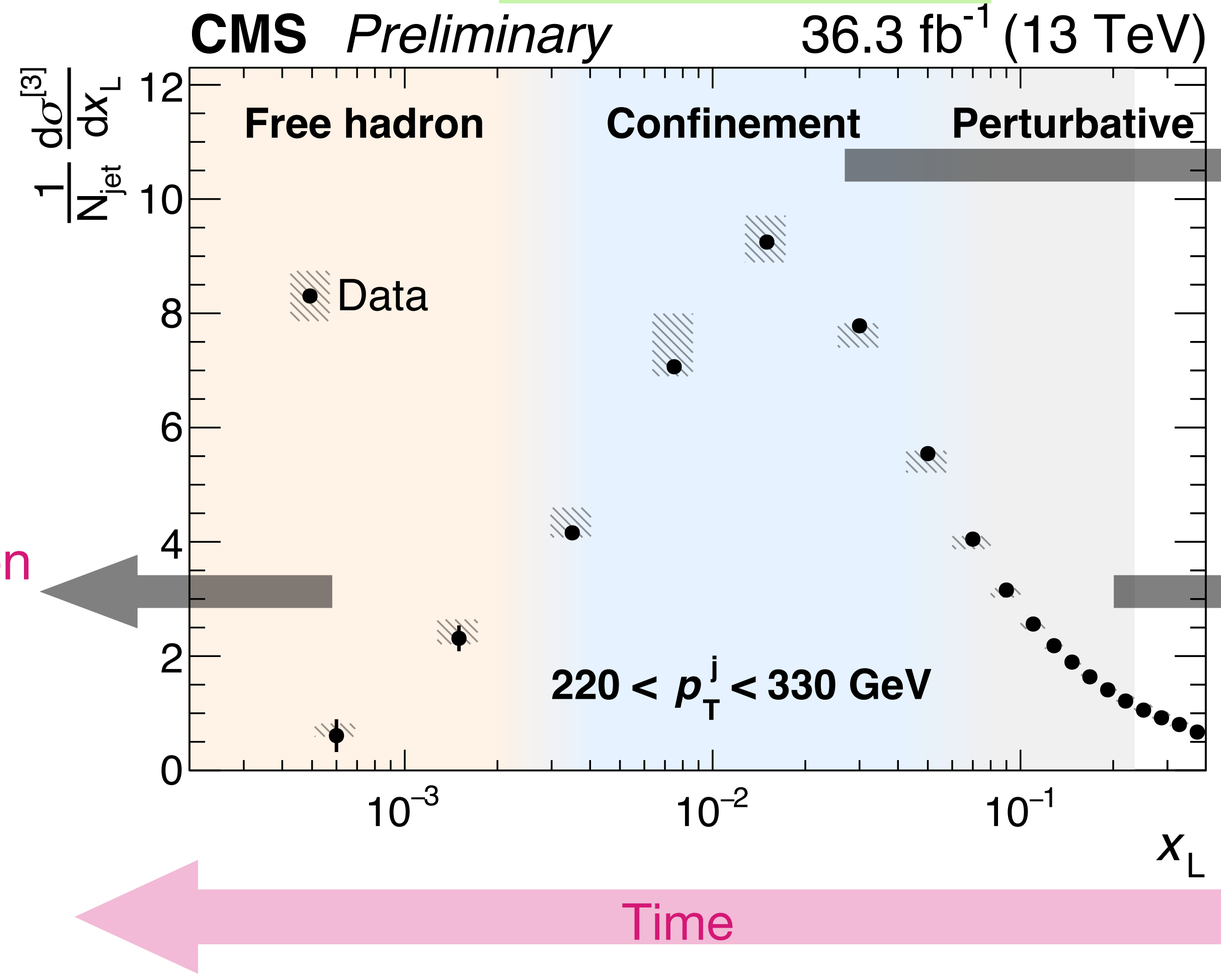
- Lund plane
- Energy energy correlators

Initial proposal: Chen, Moult, Zhang, and Zhu, *arXiv:2004.11381*

NLO+NLL: Lee, Meçaj, and Moult, *arXiv:2205.03414*

NLO+NNLL$_{approx}$: Chen, Gao, Li, Xu, Zhang, and Zhu, *arXiv:2307.07510*

Observation of evolution from parton to hadron

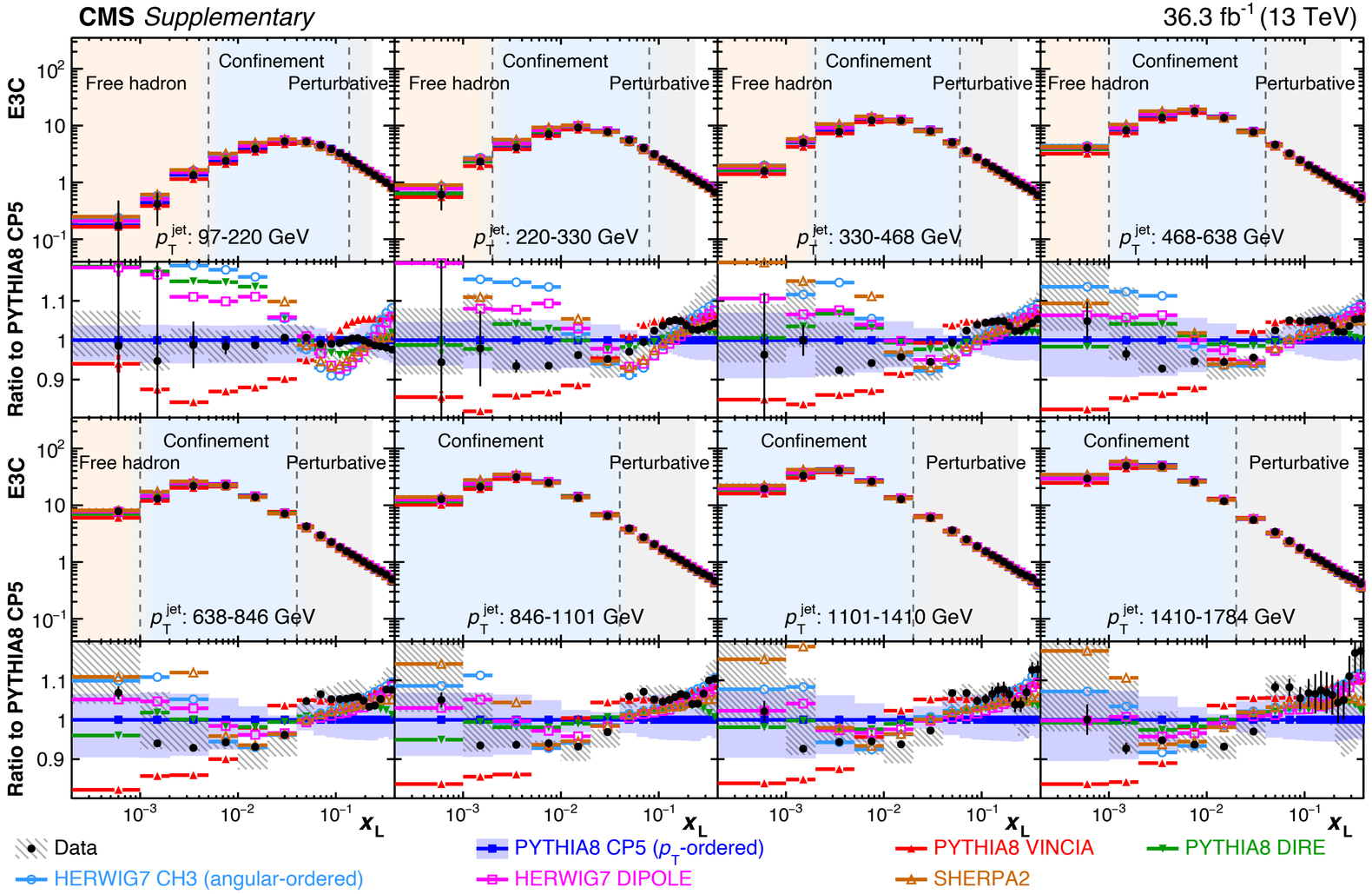


Phase transition
from parton to hadron

Non-interacting hadron
Rising scaling

Interacting partons
Falling scaling

Compare to MC to enhance understanding



Data vs various parton shower model, difference ~ 10%

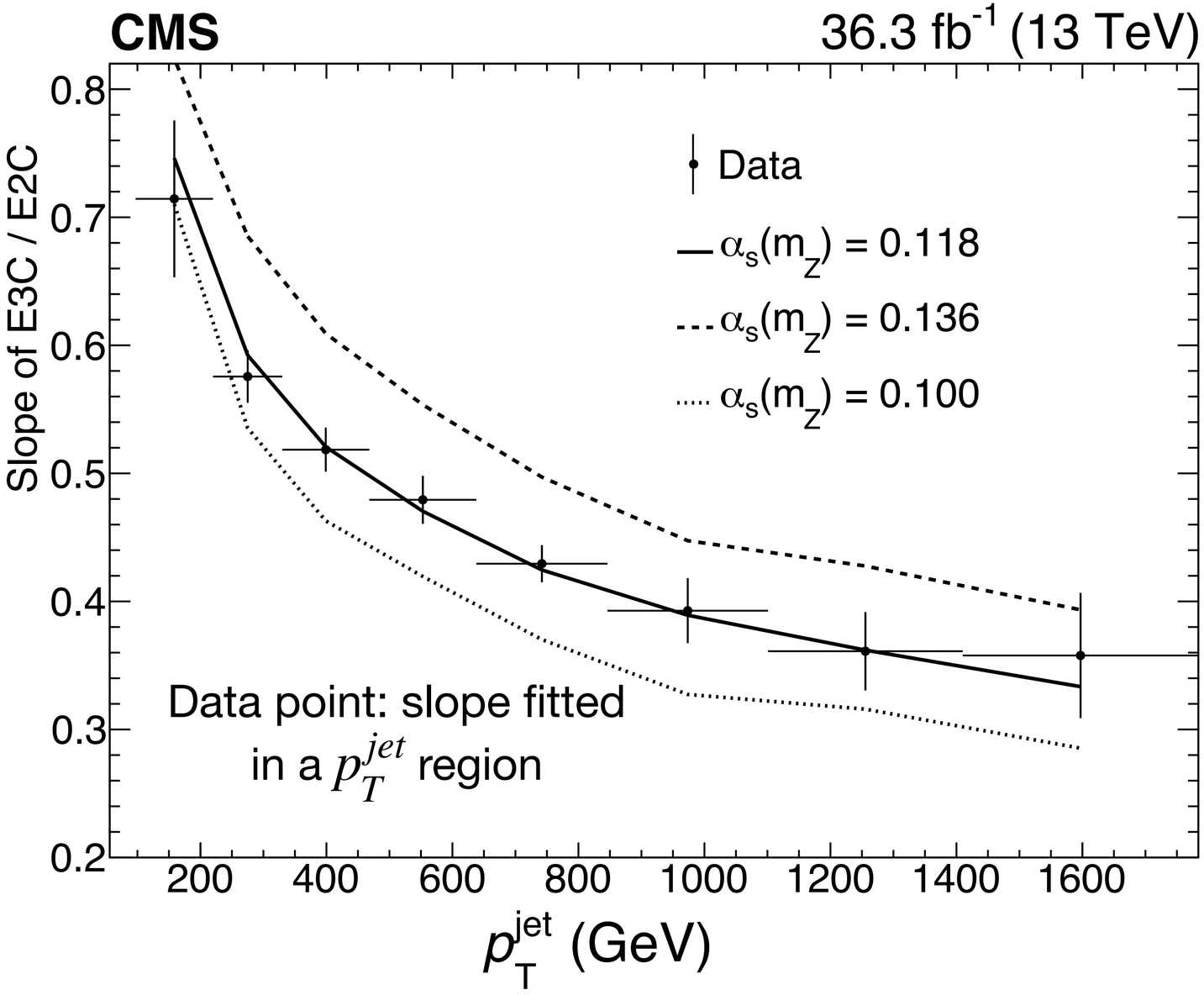
No model match data well in all p_t^{jet} regions

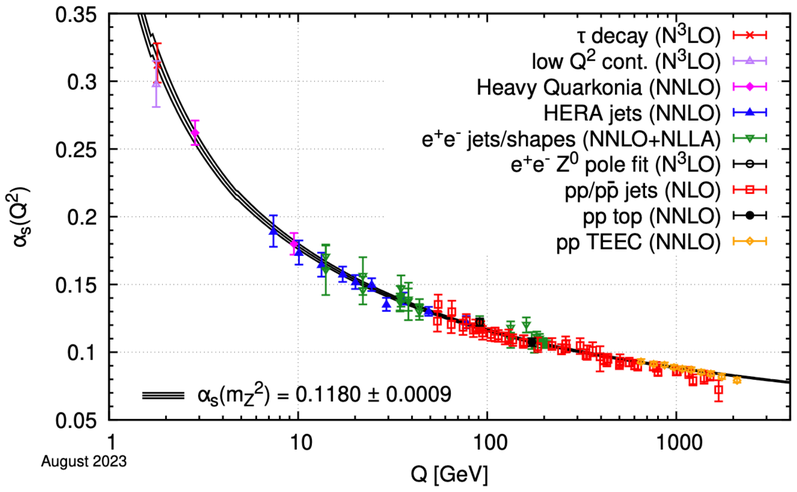
: Data stat error

: Exp systematic

: Theo systematic

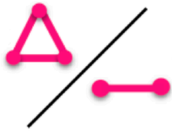
Direct observation of asymptotic freedom





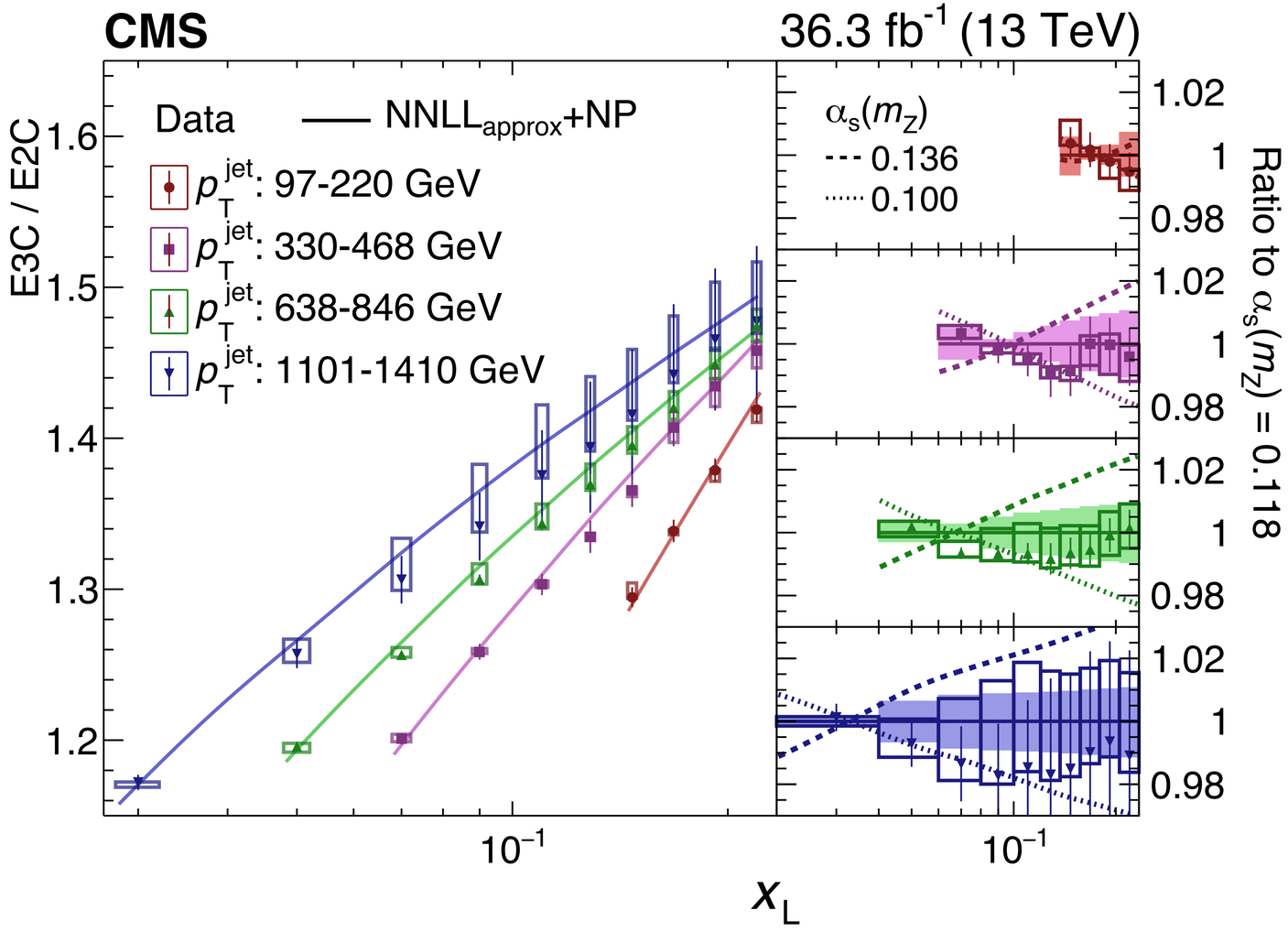
$$p_T^{jet} \uparrow \; Q \uparrow$$

$$\text{Slope} \downarrow \; \alpha_s(Q) \downarrow$$



$$\propto \alpha_S(Q) \ln x_L + O(\alpha_s^2)$$

Most precise α_s determination from jet substructure



$$\alpha_s(m_Z) = 0.1229^{+0.0040}_{-0.0050}$$

$$= 0.1229^{+0.0014(stat.)+0.0030(theo.)+0.0023(exp.)}_{-0.0012(stat.)-0.0033(theo.)-0.0036(exp.)}$$

major source

Covariance matrix

QCD scale of NNLL$_{approx}$

Neutral hadron energy scale

Uncertainty ~ 4%,
most precise from jet-substructure to date

Jet substructure

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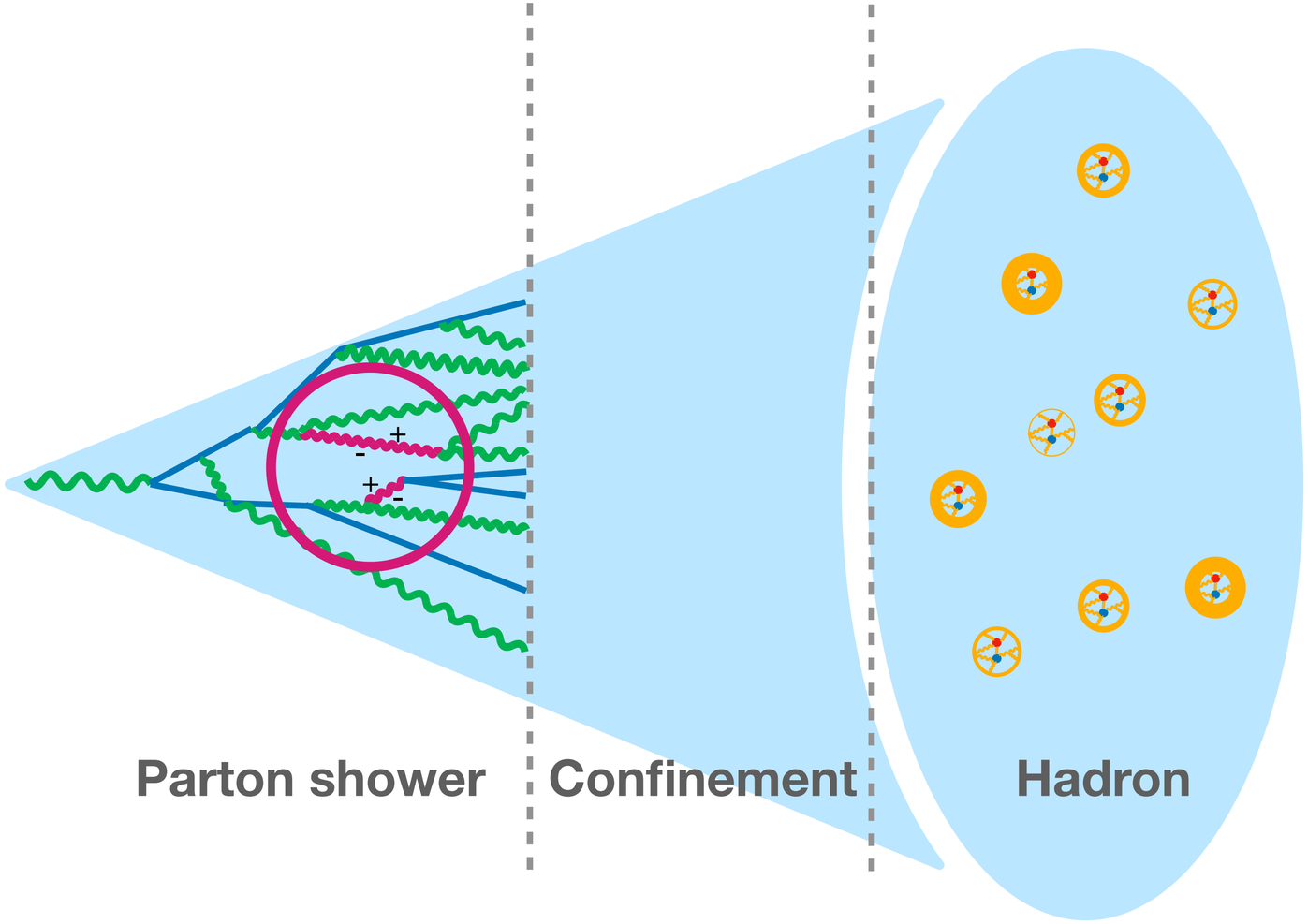
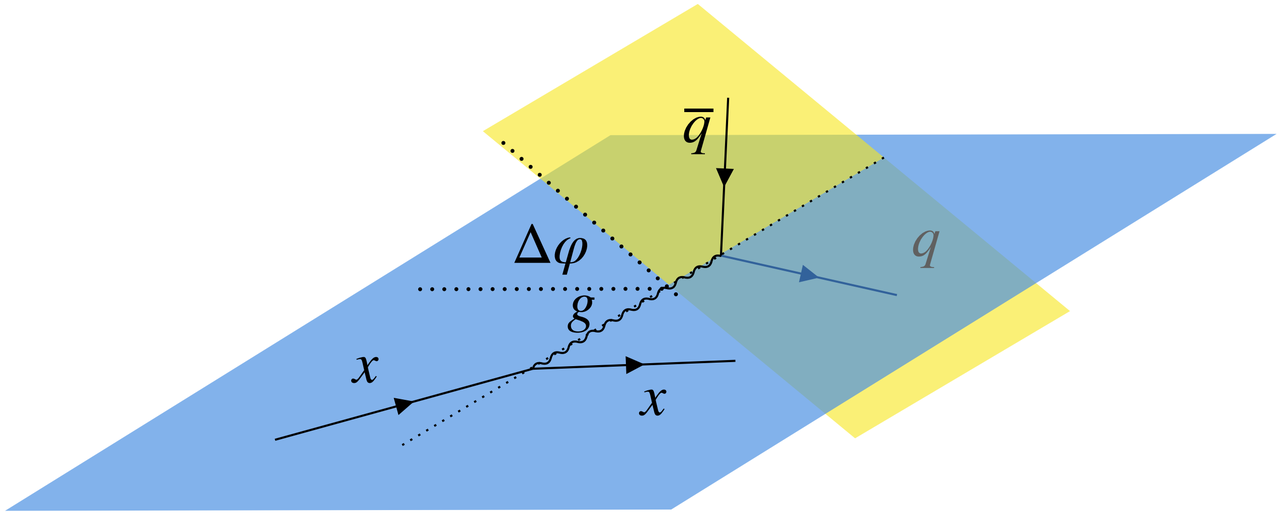
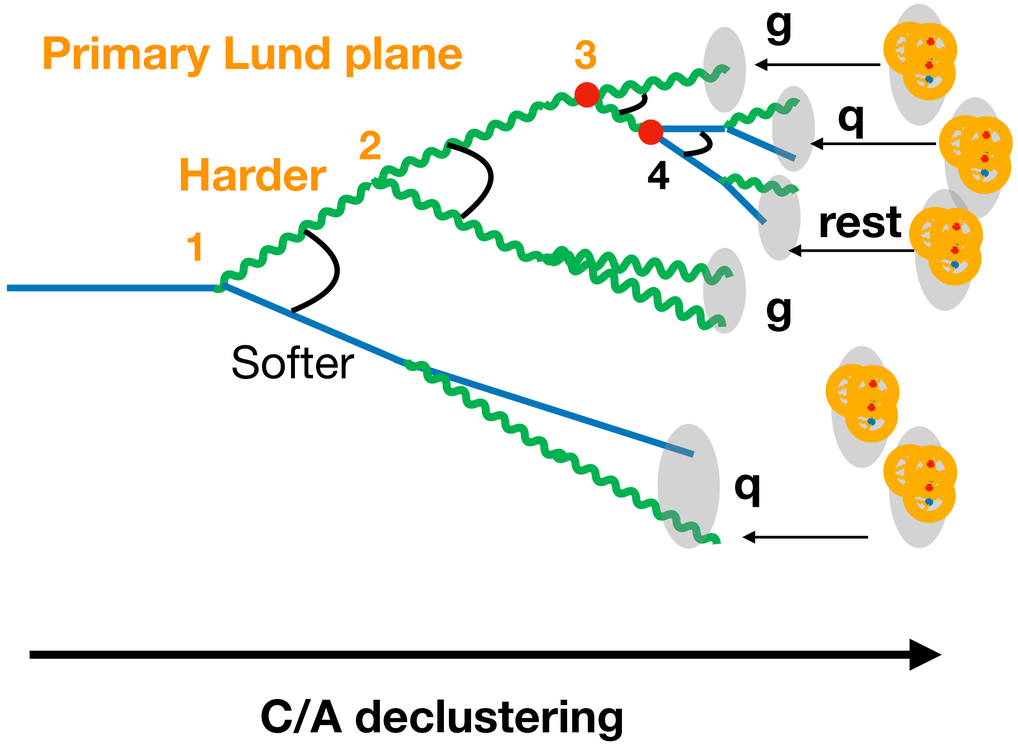


Gluon spin interference

$\Delta\varphi$ follows the distribution: 1 $+Acos(2\Delta\varphi)$ (Arising from Spin Correlation)



$x \to xg(g \to q\bar{q})$



Restore parton splitting chain and flavor tagging

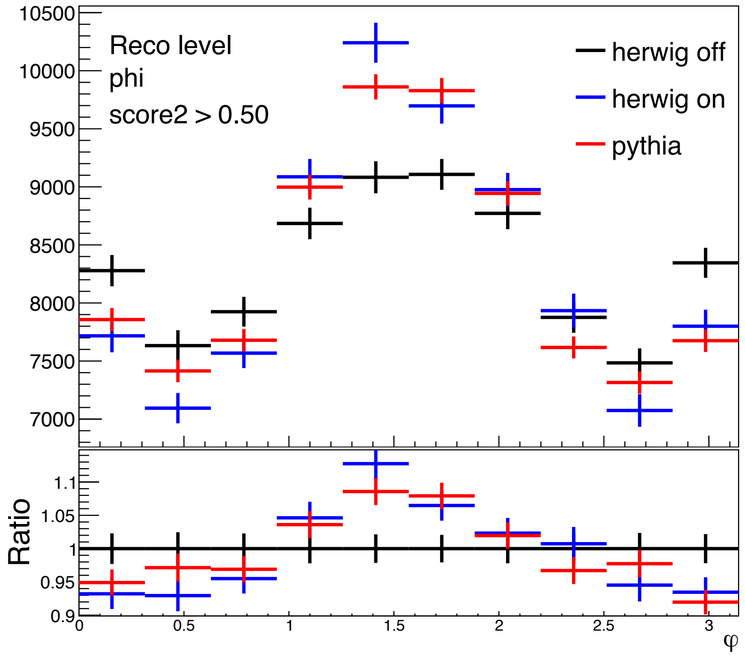
Expected significance

Herwig: Theorectical prediction Pythia: Pseudo Data

Using CombinedLimit Tool to calculate the expected significance

- Include theoretical and experimental systematics
- Included MC stat uncertainty

Score (g→qq) > 0.5
Significance : 7.0 σ



Score (g→qq) > 0.6
Significance : 4.4 σ