

Summer Study on **Jet Physics** and Beyond!

REU-Final Presentation

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Inclusive Jet and Dijet Cross-sections from $\sqrt{s}=7$ TeV pp collision

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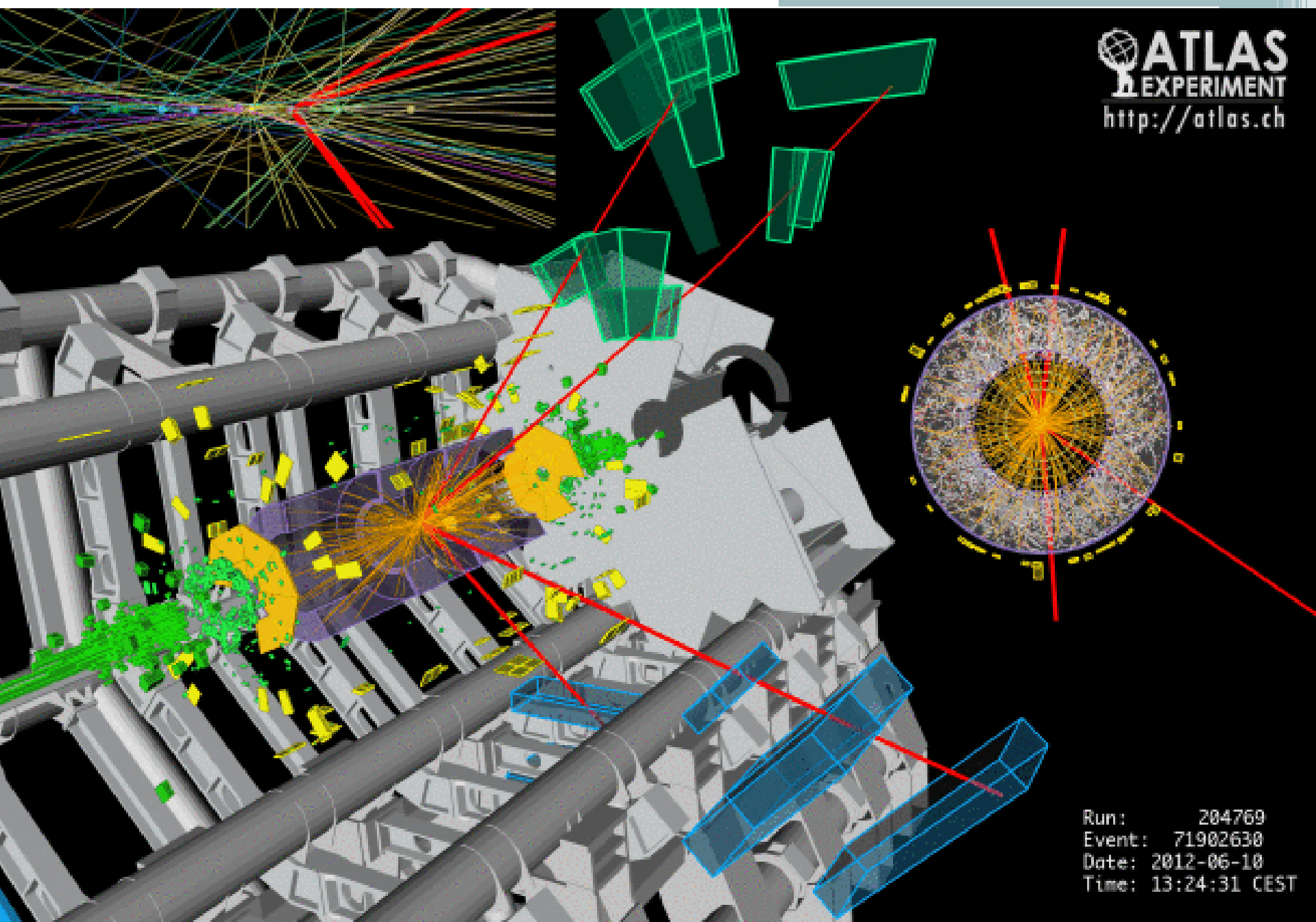
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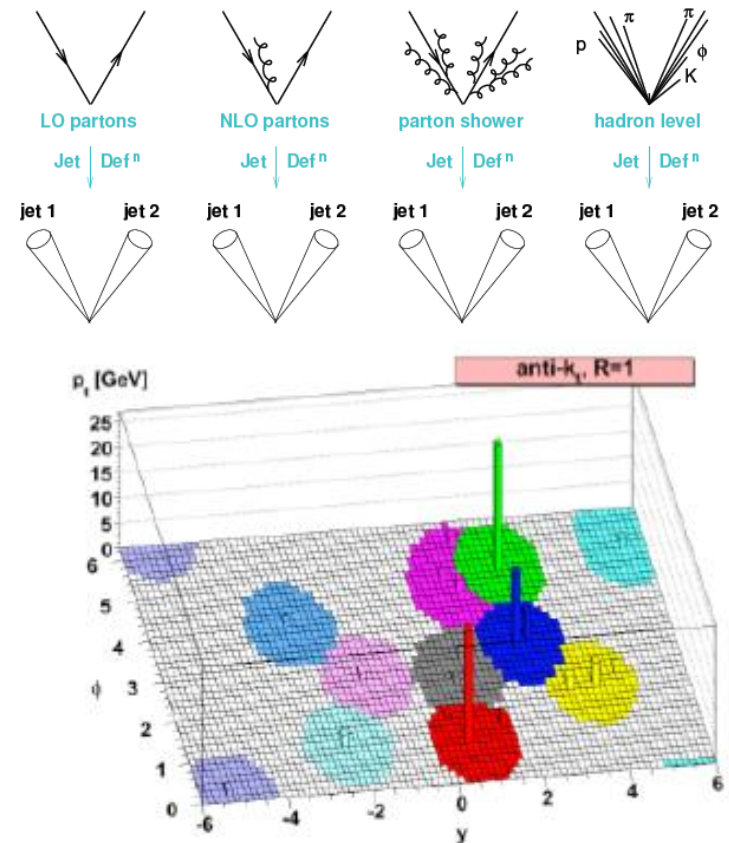
Visiting **UC Berkeley** next academic year!





Outline

- Why study Jet?
 - a. QCD
 - b. New physics hidden behind
 - c. Early Universe- QGP
- Project goal!
 - a) Inclusive and Dijet? Why?
 - b) Atlas vs CMS
 - c) LO/NLO vs Data
 - d) QCD Fit
 - e) Factorization/Renormalization
- Future Outlook



From Prof. Gavin Salam 's lecture

1. High- Q^2 Scattering

2. Parton Shower

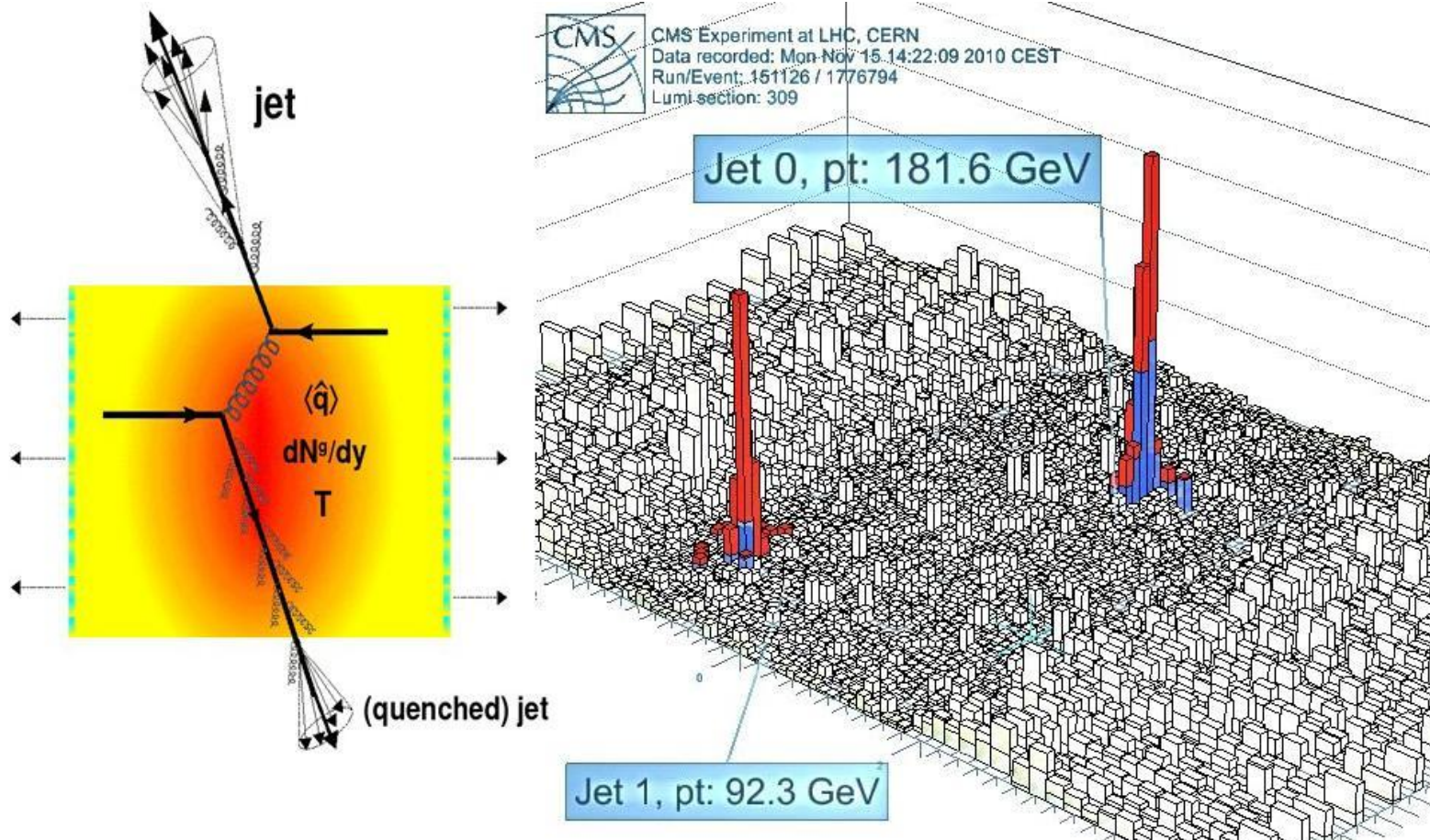
**New Physics
Hides here**

Sherpa artist

3. Hadronization

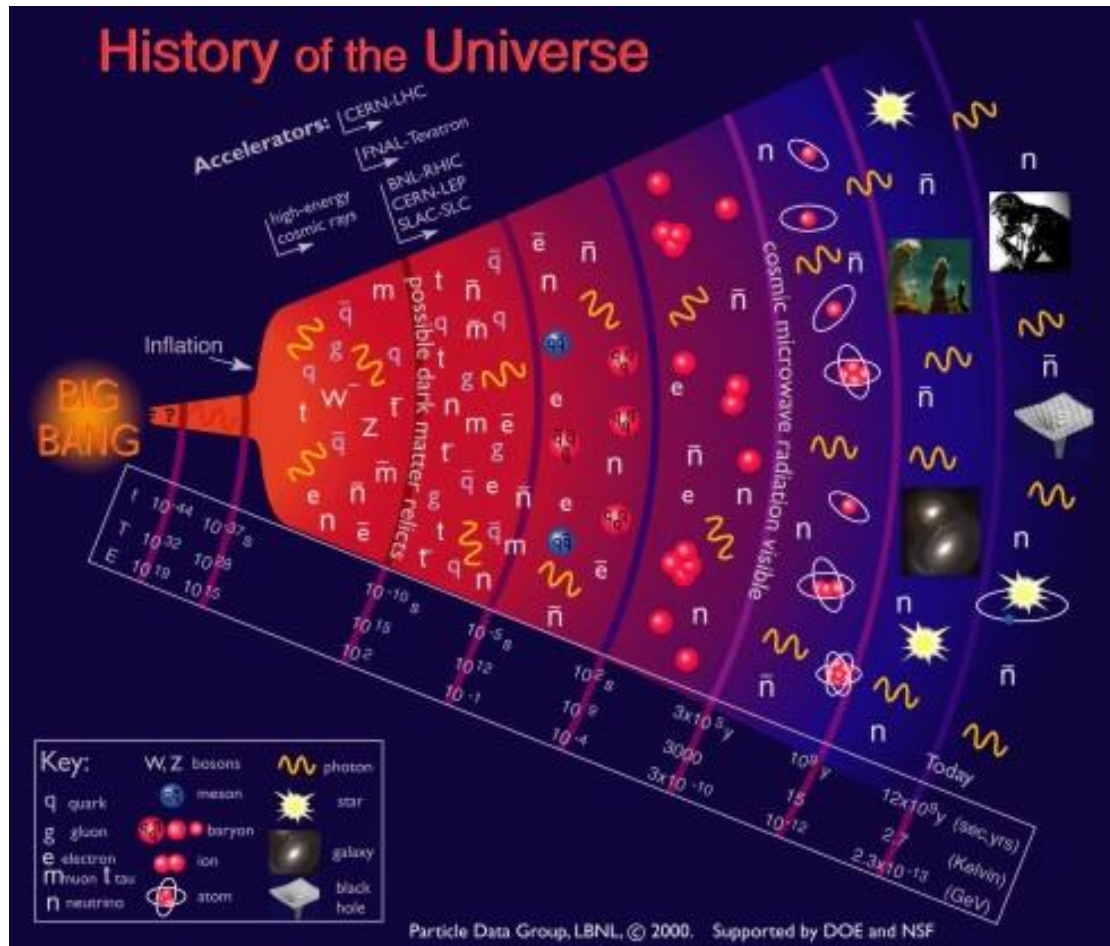
4. Underlying Event

from **Jet-quenching** to ...



Jet quenching illustration from CMS artist/analyst

Quark-Gluon Plasma / Early Universe



Inclusive and Dijet: The Data

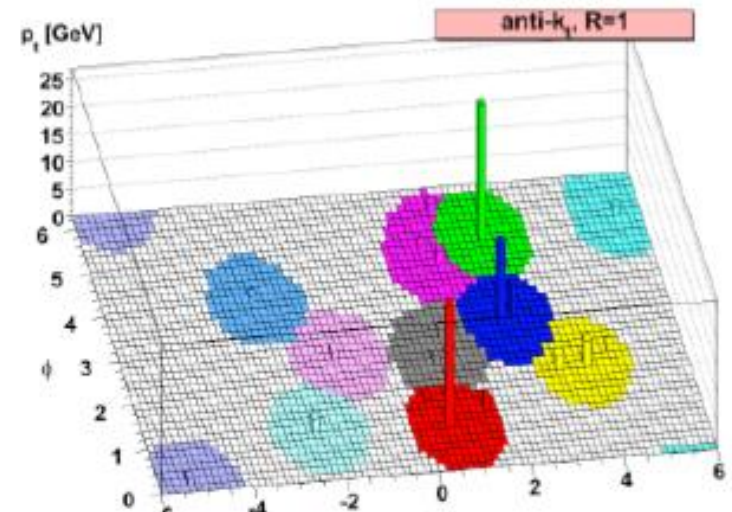
- From pp collision of $\sqrt{s} = 7 \text{ TeV}$
- **ATLAS** : 2010 data of a total integrated luminosity of 37 inverse picobarns. Anti-kT algorithm with area parameter $R=0.4$ and $R=0.6$
- **CMS**: 34 inverse picobarns, $R=0.5$ for CMS.
- jet rapidity range $|y| < 4.4$, covering p_T from 20 GeV to 1.5 TeV and dijet invariant masses from 70 GeV to 5 TeV. (for ATLAS, CMS is slightly different)

Why **Inclusive Jet** and **Dijet**?

- Not process/model dependent research
- Convenient for theorists and experimentalists (no worries on background)
- **Simple** and **relevant**
- Best for **QCD** interests
- **Know how far we can go to go beyond**

Why anti-K_T?

- Collinearly safe
- Soft/infrared Safe
- Regular Jet Area-
look at that **Fantastic Shape**!



- Based on the following **distance measures**:

- ★ distance d_{ij} between two particles i and j :

$$d_{ij} = \min \left(k_{Ti}^{2p}, k_{Tj}^{2p} \right) \frac{\Delta_{ij}}{D}$$

$$\Delta_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2$$

- ★ distance between any particle i and the beam (B) d_{iB} :

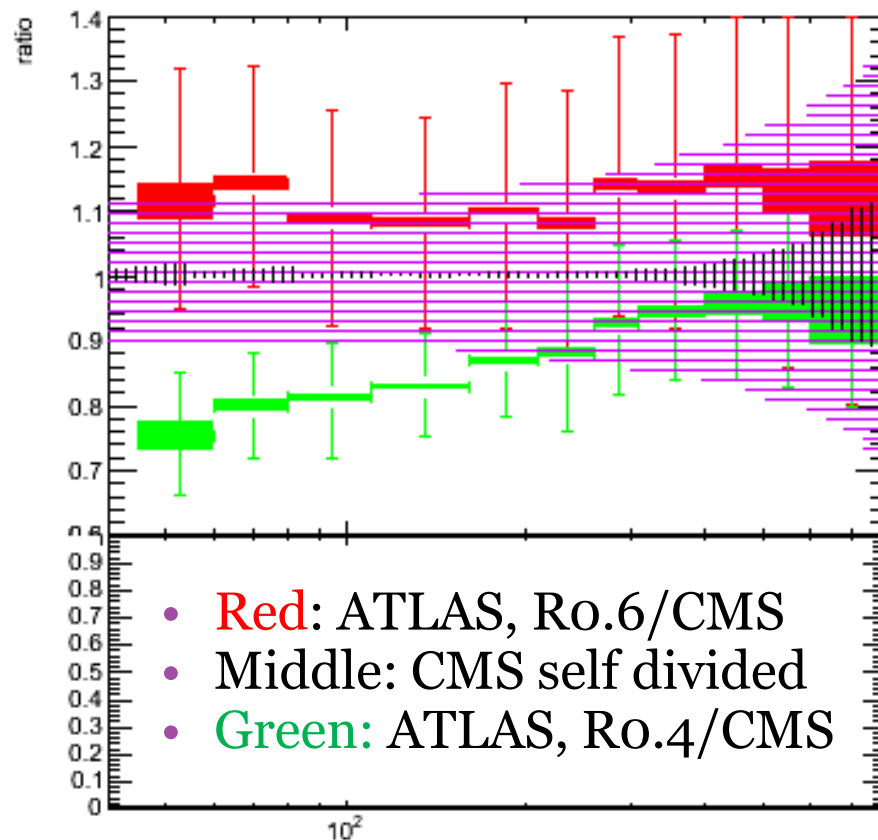
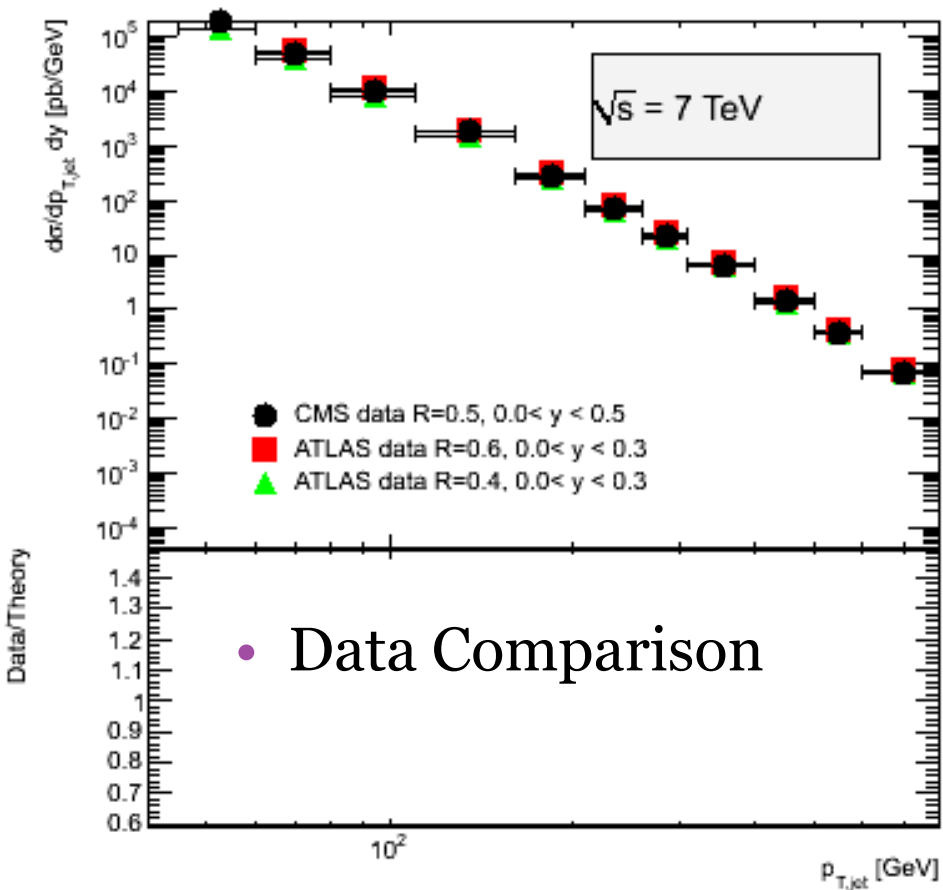
$$d_{iB} = k_{Ti}^{2p}$$

$p = -1$ for anti- k_T . $p < 0$ brings its features!

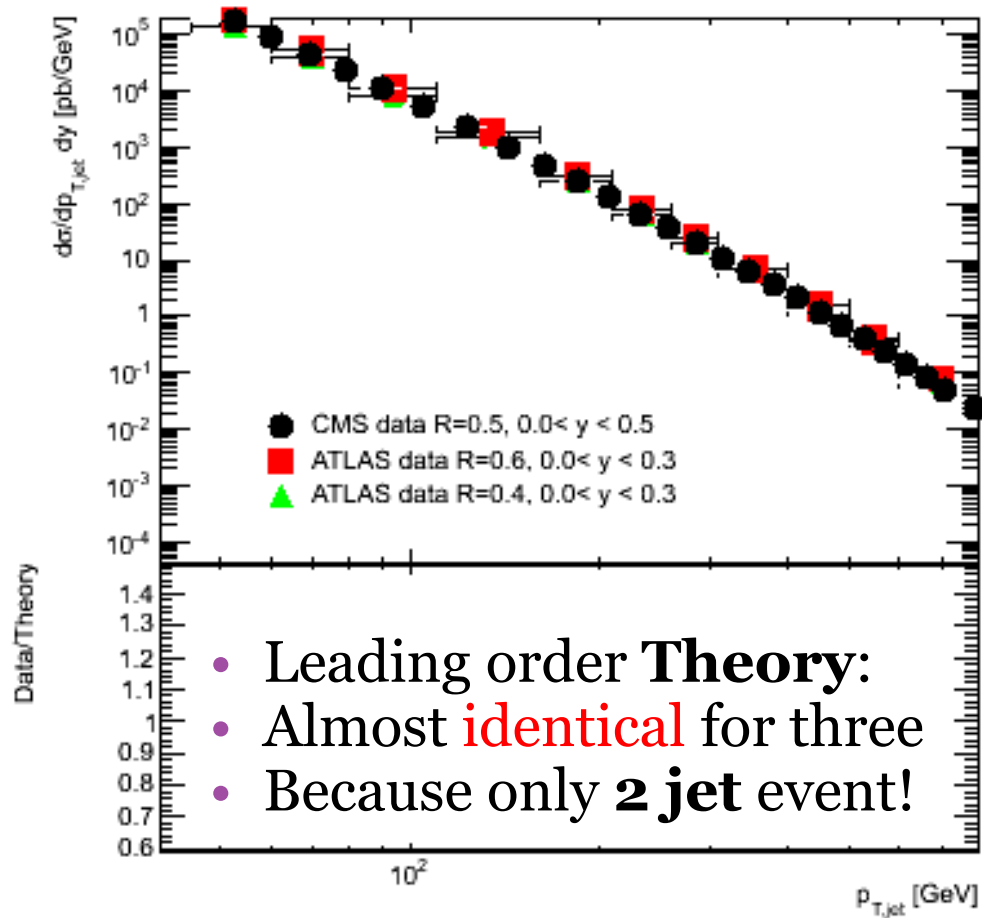
- Compute all distances d_{ij} and d_{iB} , find the **smallest**

- ★ if smallest is a d_{ij} , **combine** (sum four momenta) the two particles i and j , update distances, proceed find next smallest
- ★ if smallest is a d_{iB} , **remove** particle i , call it a **jet**

ATLAS vs CMS: Inclusive Jet Cross section



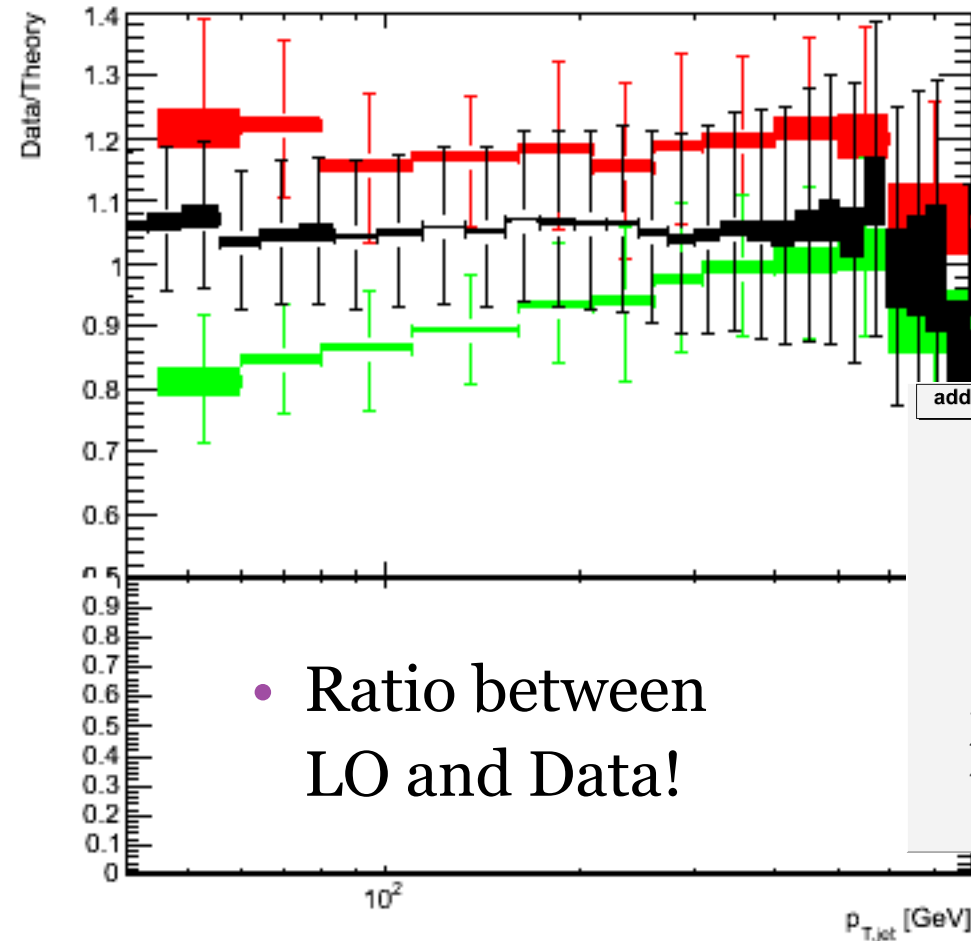
LO for inclusive Jet cross section



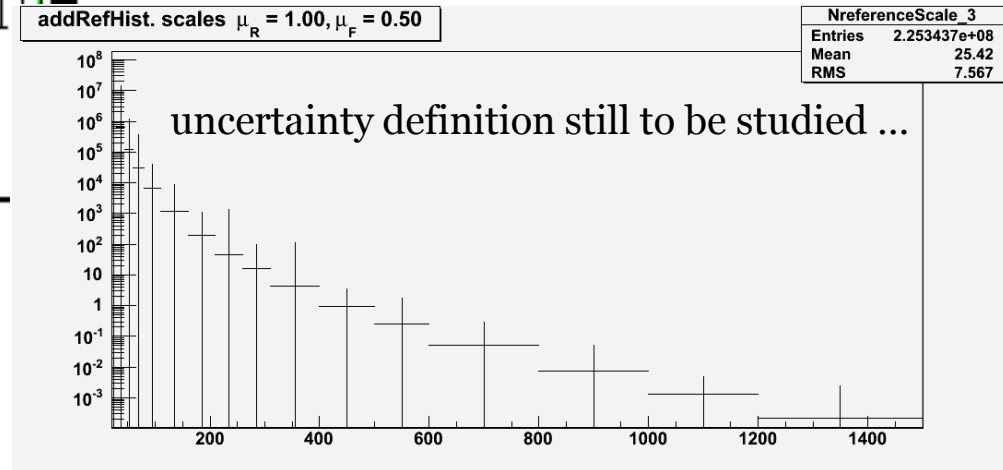
- Eight relevant **QCD 2->2** parton-parton scattering

$$\begin{aligned}
 qq' &\rightarrow qq' \\
 q\bar{q} &\rightarrow q'\bar{q}' \\
 qq &\rightarrow qq \\
 q\bar{q} &\rightarrow q\bar{q} \\
 q\bar{q} &\rightarrow gg \\
 gg &\rightarrow q\bar{q} \\
 qg &\rightarrow qg \\
 gg &\rightarrow gg
 \end{aligned}$$

LO/NLO Calculation and Comparisons



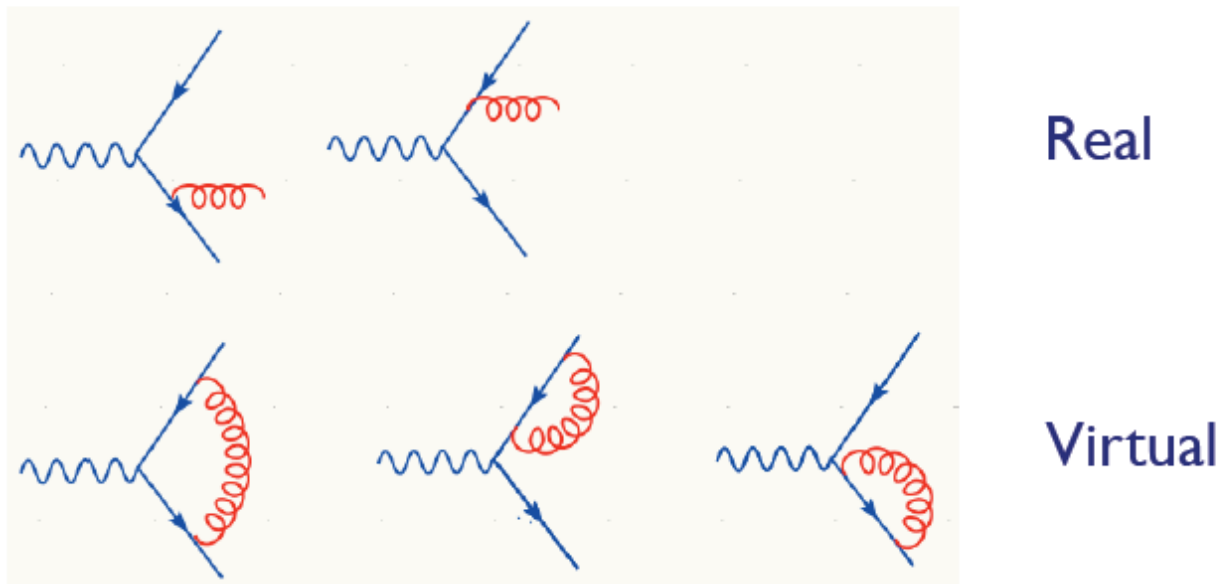
- Three should come closer to 1 in NLO!



- Working on scales and error bar...

What does that mean NLO?

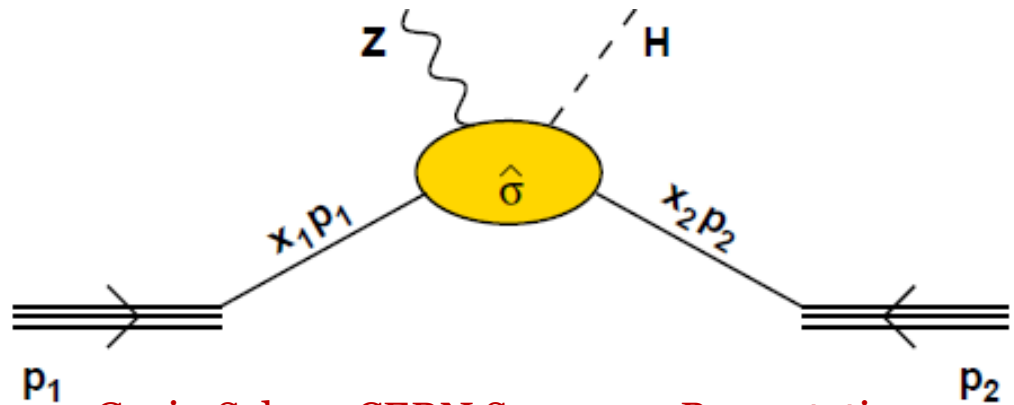
ANATOMY OF A NLO CALCULATION



- **Loop Corrections**
- 2 Jets to 2 or 3 Jets (**Extra External Leg**)
- Need to consider renormalization and hence μ_r comes into play

Factorization . Cross Section . PDF .

Cross section for some hard process in hadron-hadron collisions



Gavin Salam, CERN Sep. 2010 Presentation

$$\sigma = \int dx_1 f_{q/p}(x_1, \mu^2) \int dx_2 f_{\bar{q}/\bar{p}}(x_2, \mu^2) \hat{\sigma}(x_1 p_1, x_2 p_2, \mu^2), \quad \hat{s} = x_1 x_2 s$$

Total cross section can be described by parton distribution function and hard process->
where the **factorization scale** μ_f comes into play!

Renormalization scale illustrated

QCD corrections can be expressed as an power series:

$$\Delta_{\text{QCD}}(\mu_r) = \frac{\alpha_s(\mu_r)}{\pi} + [1.4092 + 1.9167 \ln \frac{\mu_r^2}{s}] \left(\frac{\alpha_s(\mu_r)}{\pi} \right)^2 + [-12.805 + 7.8179 \ln \frac{\mu_r^2}{s} + 3.674 \ln^2 \frac{\mu_r^2}{s}] \left(\frac{\alpha_s(\mu_r)}{\pi} \right)^3 + \dots$$

in lowest order we have
no clue what the scale is

in higher orders both α_s and the
coeff. fct. depend logarith. on
the scale: cancellations

&
 μ_r should be of the order of s

Future Outlook

- non-perturbative correction- **Shower, Underlying Events...**
- **QCD fit**: parameters in the PDF
- Determine **factorization/renormalization scales**

...I also spend my time talk to these guys, to know my future study...



Apparently not the best of times...

- No major deviation from the Standard Model
- Harder to build new **discovery machine**
- **SUSY** and **Extra dimensions** haven't showed up maybe in TeV region?
- **Too many ideas, constraints, less surprising**
 - **hard time for Phenomenologist!**

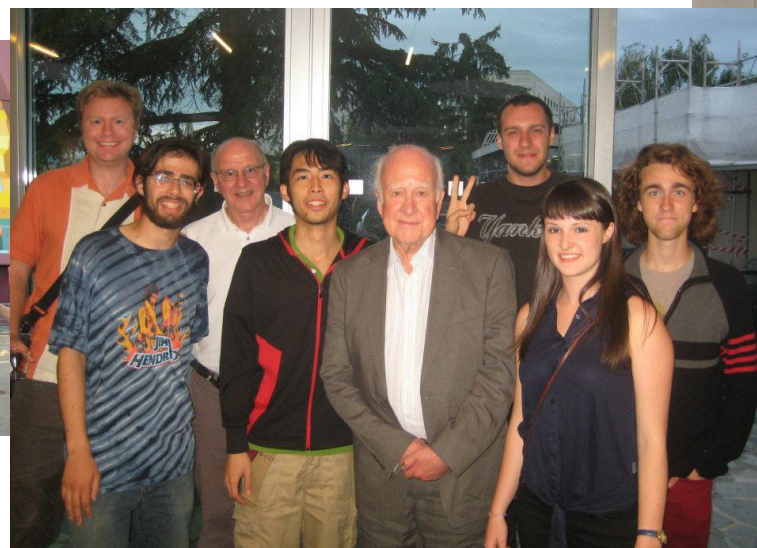
Also not the worst of times ...

- Wait for **next February (spin)** and **years to come (couplings)**
 - **LHC**, **ILC** and **CLIC** – precision time again
 - Still super exciting to be a **HEP Experimentalist**
 - **Cosmological** observations thriving
 - **exciting time for experimentalists still**
- Eying ILC and Cosmology

It is our time

Let's get the party started

Know how far we can go to go beyond!



Thanks, REU group!

