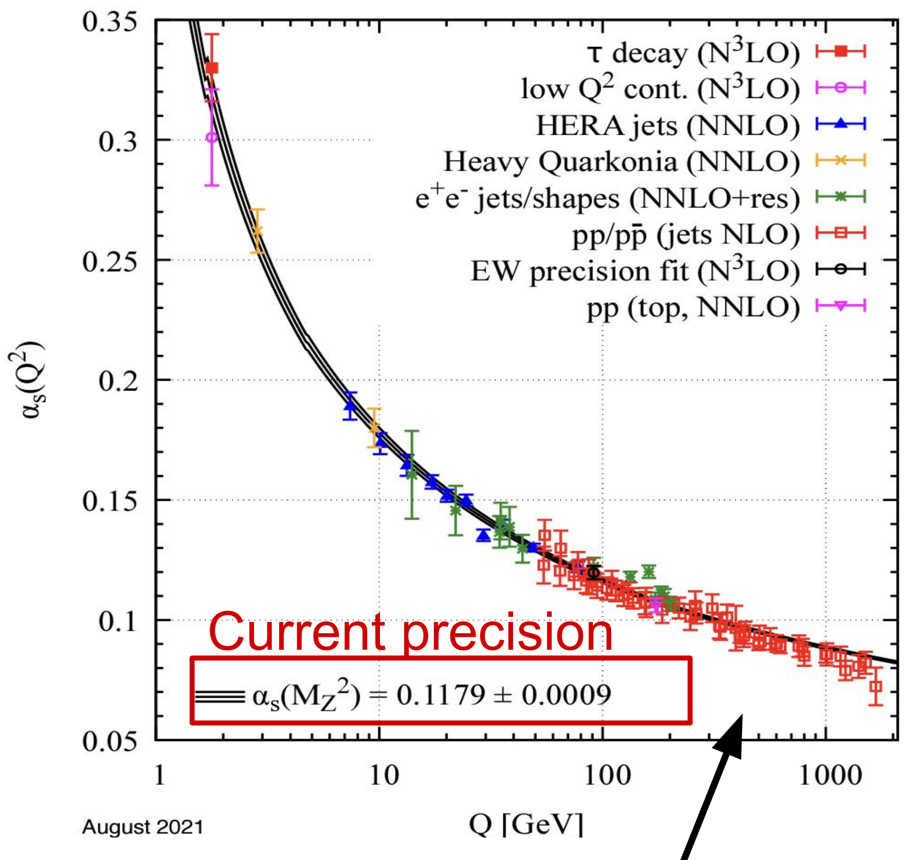
QCD & Lund Jet Plane studies@FCC-ee

FUTURE CIRCULAR COLLIDER Innovation Study | LPNHE PARIS | anr agence nationale de la recherche | SORBONNE UNIVERSITÉ | cnrs IN2P3 Les deux infinis | Université Paris Cité

R.C. Camacho Toro, L. Delagrange, B. Malaescu, L. Panwar, L. Poggioli, ECFA, Paris 2024

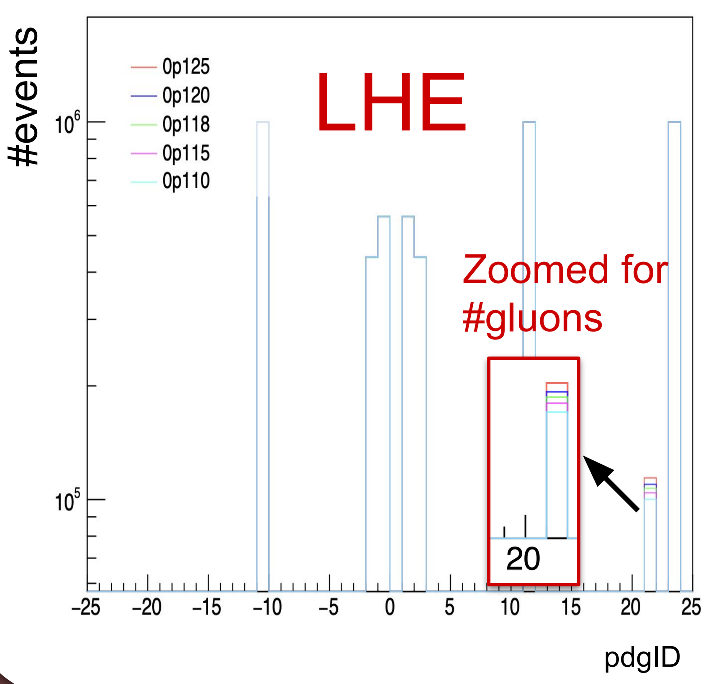
- Analyse prospects of **QCD study@FCC-ee** using **3/2 Jet cross-section ($R_{3/2}$)** study and **Lund Jet Plane (LJP) representation**
- Aim to study the **sensitivity to α_s at FCC-ee**, to probe α_s for different energies and test the Renormalization Group Equation (RGE) in QCD
- Also look for the potential use of LJP for improving jet tagging and for the optimization of detector parameters @FCC-ee
- **Why FCC-ee?**
  - Provides a clean collision environment with high statistics (10^6 X LEP Data)
  - Expect factor of 10 improvement with respect to the current α_s precision

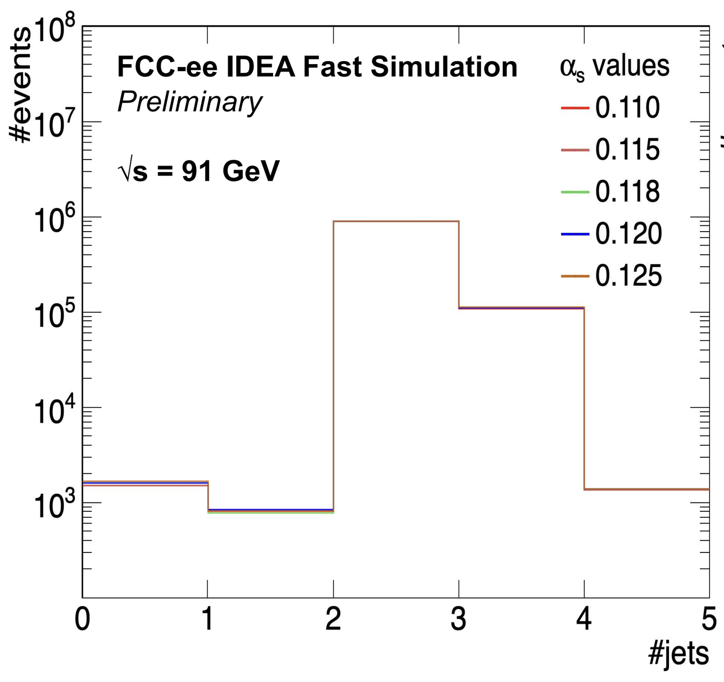


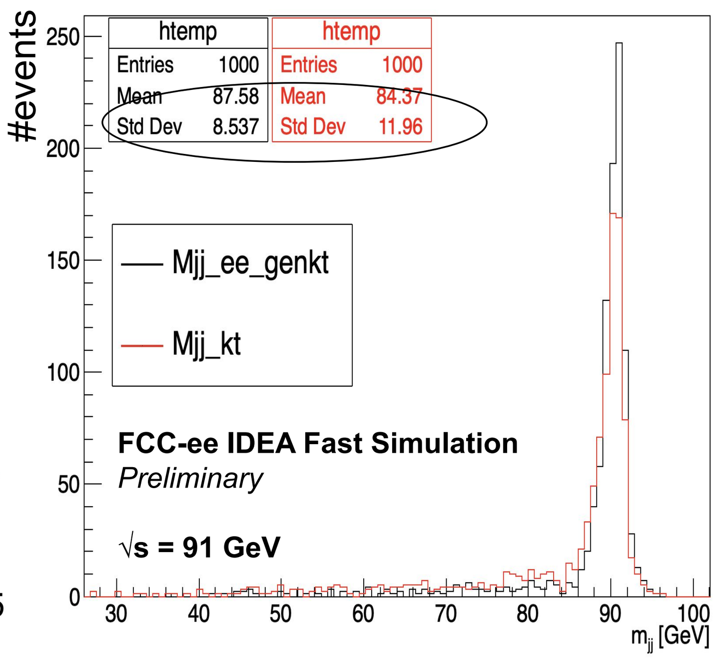
α_s evaluations using different processes, along with a global fit at Z-pole

MC Simulation

- LHE events from Madgraph (MG5_aMC@NLO); processed with Pythia8 and Delphes with default **IDEA** detector card
  - Process **ee → Z→ uu/dd @√s = 91 GeV** with α_s values: [0.110, 0.115, **0.118**, 0.120, 0.125]; 1M events/sample







- Various jet reconstruction algorithms are studied
  - ee generalised k_t algorithm with R = 1.5 and p = -1 performs better

4.5 Generalised k_t algorithm for e^+e^- collisions

FastJet also provides native implementations of clustering algorithms in spherical coordinates (specifically for e^+e^- collisions) along the lines of the original k_t algorithms [24], but extended following the generalised pp algorithm of [14] and section 4.4. We define the two following distances:

$$d_{ij} = \min(E_i^{2p}, E_j^{2p}) \frac{(1-\cos\theta_{ij})}{(1-\cos R)}, \quad (9a)$$

$$d_{iB} = E_i^{2p}, \quad (9b)$$

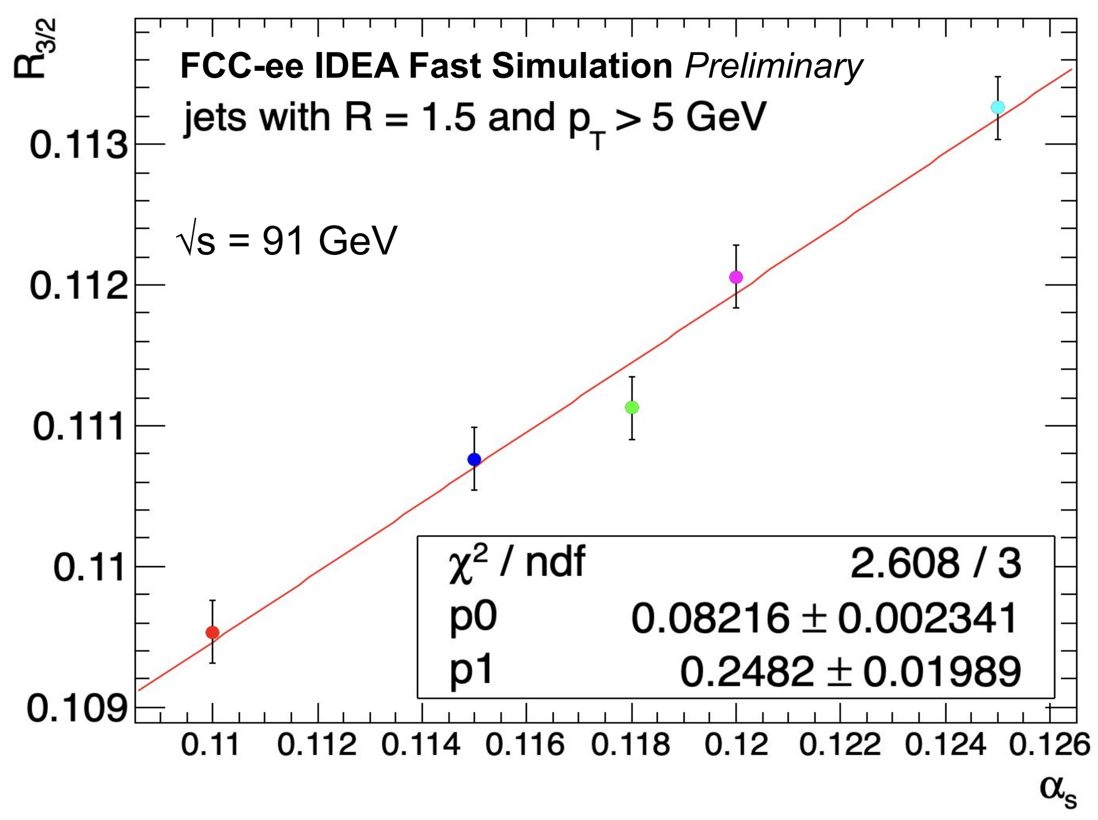
arXiv:1111.6097

for a general value of p and R. At a given stage of the clustering sequence, if a d_{ij} is smallest then i and j are recombined, while if a d_{iB} is smallest then i is called an "inclusive jet".

$R_{3/2}$ Study

$$R_{3/2} = \frac{\text{The number of events with at least 3 jets}}{\text{The number of events with at least 2 jets}}$$

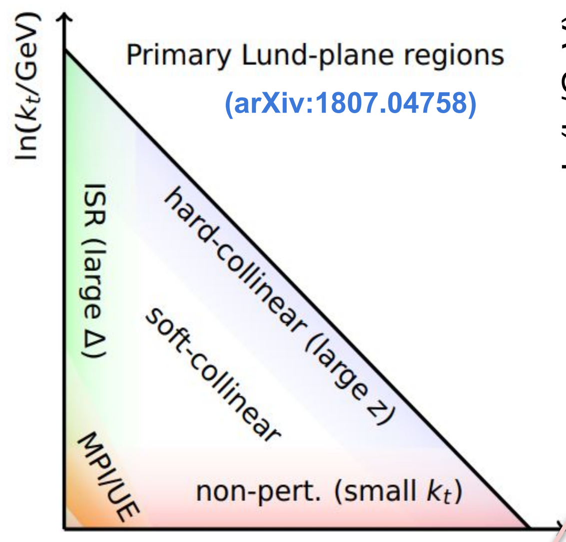
- Select jets with p_T > 5 GeV in an event
- Perform study for R=0.5 and R=1.5 jets
- Observe dependency of $R_{3/2}$ on α_s:

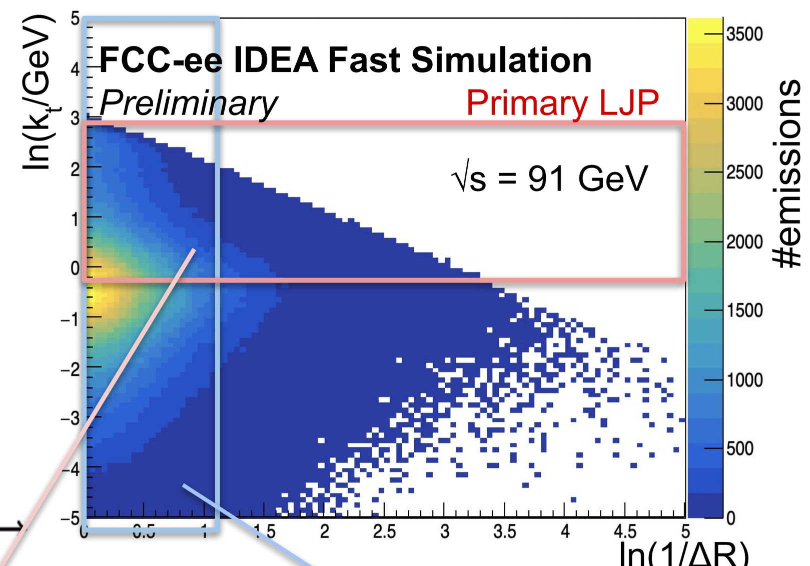


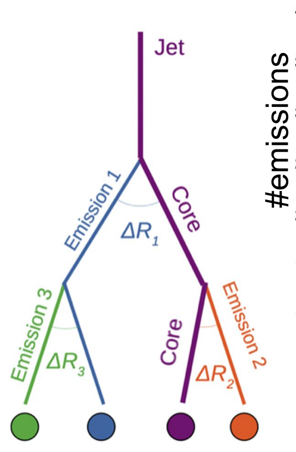
Jets	Variation in $R_{3/2}$
R=0.5	0.38 ± 0.02 $\Delta\alpha_s$
R=1.5	0.25 ± 0.02 $\Delta\alpha_s$

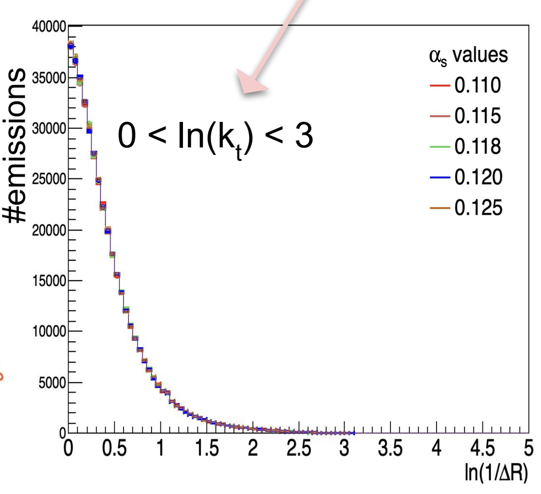
- Study ongoing with jets at hadron level

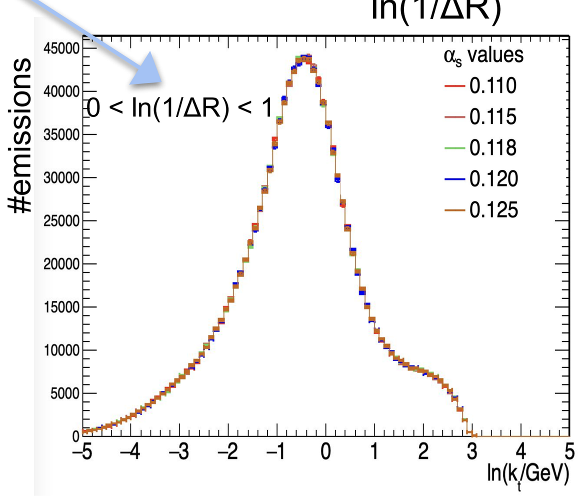
Lund Jet Plane Study











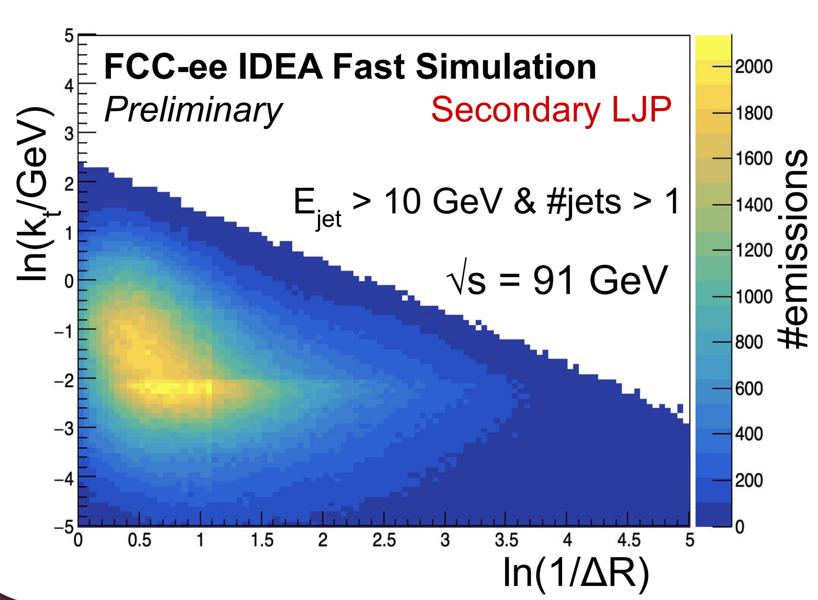
- LJP works as handle to separate perturbative and non-perturbative effects related to QCD jet formation in a 2D representation using angle and energy information of emissions inside jets
- Jet declustering with EECambridge algorithm; perform angular order declustering for jets originating from ee collisions

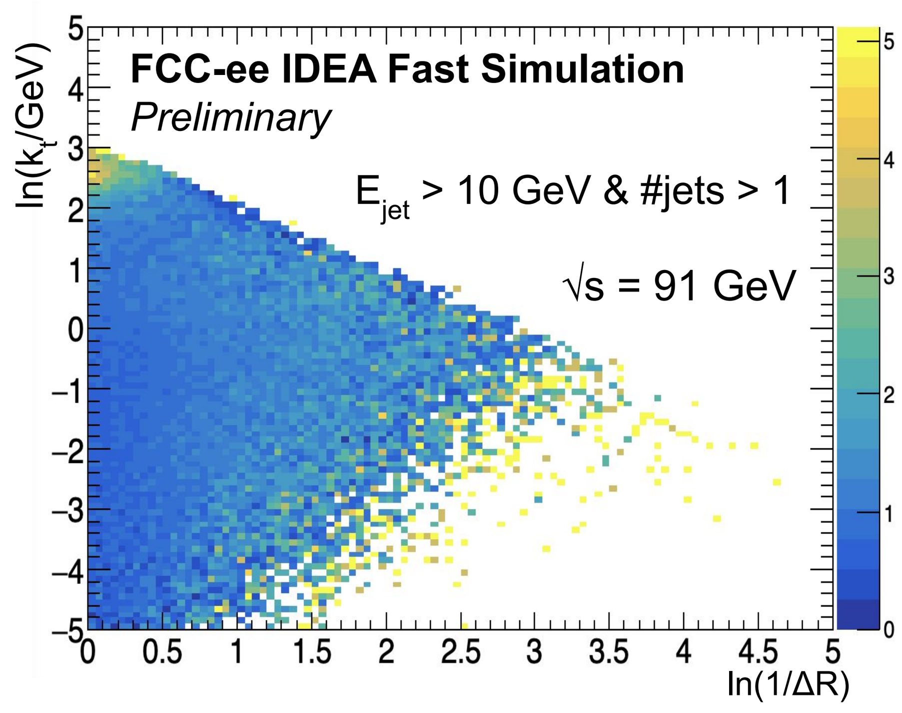
ΔR / k_t = angle / transverse momentum of emission with respect to core

Average density of emissions in LJP can be given as:

$$\rho(k_T, \Delta R) \equiv \frac{1}{N_{\text{jets}}} \frac{d^2 N_{\text{emissions}}}{d\ln(k_T/\text{GeV})\, d\ln(R/\Delta R)} \approx \frac{2}{\pi} C_R \alpha_S(k_T)$$

- Extend study for **secondary LJP** which is mostly induced from gluon





Jet Tagging:

Initial study for quark and gluon jets, will extend to heavy (Z→bb) vs light flavour (H→gluglu) jet tagging