Summer Study on Jet Physics and Beyond!

REU-Final Presentation

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Inclusive Jet and Dijet Cross-sections from √s= 7 TeV pp collision

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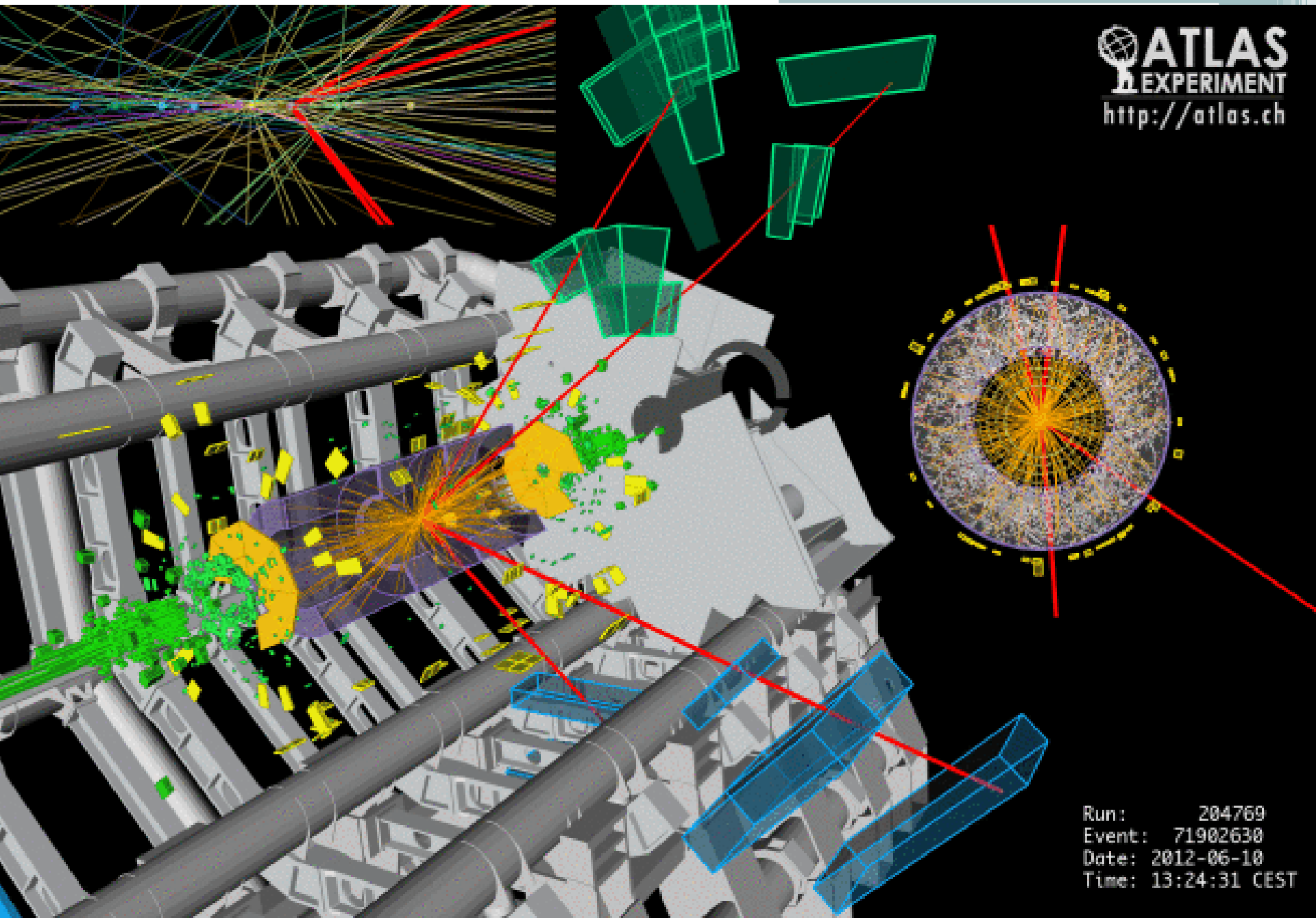
Exchange to **UC Berkeley** next semester for 1 year!


ATLAS
EXPERIMENT
http://atlas.ch
Run: 204769
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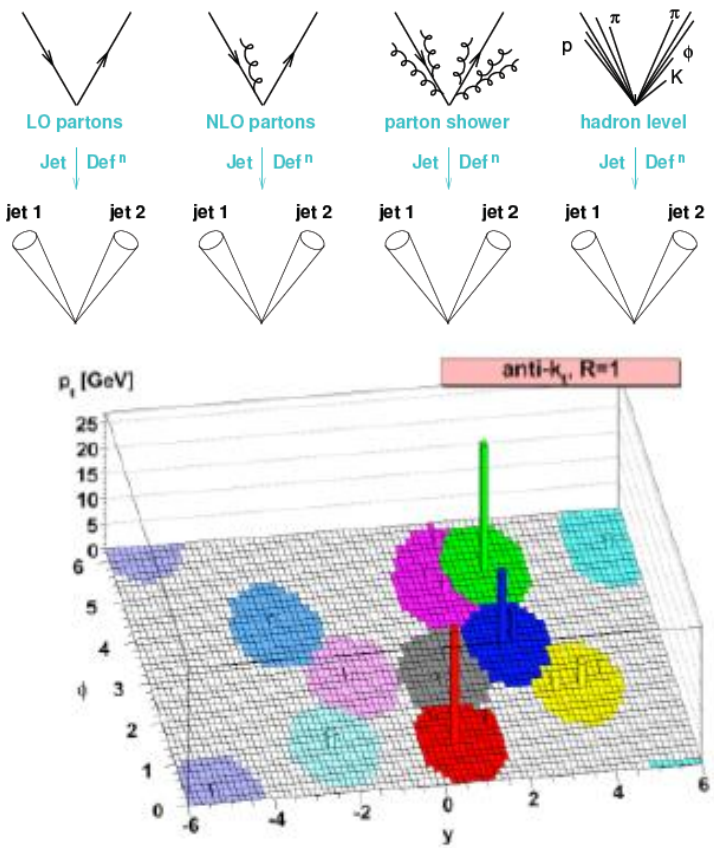
Date: 2012-06-10
Time: 13:24:31 CEST

Outline

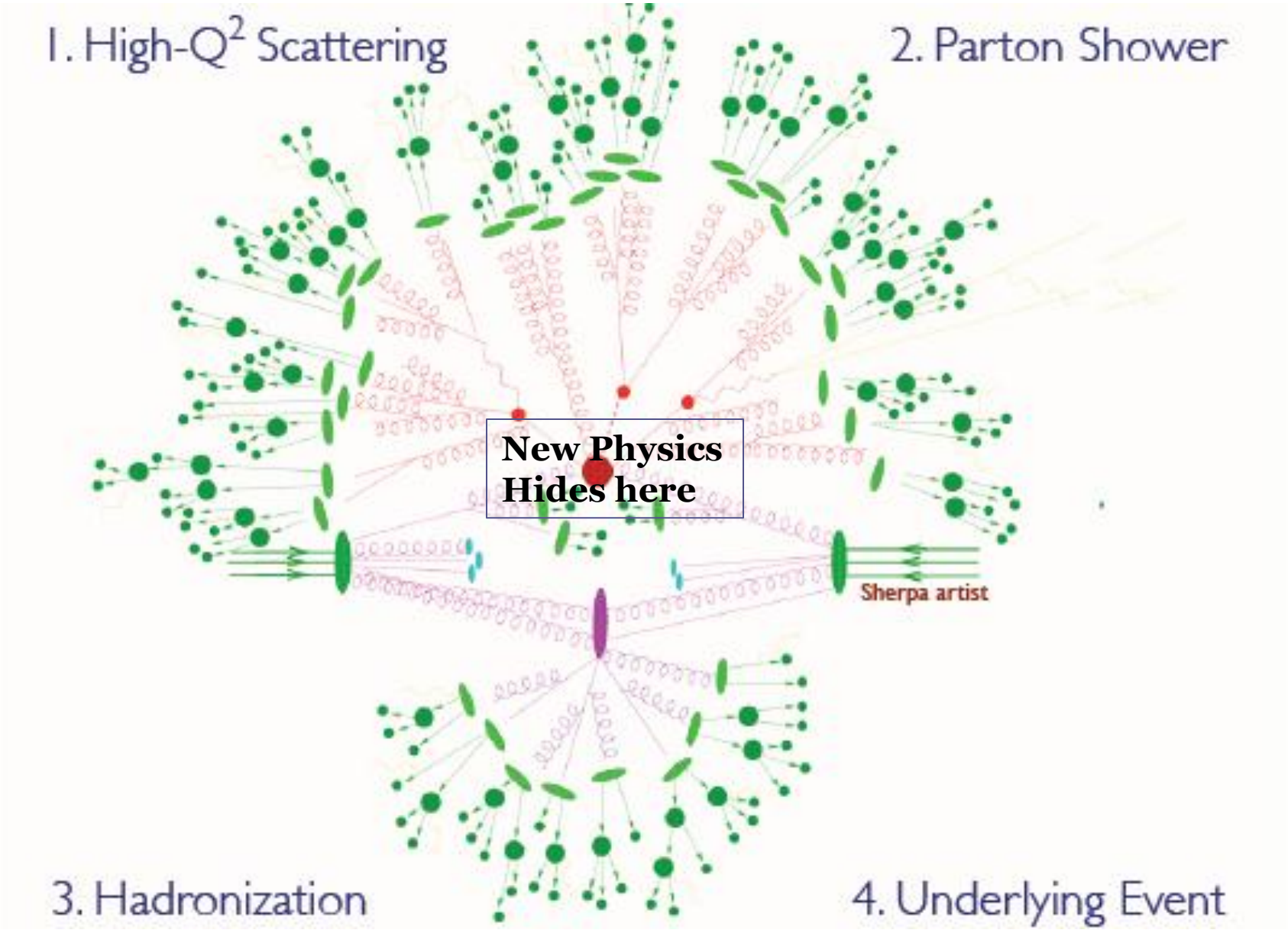
- Why study Jet?
  a. **QCD**
  b. **New physics** hidden behind
  c. Early Universe- **QGP**

- Project goal!
  a) **Inclusive** and **Dijet**? Why?
  b) **Atlas** vs **CMS**
  c) **LO/NLO** vs Data
  d) QCD Fit
  e) **Factorization/Renomalization**

- Future Outlook

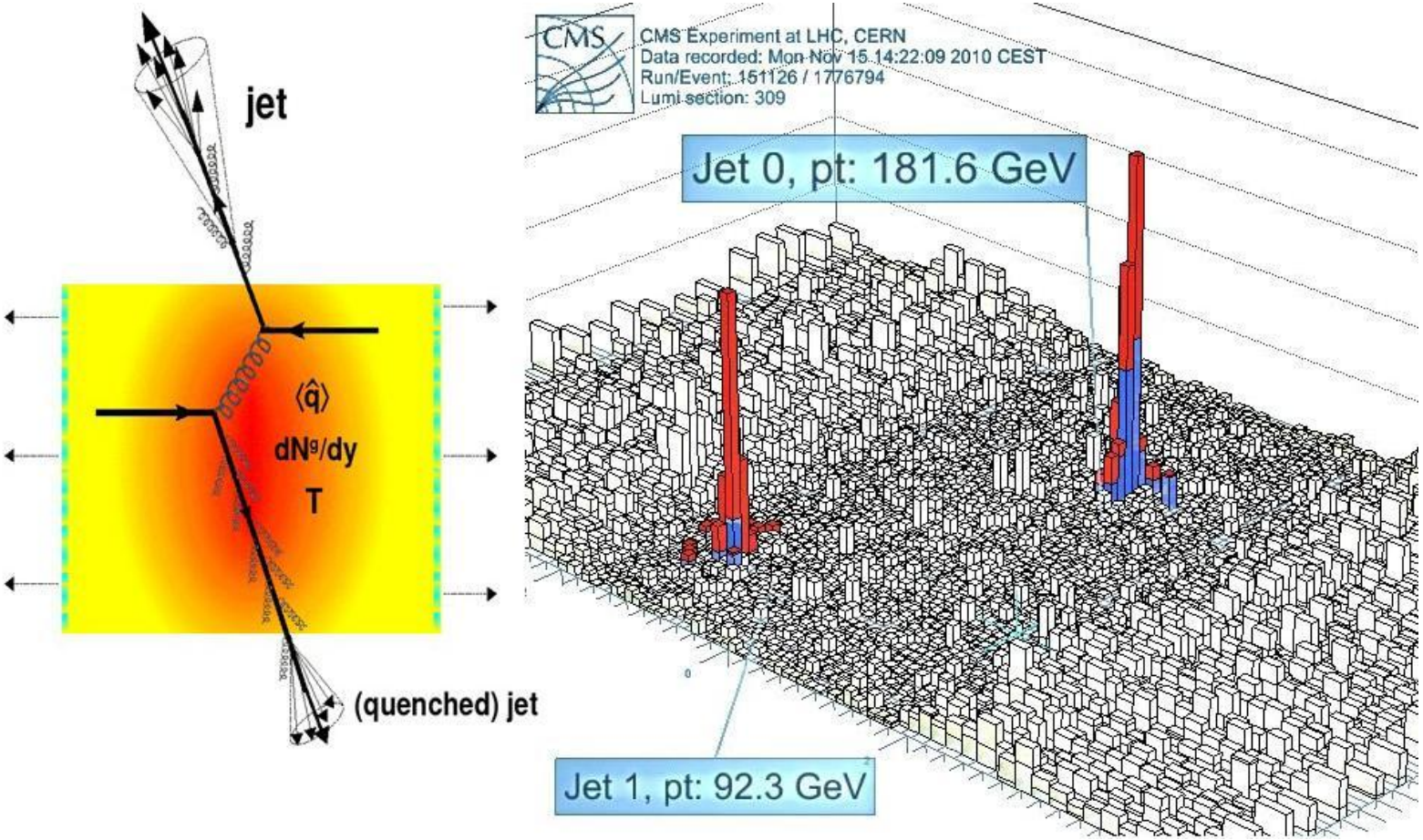


From Prof. Gavin Salam 's lecture



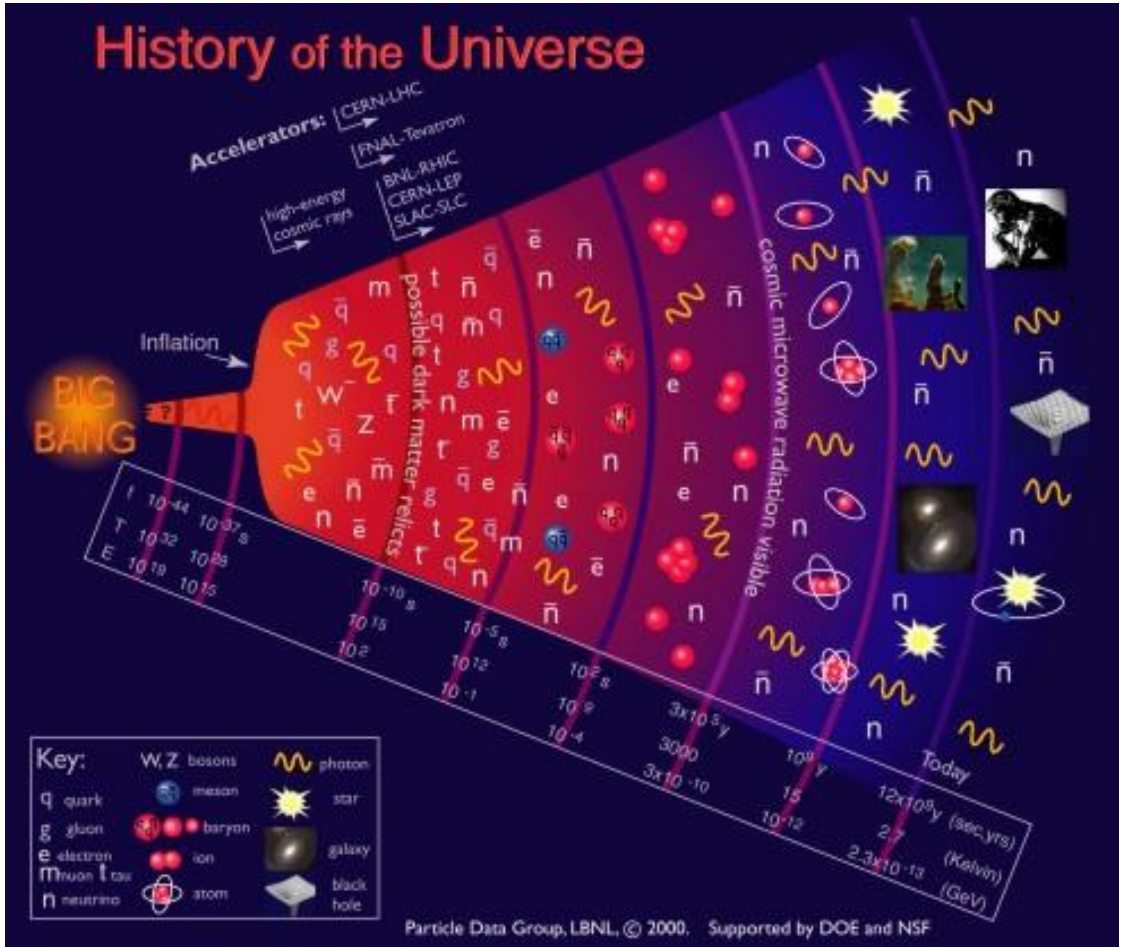
By Sherpa Artist: http://sherpa.hepforge.org/doc/SHERPA-MC-1.2.0/Sherpa_7.html

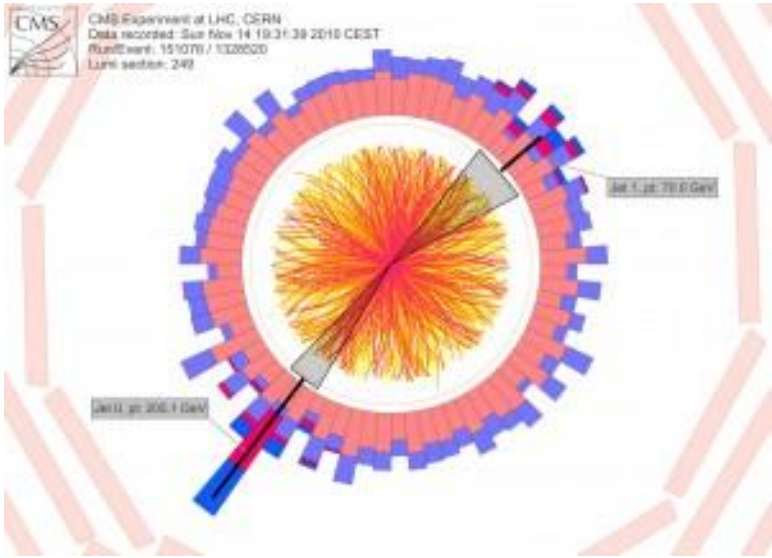
from **Jet-quenching** to …



Jet quenching illustration from CMS artist/analyst

Quark-Gluon Plasma/ Early Universe





Jet quenching in the CMS detector

Inclusive and Dijet: The Data

- From pp collision of **$\sqrt{s}$ = 7 TeV**

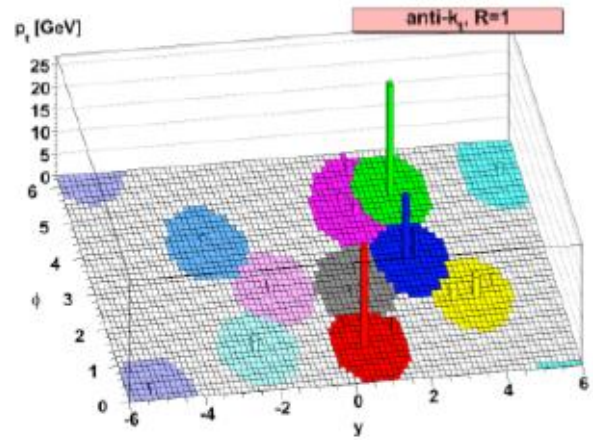
- **ATLAS :** 2010 data of a total integrated luminosity of 37 inverse picobarns. Anti-kT algorithm with area parameter R=0.4 and R=0.6
- **CMS:** 34 inverse picobarns, R=0.5 for CMS.

- jet rapidity range |y|<4.4, covering pT 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 $\mathbf{d_{ij}}$ between two particles i and j:

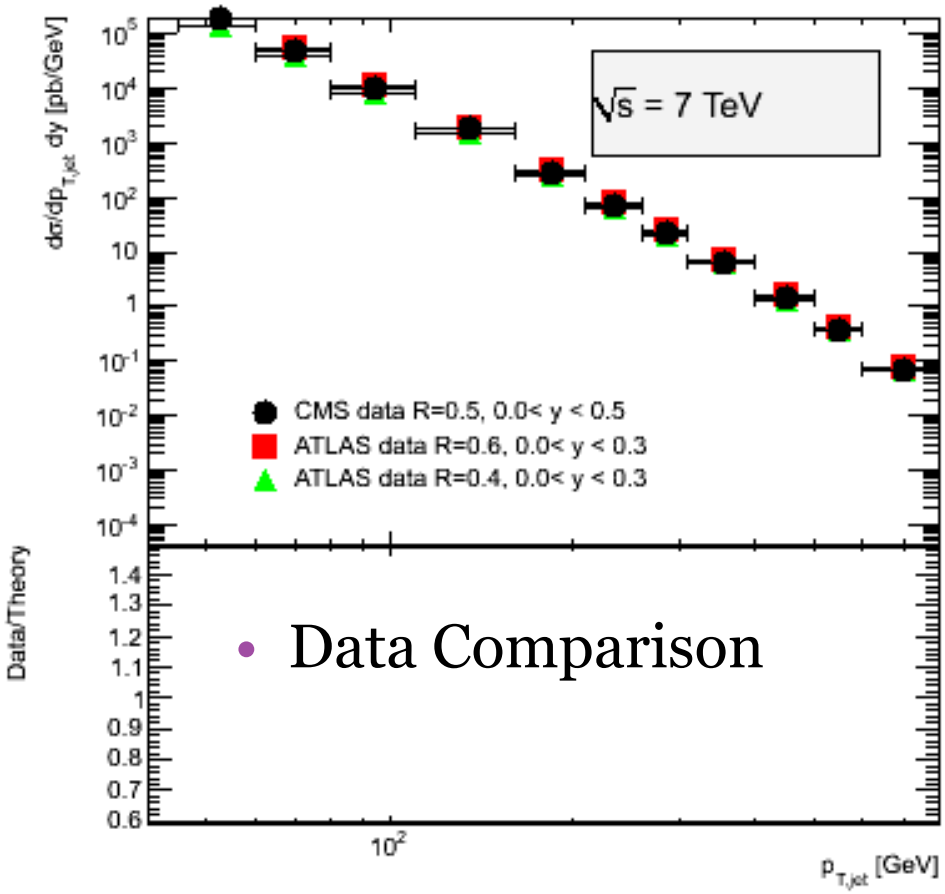
$$\boxed{d_{ij} = \min\left(k_{\mathrm{T}i}^{2p}, k_{\mathrm{T}j}^{2p}\right)\frac{\Delta_{ij}}{D}} \qquad \Delta_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2$$

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

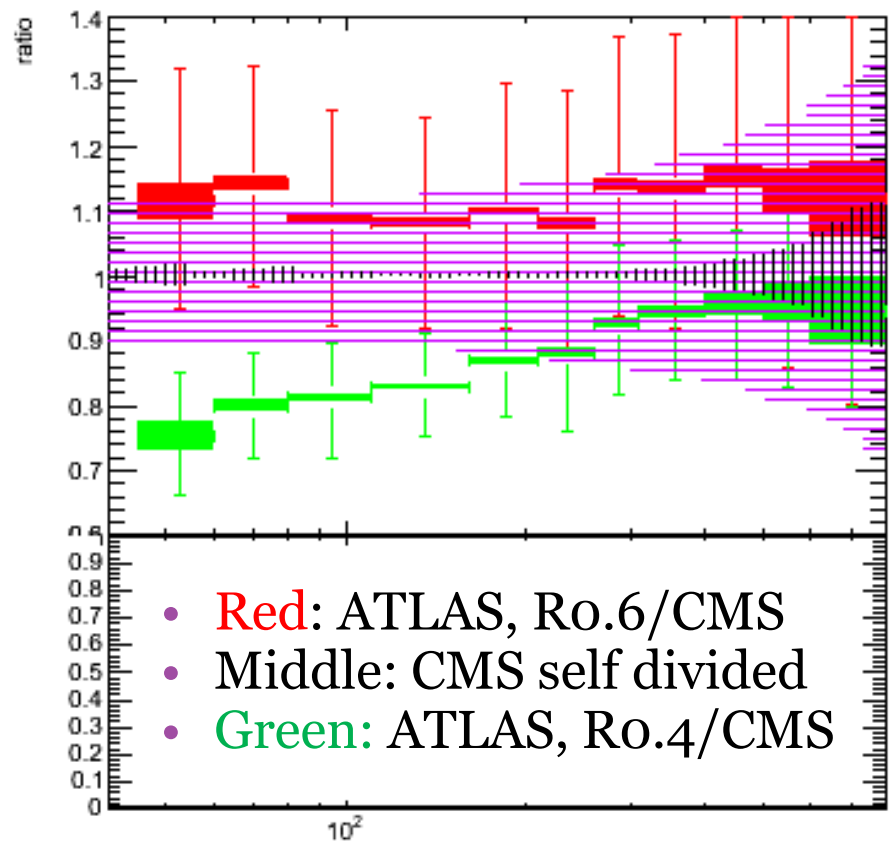
$$\boxed{d_{iB} = k_{\mathrm{T}i}^{2p}}$$

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

ATLAS vs CMS:
Inclusive Jet Cross section

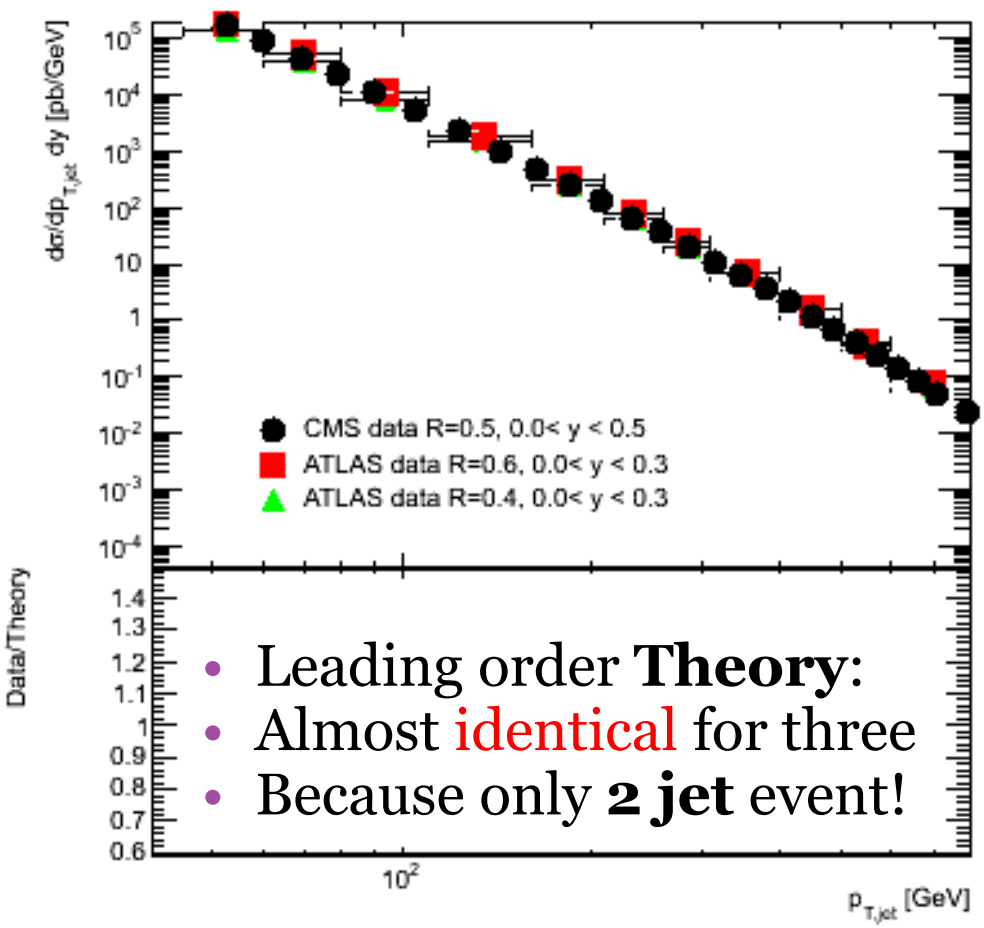


- Data Comparison



- Red: ATLAS, R0.6/CMS
- Middle: CMS self divided
- Green: ATLAS, R0.4/CMS

LO for inclusive Jet cross section

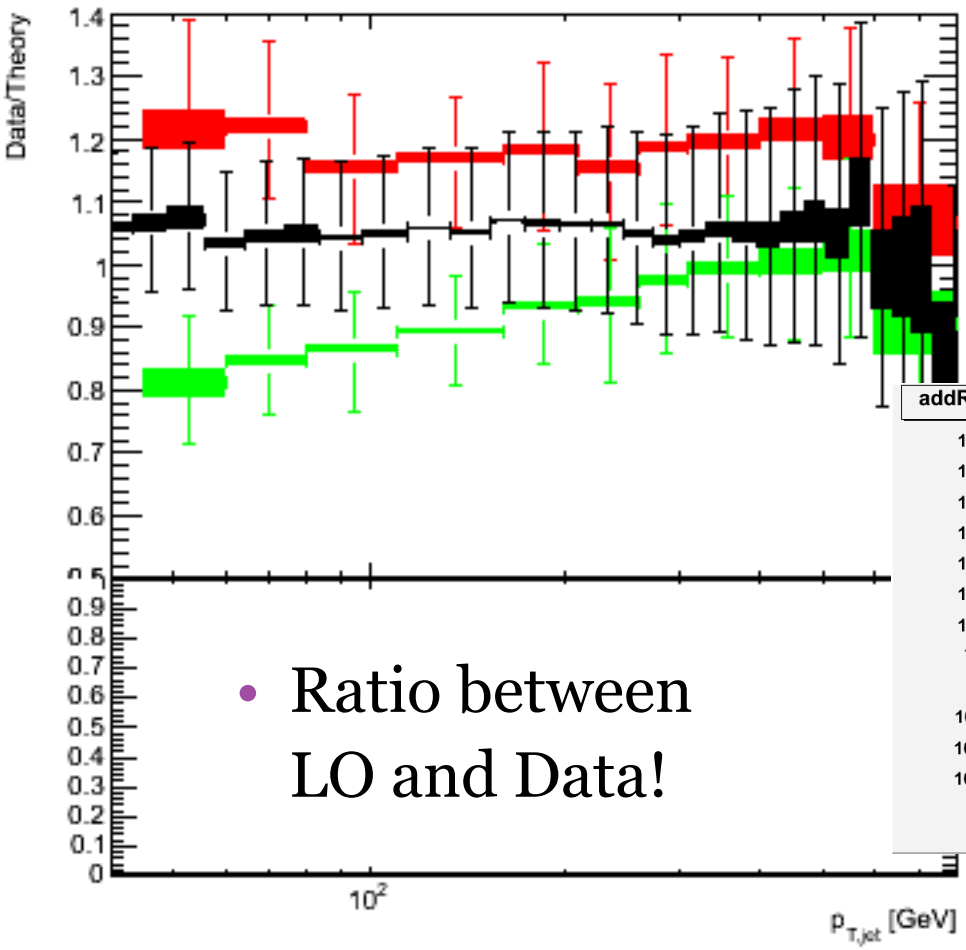


- Leading order **Theory**:
- Almost identical for three
- Because only **2 jet** event!

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

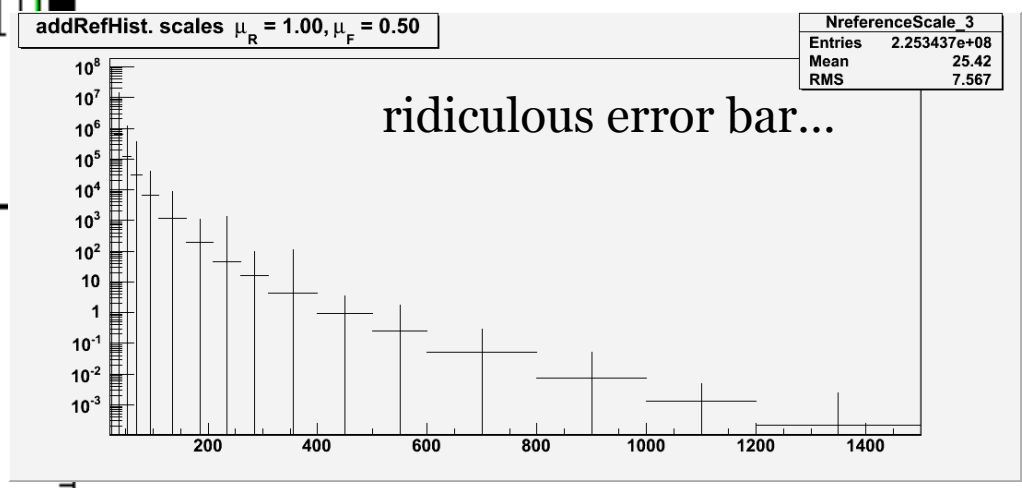
$$qq' \rightarrow qq'$$
$$q\bar{q} \rightarrow q'\bar{q}'$$
$$qq \rightarrow qq$$
$$q\bar{q} \rightarrow q\bar{q}$$
$$q\bar{q} \rightarrow gg$$
$$gg \rightarrow q\bar{q}$$
$$qg \rightarrow qg$$
$$gg \rightarrow gg$$

LO/NLO Calculation and Comparisons



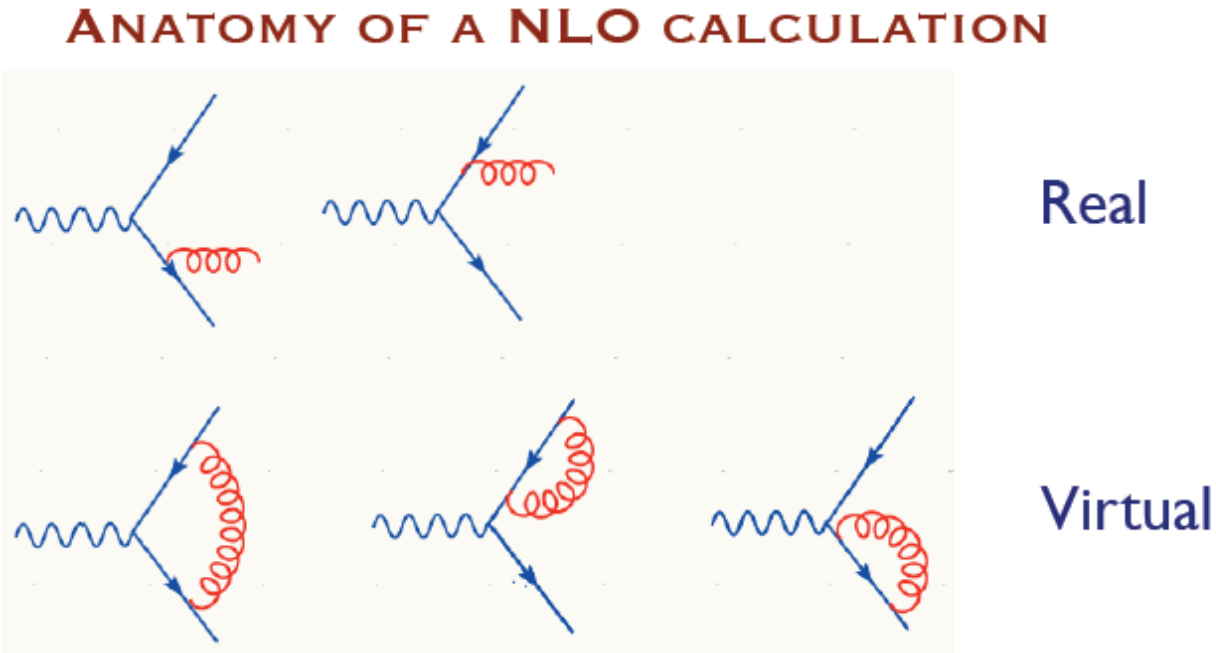
- Ratio between LO and Data!

- Three should come closer to 1 in NLO!



- Working on scales and error bar...

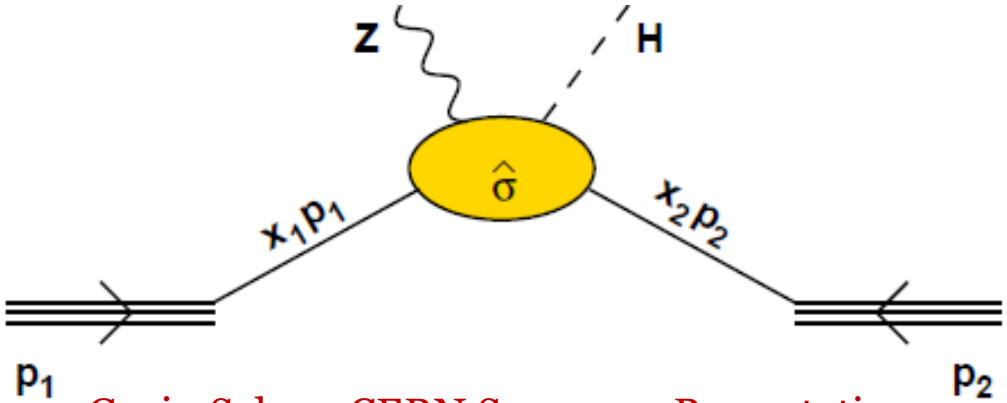
What does that mean NLO?



- **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:

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

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

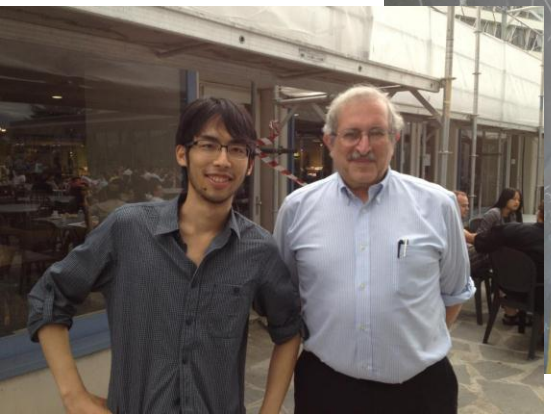
&

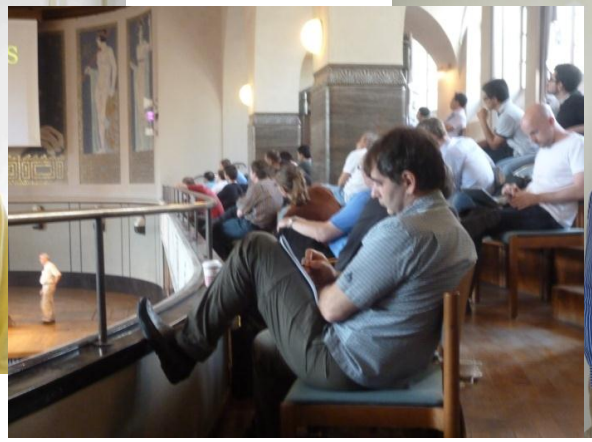
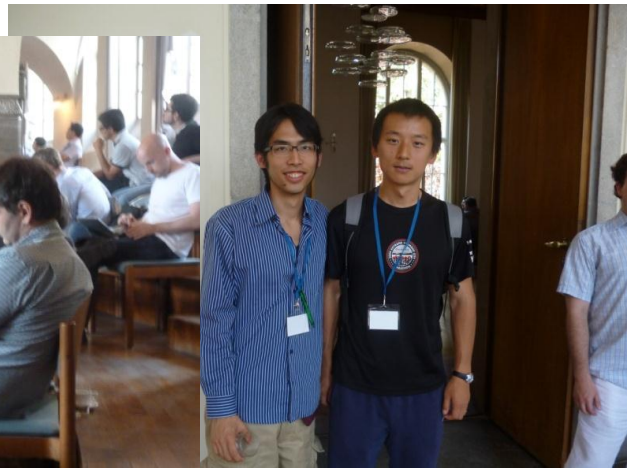
μ_r should be of the order of s

Future Outlook

- non-purturbative 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 …

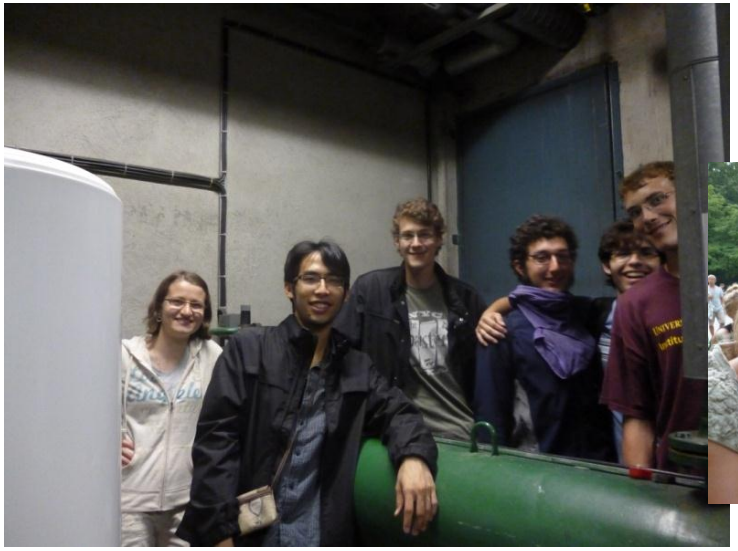
- Wait for **next February (spin)** and **years to come (couplings)**
- LHC, ILC and CLIC – precision time again
- Still super exciting to be a **HEP Experimentalist**
- **Cosmological** observations thriving

- Eying ILC and Cosmology

It is our time

Let's get the party started

Know how far we can go to go beyond!

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Thanks, REU group!