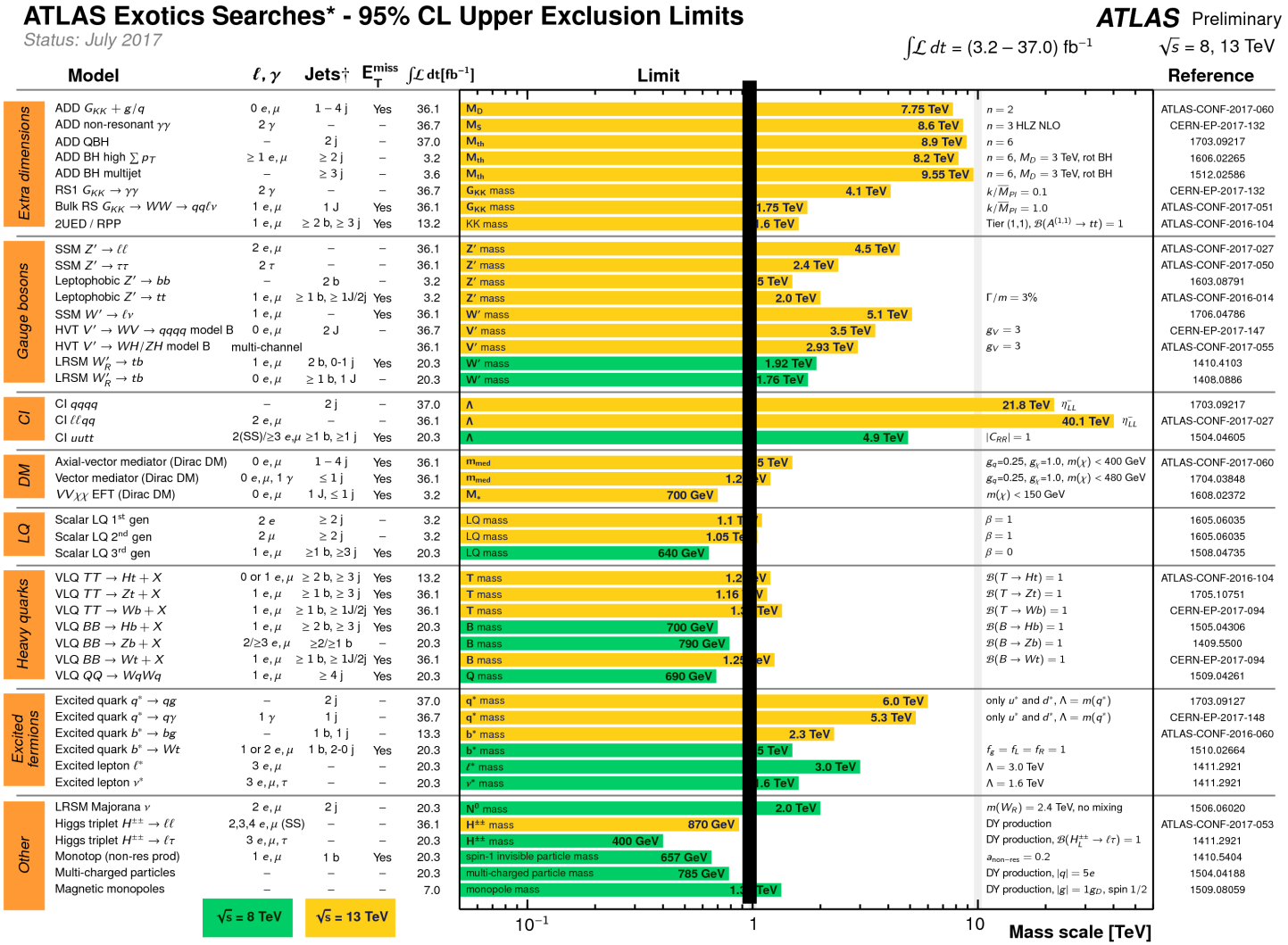
Jet physics in ATLAS
Lecture 2

Mathis Kolb

Student Lecture
RTG Particle Physics Beyond the Standard Model

02.05.2018

New physics at high scales



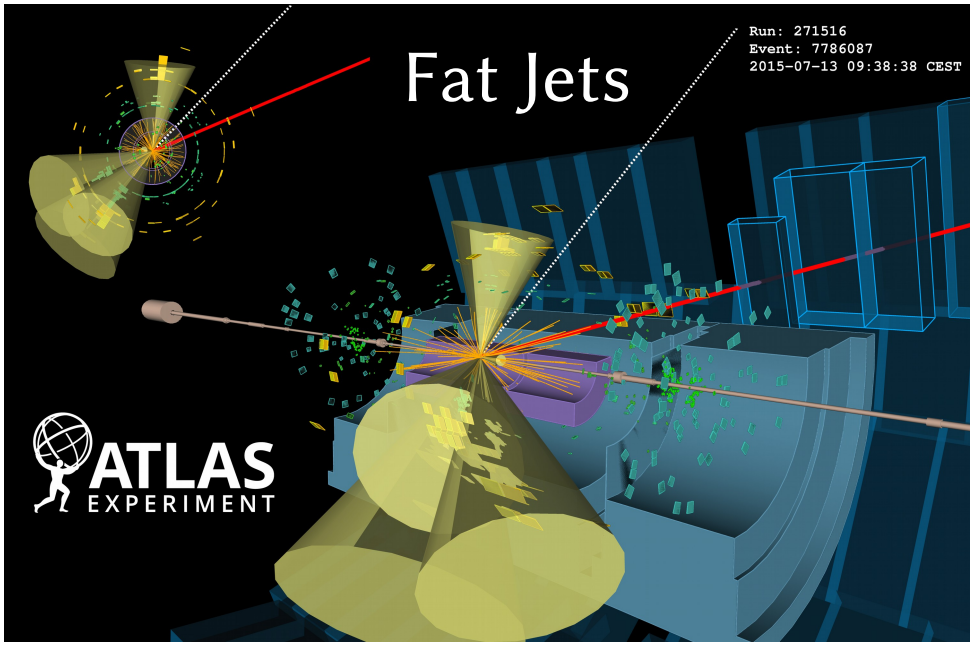
*Only a selection of the available mass limits on new states or phenomena is shown.

†Small-radius (large-radius) jets are denoted by the letter j (J).

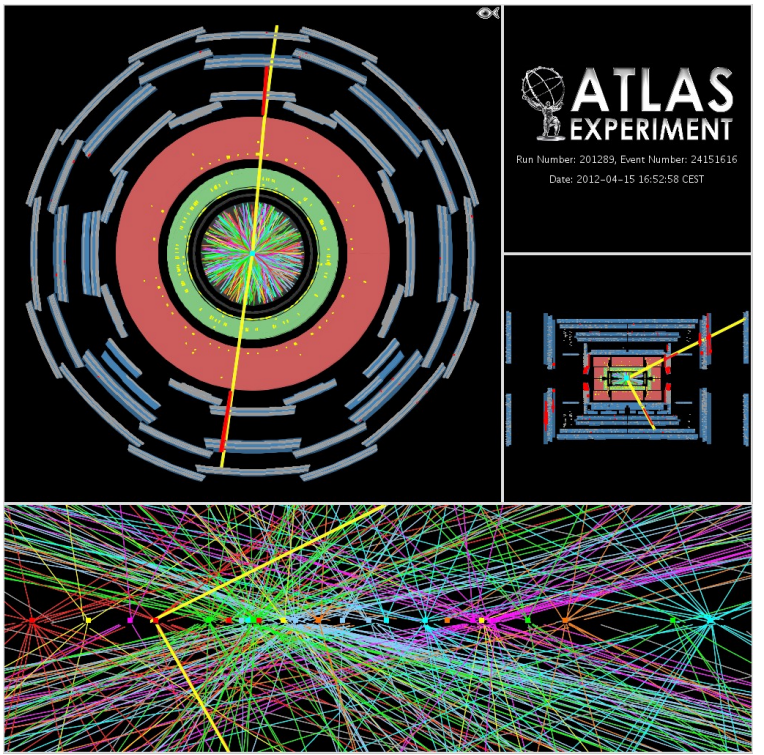
Source:
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/ATLAS_Exotics_Summary/ATLAS_Exotics_Summary.pdf

Jets in LHC environment

Boosted pp⟶tt event in 2015



pp⟶ Z⟶μμ in 2012, n_{PV} = 25

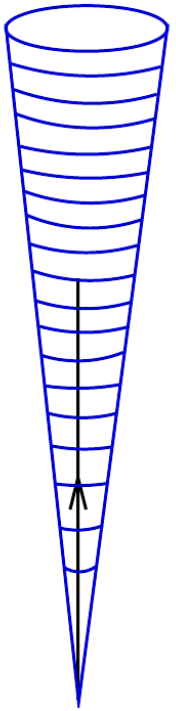


- Higher energies – Boost
- Higher luminosities – Pile-up

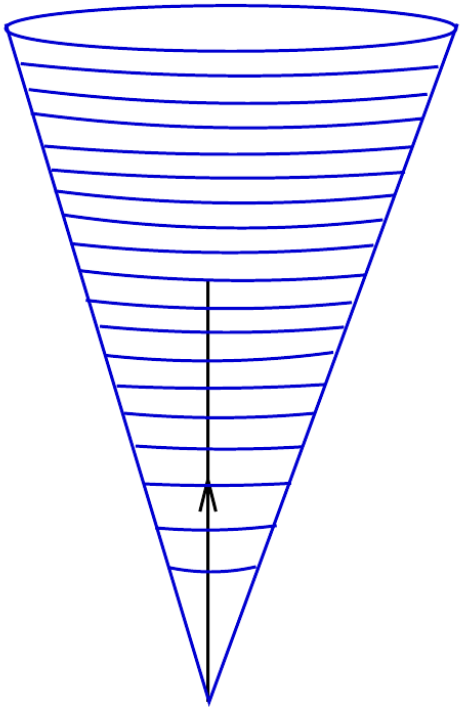
Source: https://twiki.cern.ch/twiki/bin/view/AtlasPublic/EventDisplayRun2Physics

Jet radius R

Small jet radius



Large jet radius

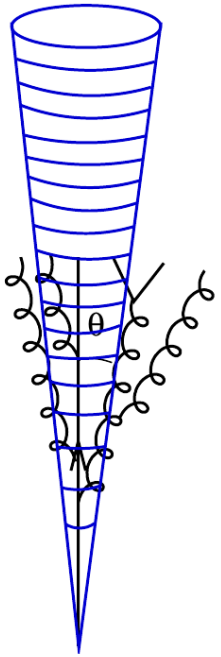


- Single parton

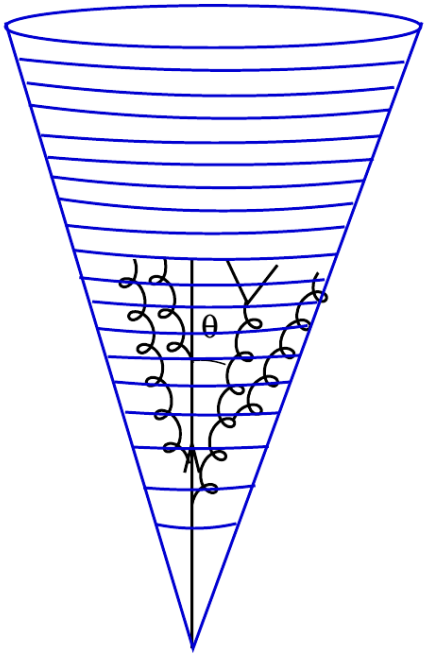
Source: https://physicslearning.colorado.edu/tasi/tasi_2013/notes/june12/Salam3.pdf

Jet radius R

Small jet radius



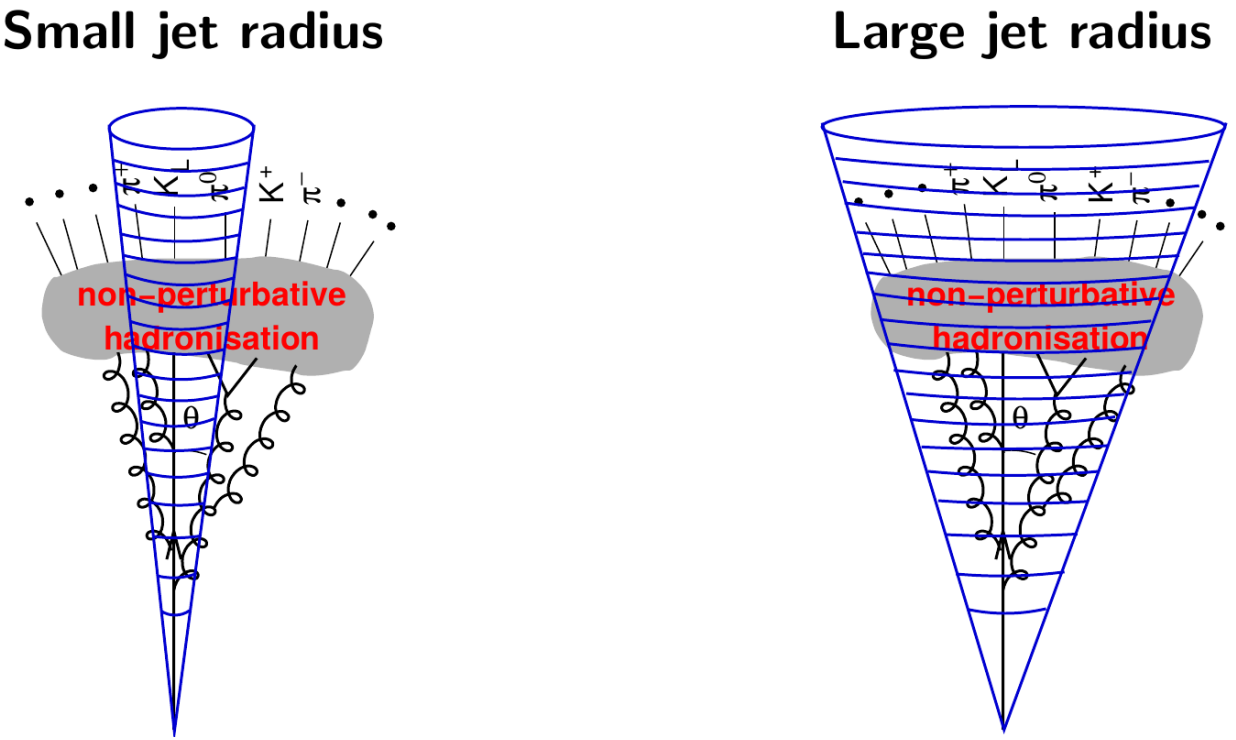
Large jet radius



- Perturbative fragmentation

Source: https://physicslearning.colorado.edu/tasi/tasi_2013/notes/june12/Salam3.pdf

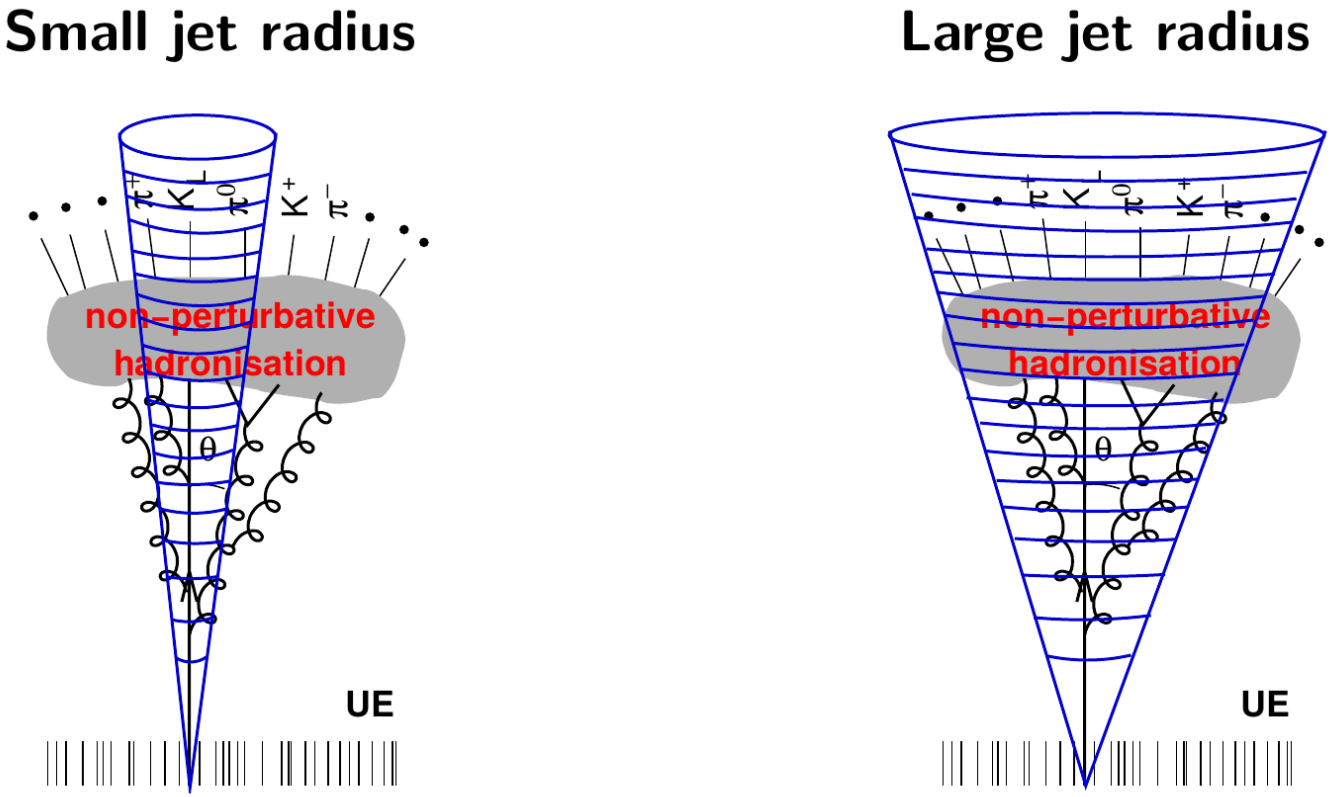
Jet radius R



- Non-perturbative fragmentation

Source: https://physicslearning.colorado.edu/tasi/tasi_2013/notes/june12/Salam3.pdf

Jet radius R

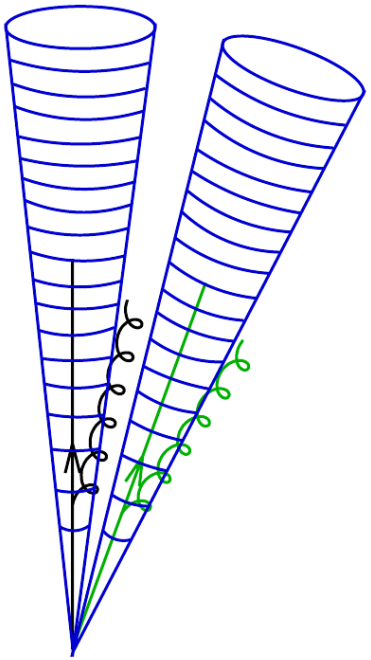


- Underlying event and pile-up

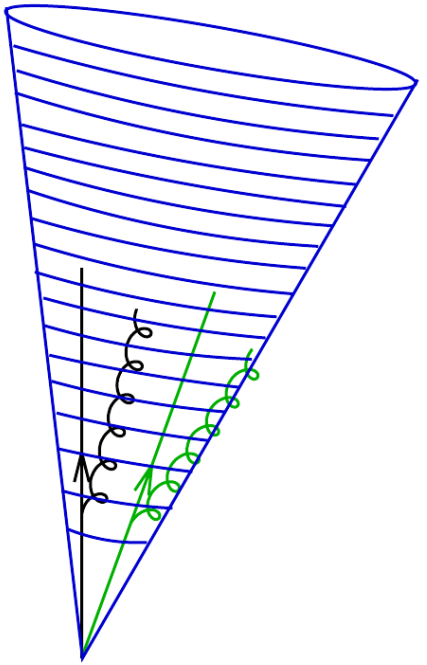
Source: https://physicslearning.colorado.edu/tasi/tasi_2013/notes/june12/Salam3.pdf

Jet radius R

Small jet radius



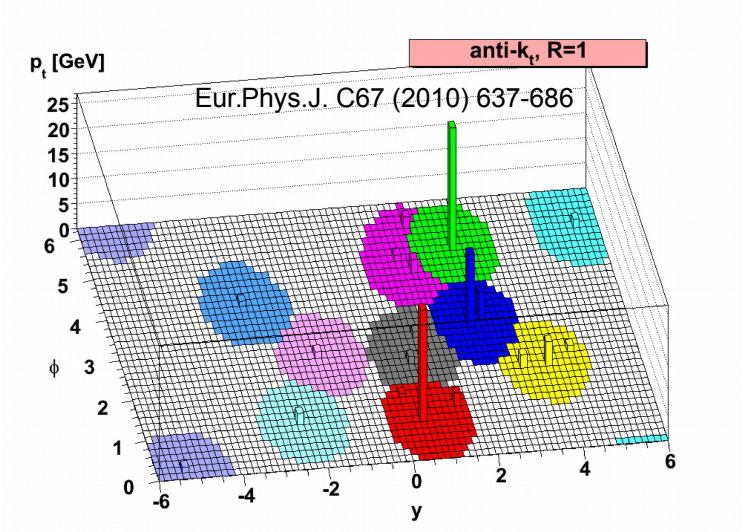
Large jet radius

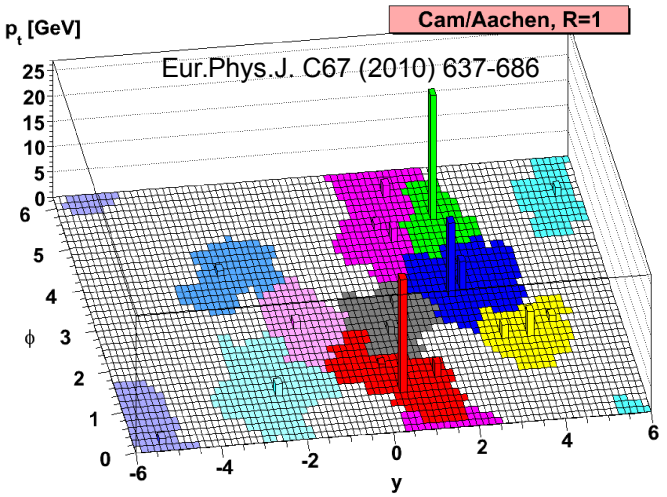


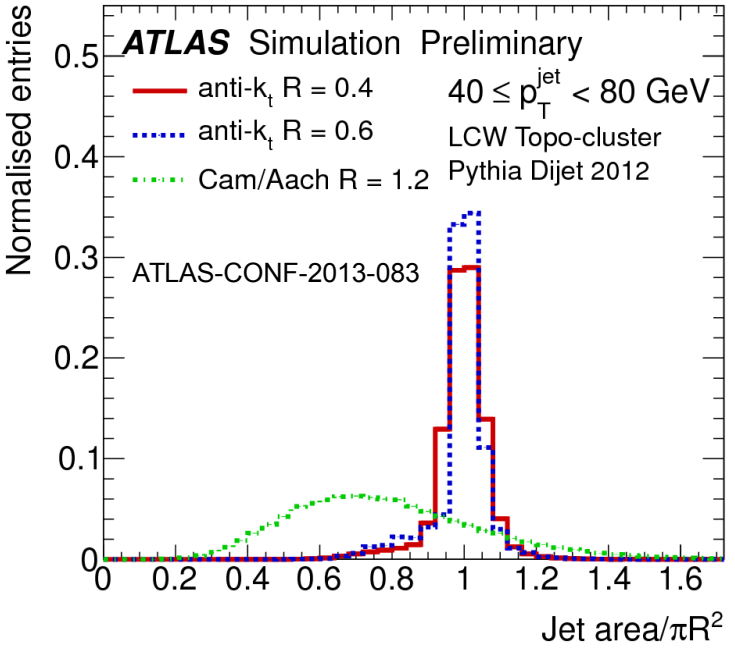
- Several hard partons

Source: https://physicslearning.colorado.edu/tasi/tasi_2013/notes/june12/Salam3.pdf

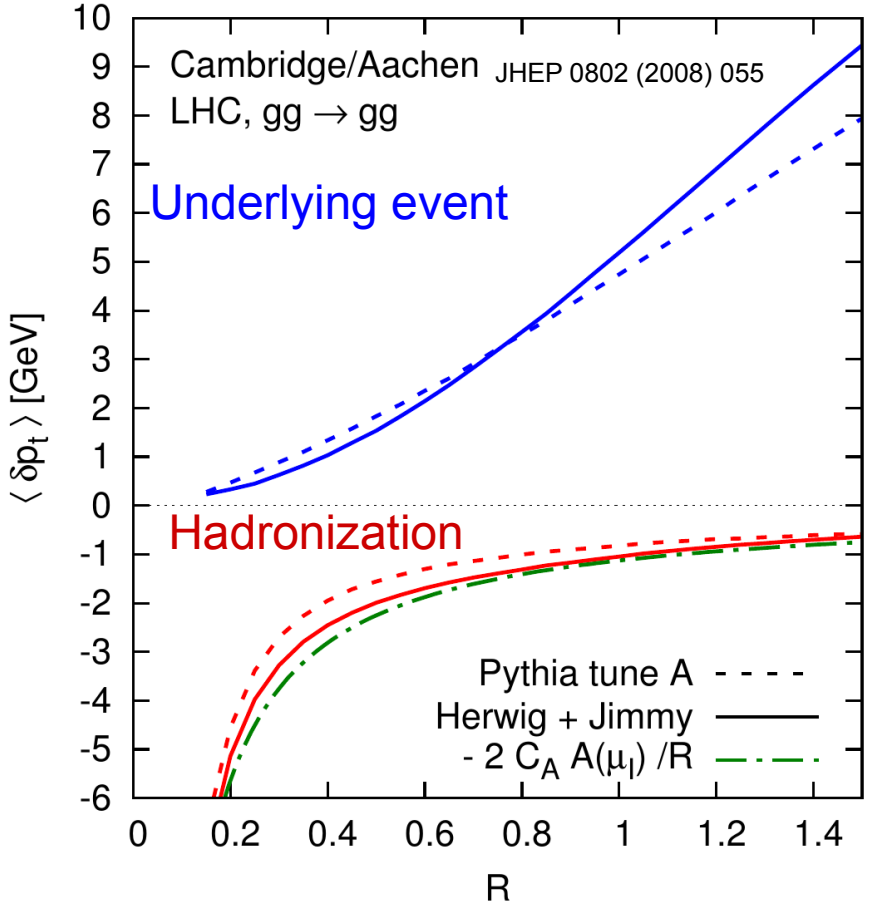
Jet area – reach of algorithm





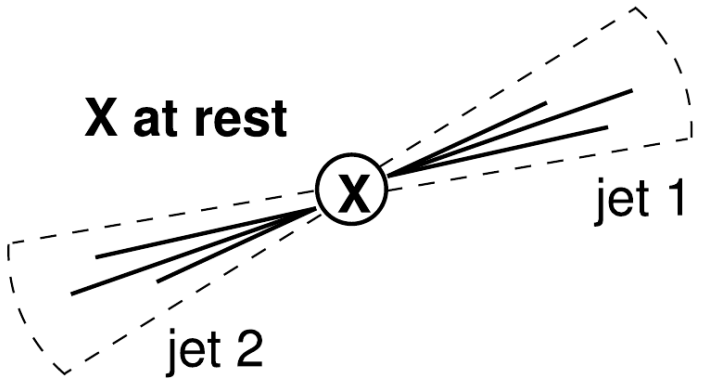


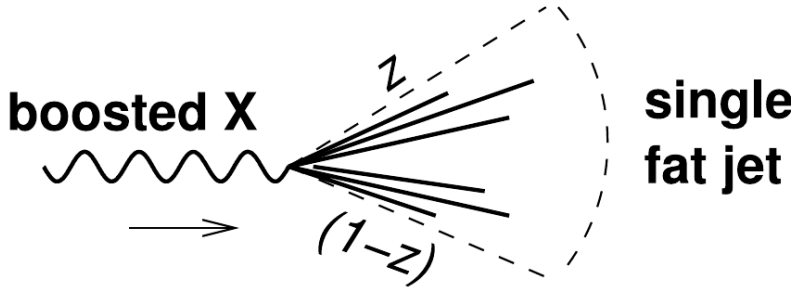
Simulation of correction



- C/A jets with 55 < pT < 70 GeV
- Parton level process: gg ⟶ gg
- UE ~ R^2, shift is 5 GeV for R=1
- Hadronization ~ 1/R, shift is -1 GeV
- R^{opt}=0.41 for quarks and 0.54 for gluons

Boosted particle decays



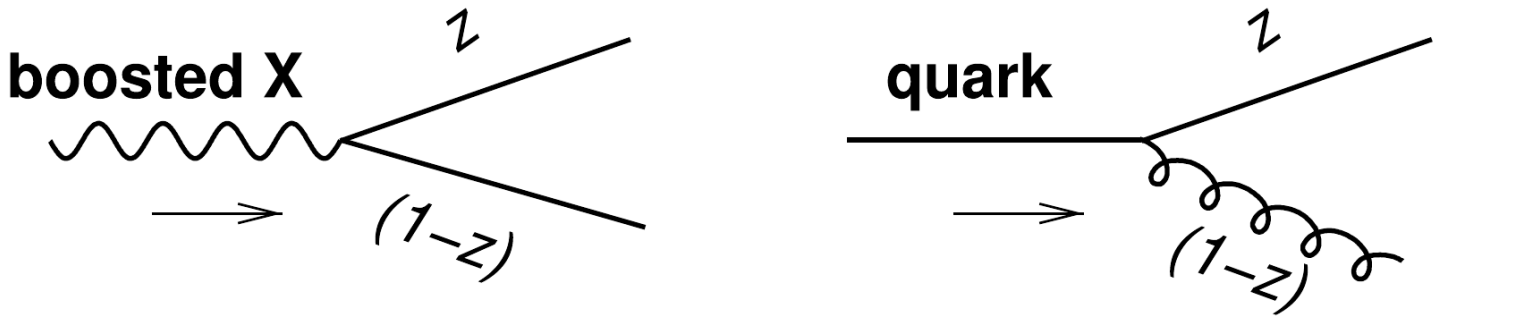


Source: https://gsalam.web.cern.ch/gsalam/repository/talks/2014-CFHEP-jets3.pdf

$$\Delta R \approx \frac{2\mathrm{m}}{p_T}$$

- "Fat jets": boosted massive hadronically decaying objects
- QCD jets are massive oo

Jet structure in Signal and Background



Source: Eur.Phys.J. C75 (2015) no.9, 415

$\approx$ flat for Higgs

$$P_{qg} = \frac{4}{3}\frac{1+z^2}{1-z}$$

- Remove background with cut on z
- Review sequential recombination algorithms

Sequential Recombination

$$\Delta R_{ij} = \sqrt{\Delta\phi_{ij}^2 + \Delta y_{ij}^2}$$

$$d_{ij} = \min(p_{Ti}^{2n}, p_{Tj}^{2n}) \frac{\Delta R_{ij}^2}{R^2}$$

$$d_{iB} = p_{Ti}^{2n}$$

$n = 1$	k_T-algorithm
$n = 0$	Cambridge-Aachen
$n = 1$	anti-k_T-algorithm

1. Find smallest d_{ij},d_{iB}
2. If $d_{ij}^{\min} < d_{iB}^{\min}$ recombine i and j
3. If $d_{iB}^{\min} < d_{ij}$min call i a jet and remove it
4. Repeat from 1. until no particles are left
5. Only use jets with $p_T > p_T^{\min}$

Splitting scales

$$d_{ij} = \min(p_{T,i}, p_{T,j})\Delta R_{ij} \approx \sqrt{\frac{x}{1-x}}m$$

Mass drop

$$i + j \to p \text{ and } m_p \gg m_i, m_j$$

1. Undo last clustering $p \to i + j$
2. If $\dfrac{m_i}{m_p} < \mu$ and $\sqrt{v} \equiv_{ij} \times \min(p_{T,i}, p_{T,j})/m_p > \sqrt{v_{\text{cut}}}$
3. Else repeat from 1

Summary

- Fat jets require new reconstruction techniques
- Jet substructure is one of the primary tools in searches for new heavy particles