Event reconstruction with **shower deconstruction**

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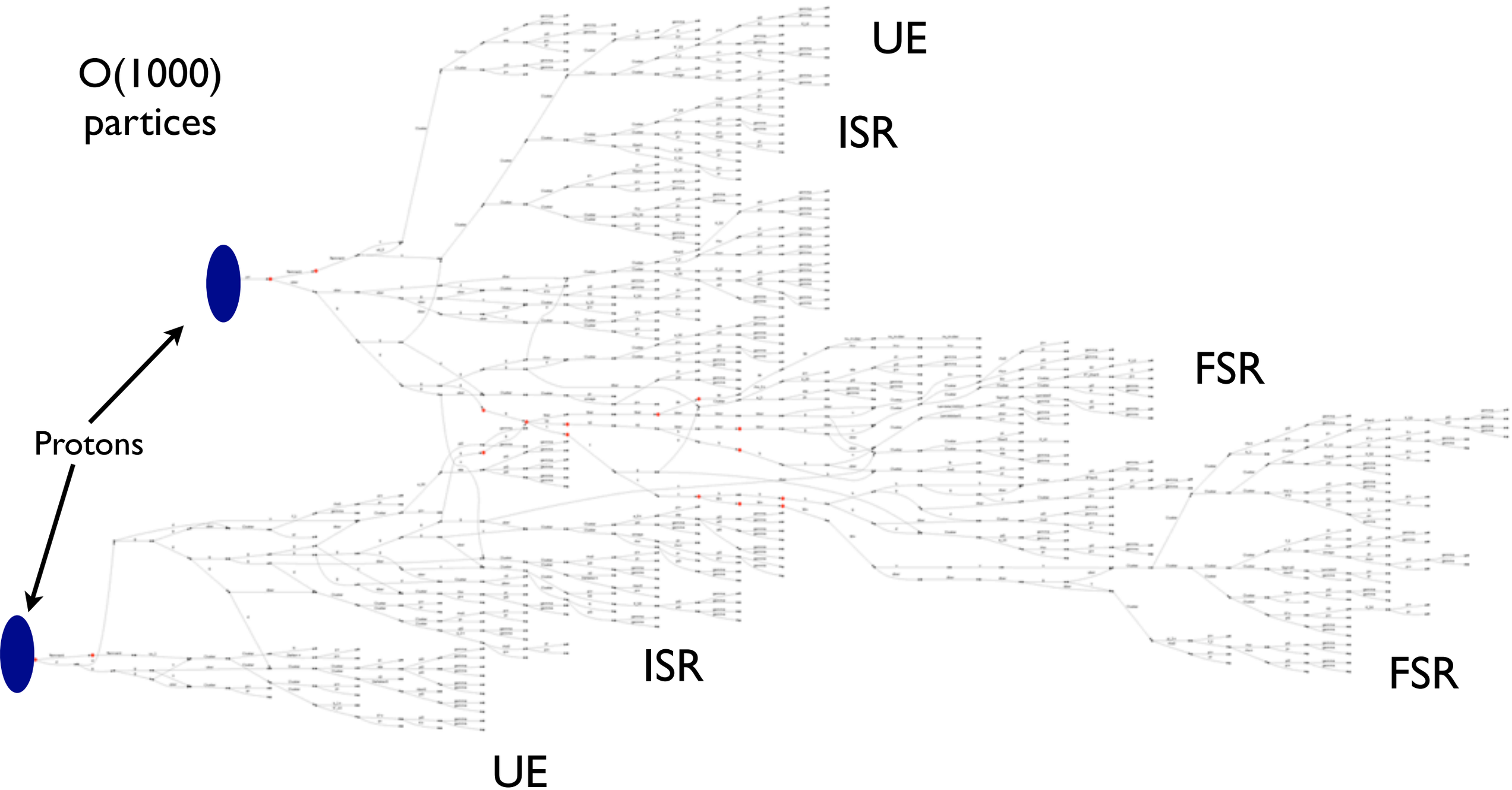
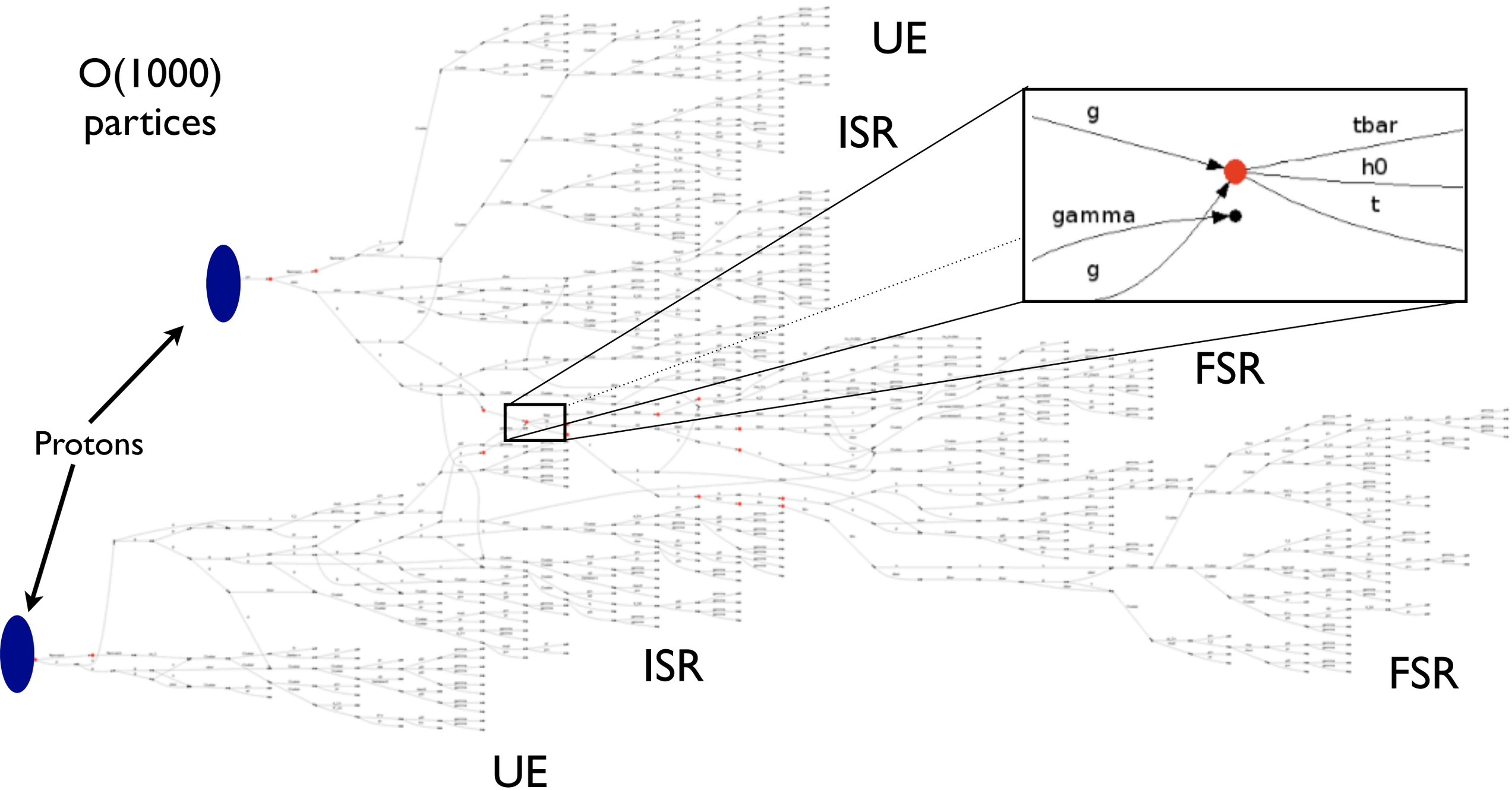
together with Davison Soper (UO)

LHC hosts complex environment!

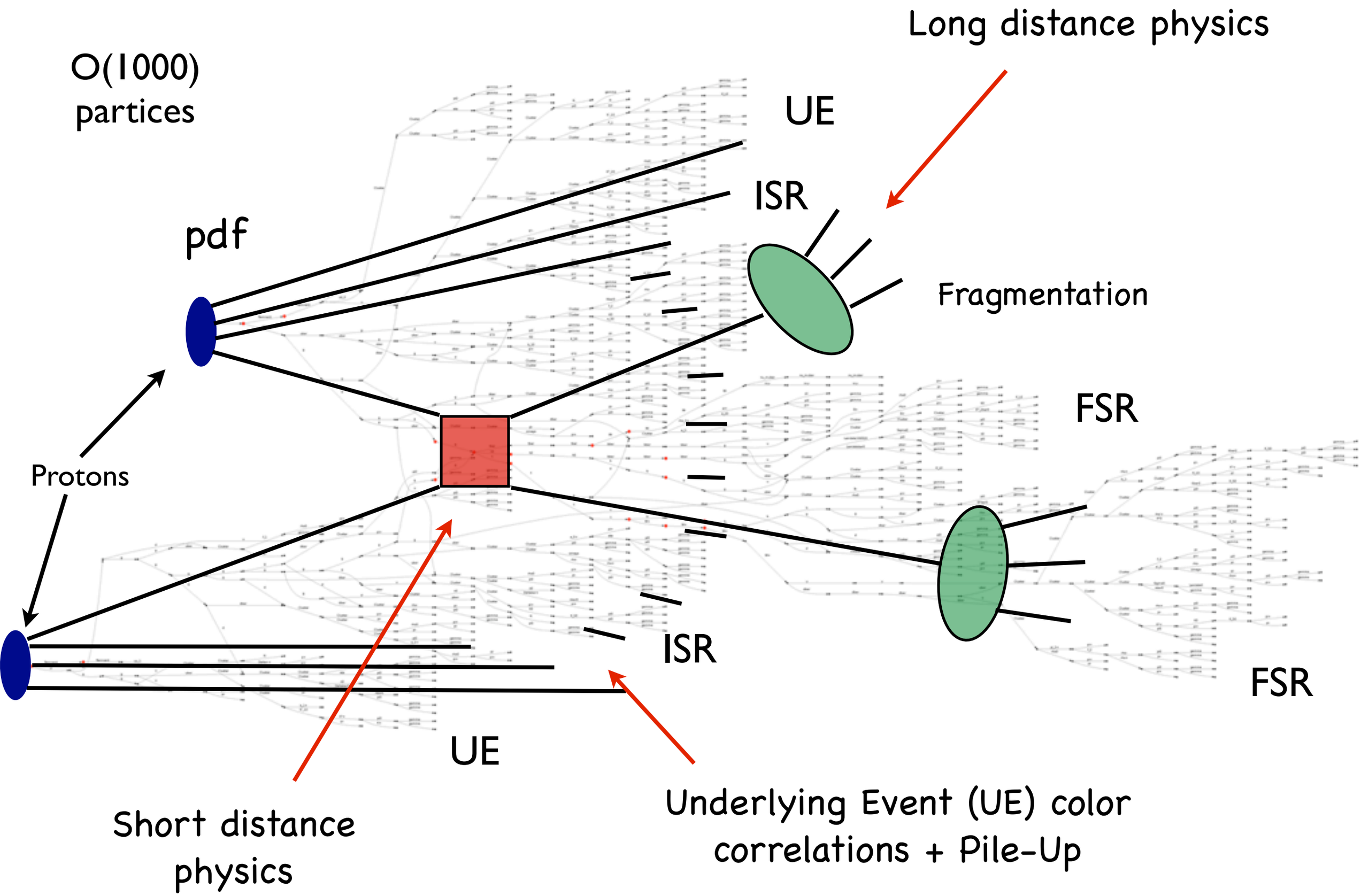


Tedious for theorists and experimentalists

LHC hosts complex environment!



Tedious for theorists and experimentalists


Long distance physics
O(1000)
partices
UE
ISR
pdf
Fragmentation
FSR
Protons
ISR
FSR
UE
Short distance
physics
Underlying Event (UE) color
correlations + Pile-Up

More information -> better discrimination

Our approach:

"Shower deconstruction"

- a new method to search for New Physics -

- Maximal information approach to discriminate signal from backgrounds
  -> UE, ISR, FSR, hard process
- We want one discriminating analytic function
- Have to respect experimental limitations

Playground: Boosted HZ final state

"Mirror, mirror on the wall ..."

Do I look like a Higgs jet or do I look like a gluon jet?

"Mirror, mirror on the wall ..."

Do I look like a Higgs jet or do I look like a gluon jet?

Don't answer:

To me you just look like a fat jet

"Mirror, mirror on the wall ..."

Do I look like a Higgs jet or do I look like a gluon jet?

Don't answer:

To me you just look like a fat jet

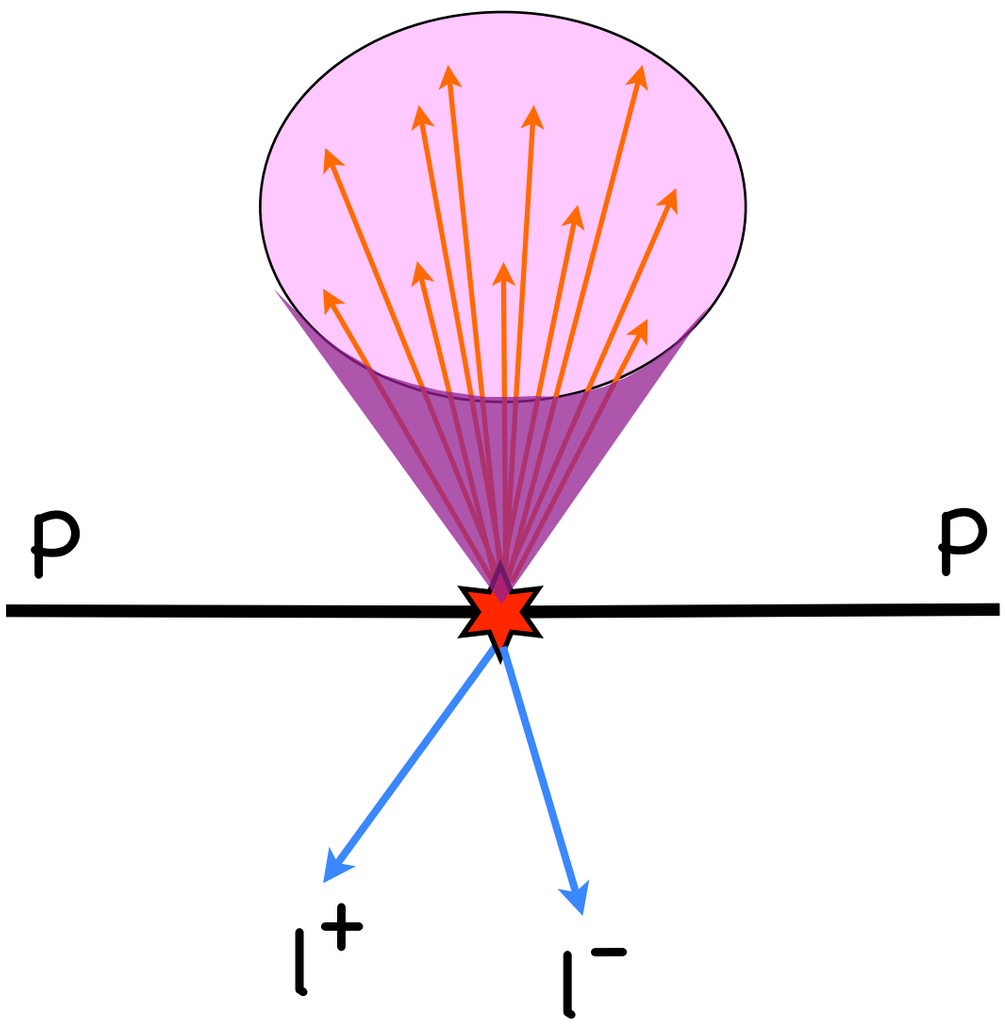
Idea: [M. H. Seymour, Z. Phys. C 62, 127 (1994)]

Trailblazing analysis: [Butterworth, Davison, Rubin, Salam PRL 100 (2008)]
confirmed by ATLAS [ATL-PHYS-PUB-2009-088]

Meanwhile many more approaches (see other talks)

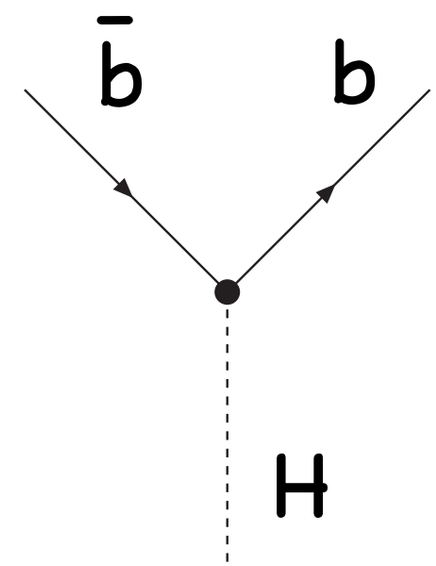
Shower deconstruction

- a new method to search New Physics -

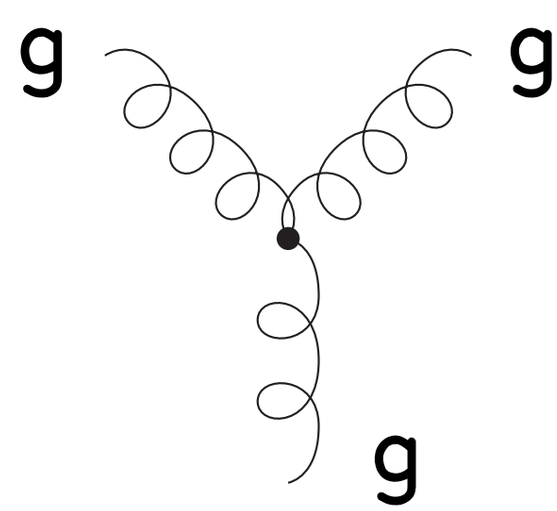


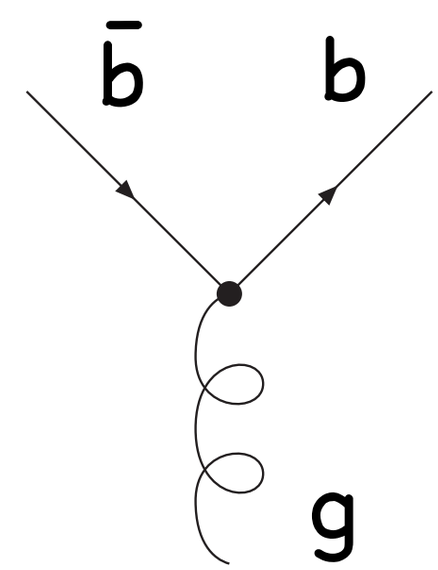
pT>200 GeV

signal



background

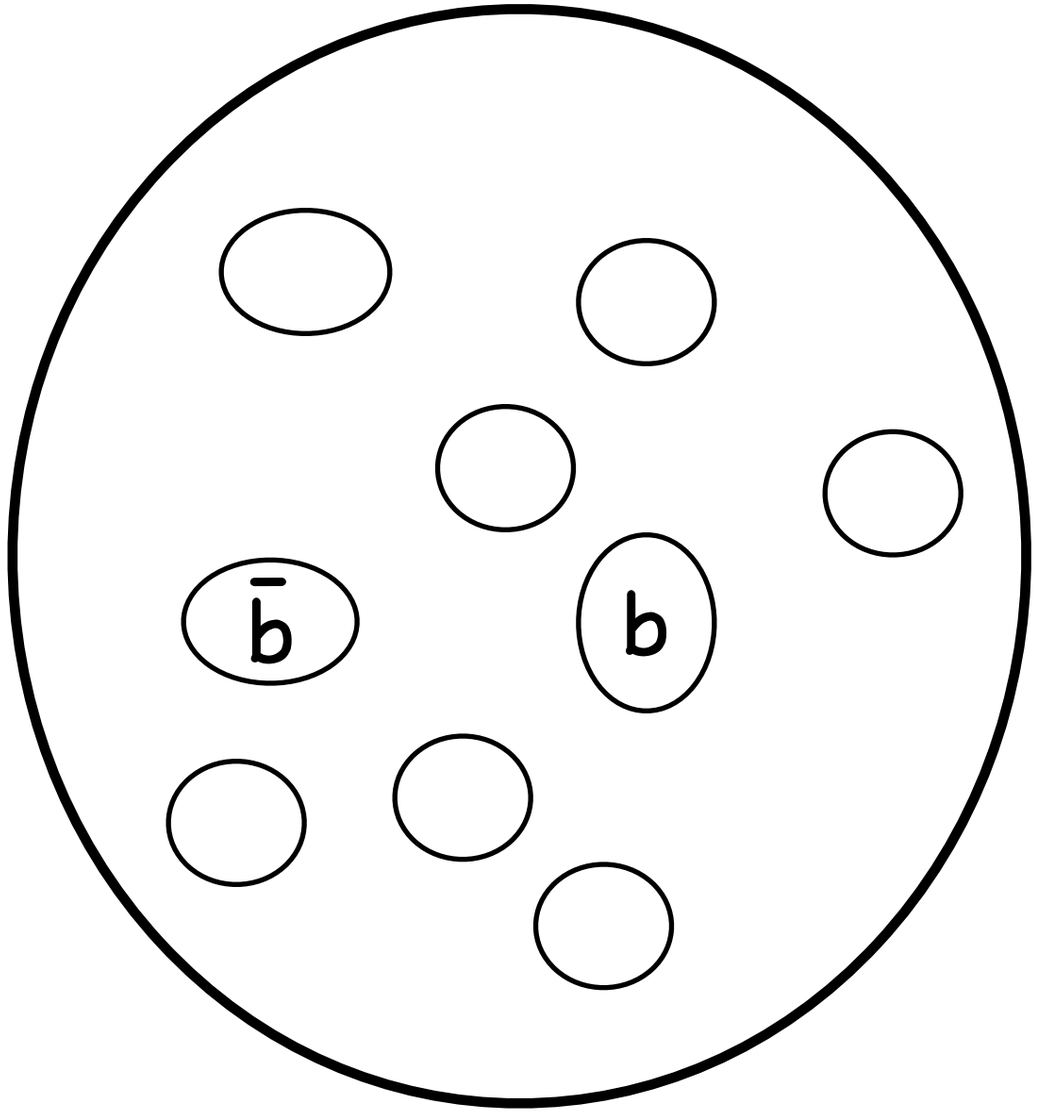




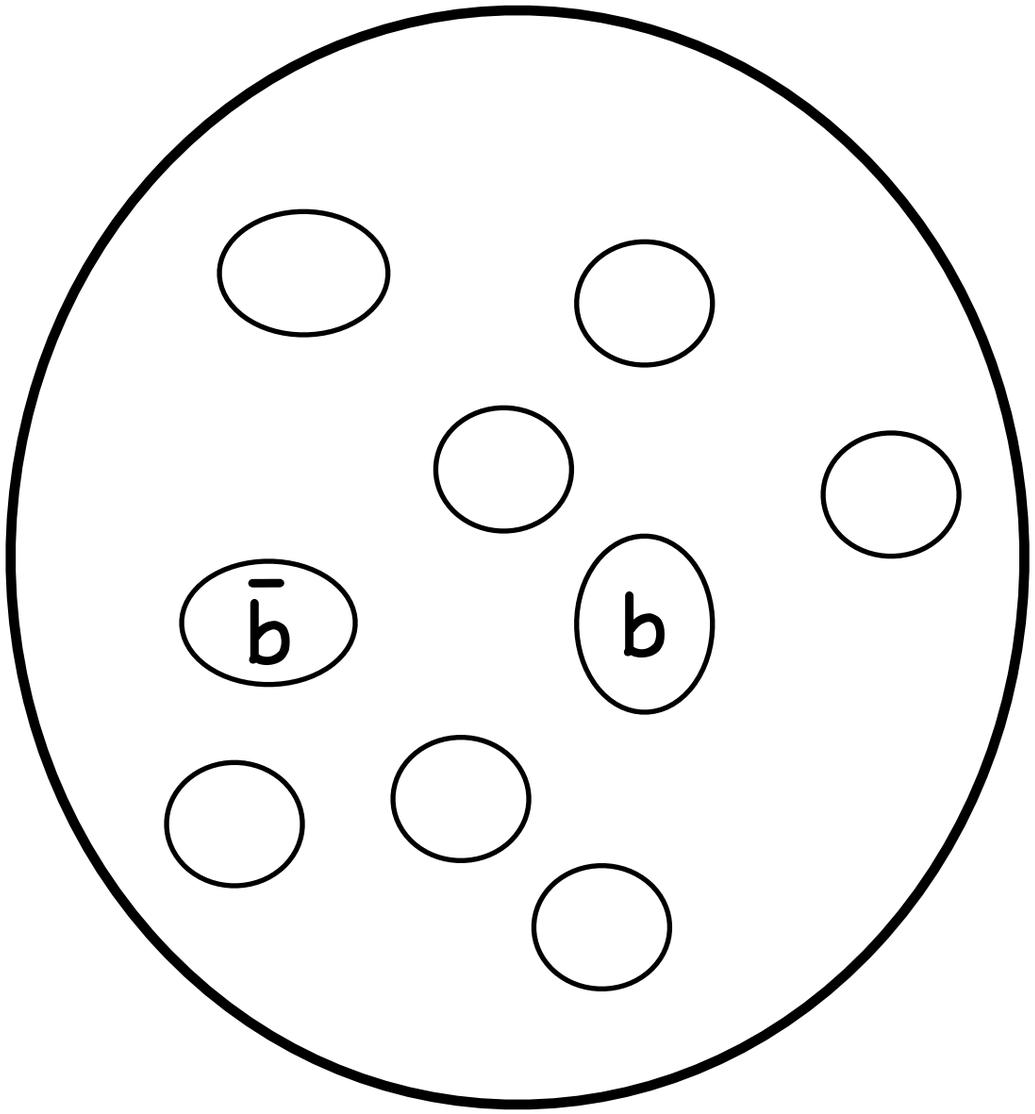
Recombine fat jet's constituents to microjets

(kT, R=0.15, pT > 1 GeV)

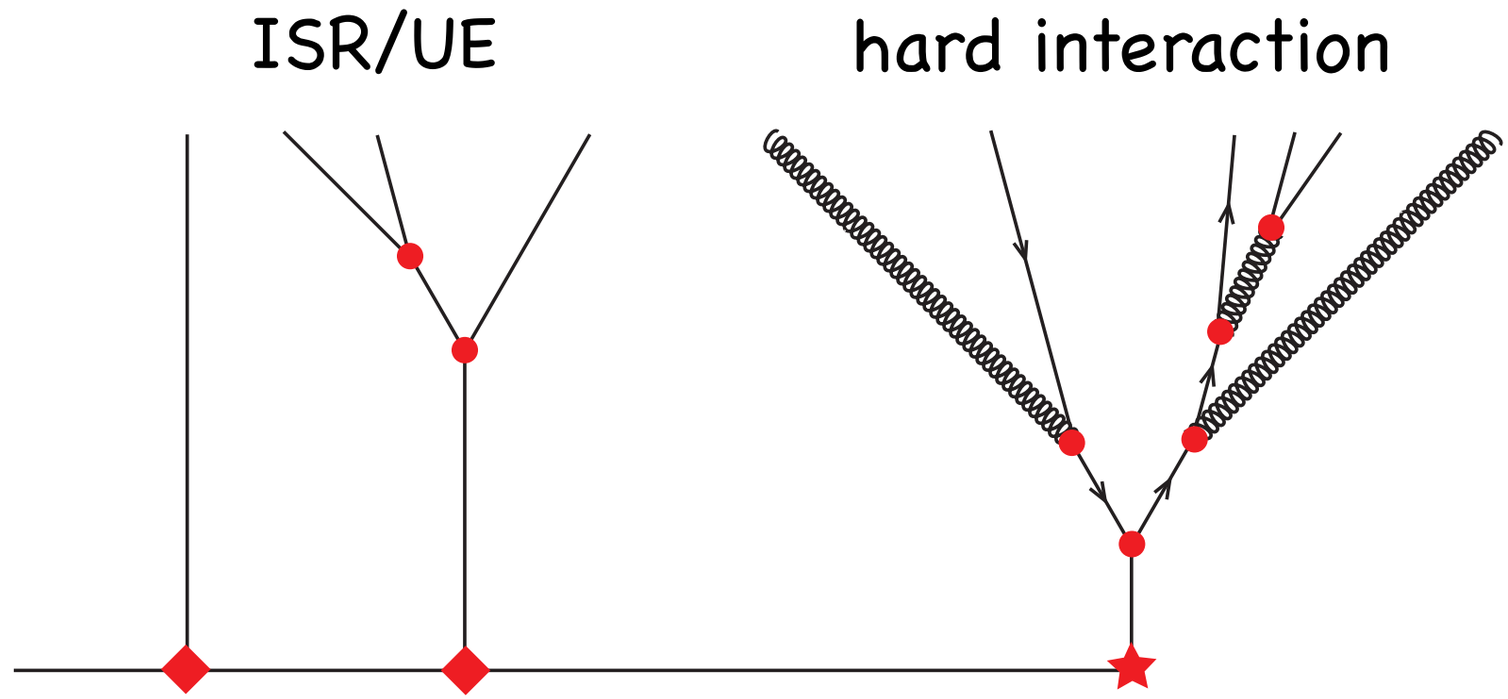
microjets are basic elements of event/fat jet



Fat jet: R=1.2, anti-kT



microjets
R=0.15, kT

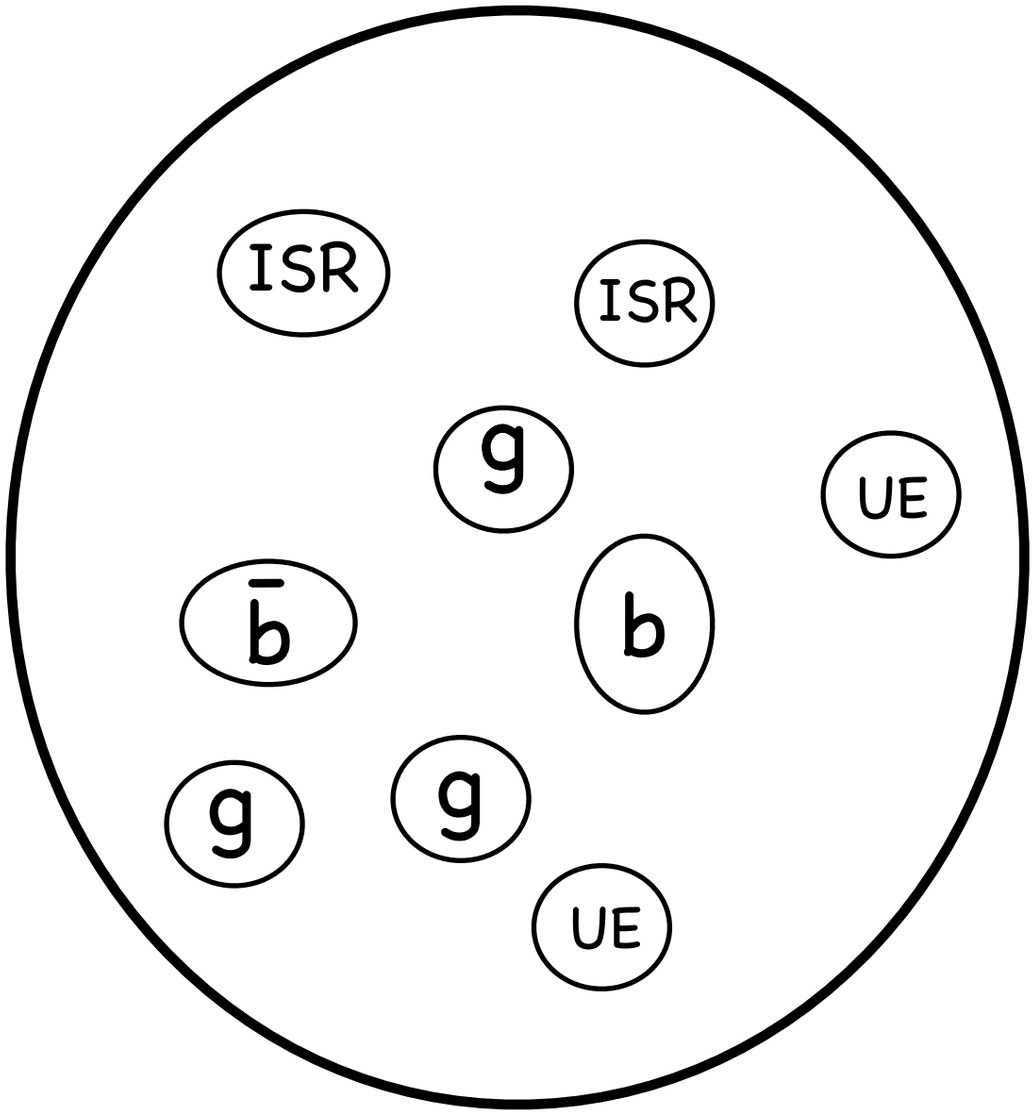


Build all possible shower histories

signal vs background hypothesis based on:

- Emission probabilities
- Color connection
- Kinematic requirements
- b-tag information

Fat jet: R=1.2, anti-kT



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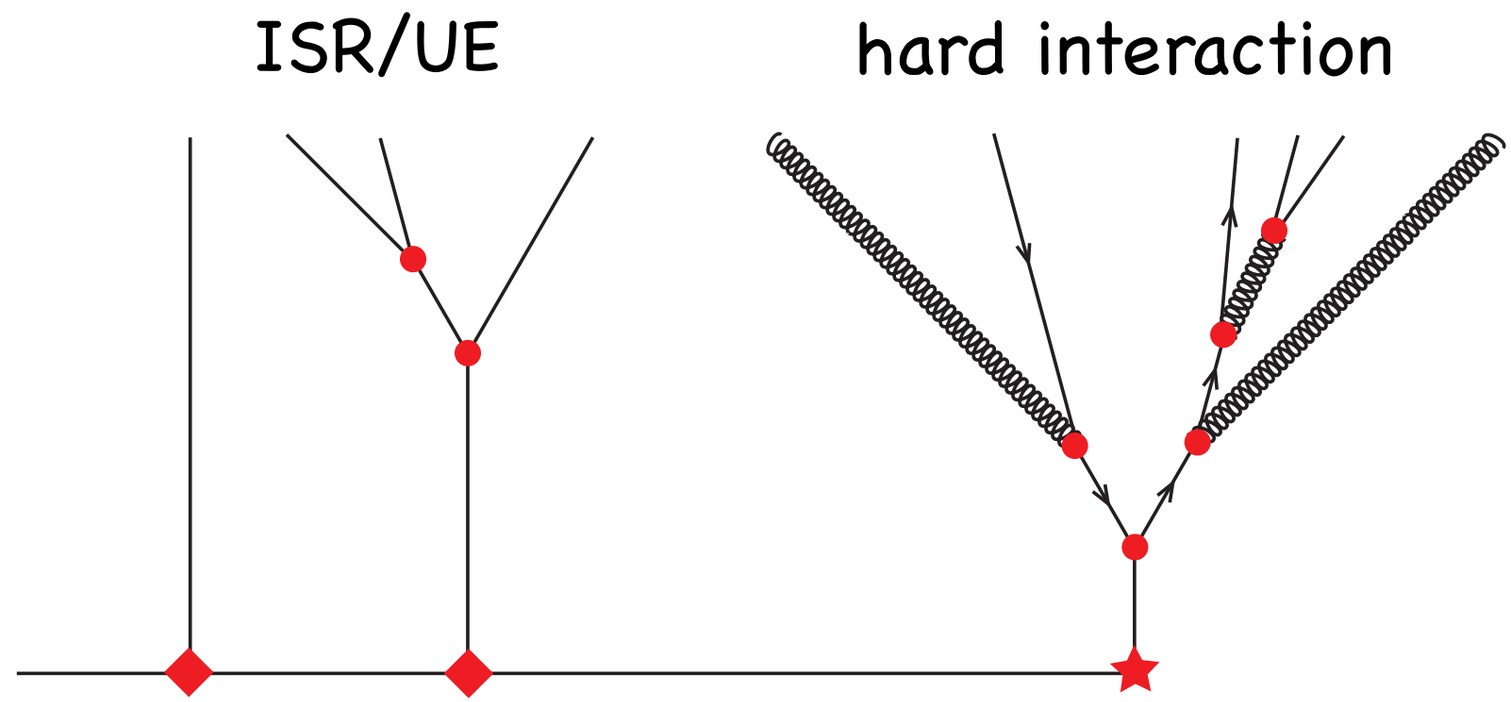

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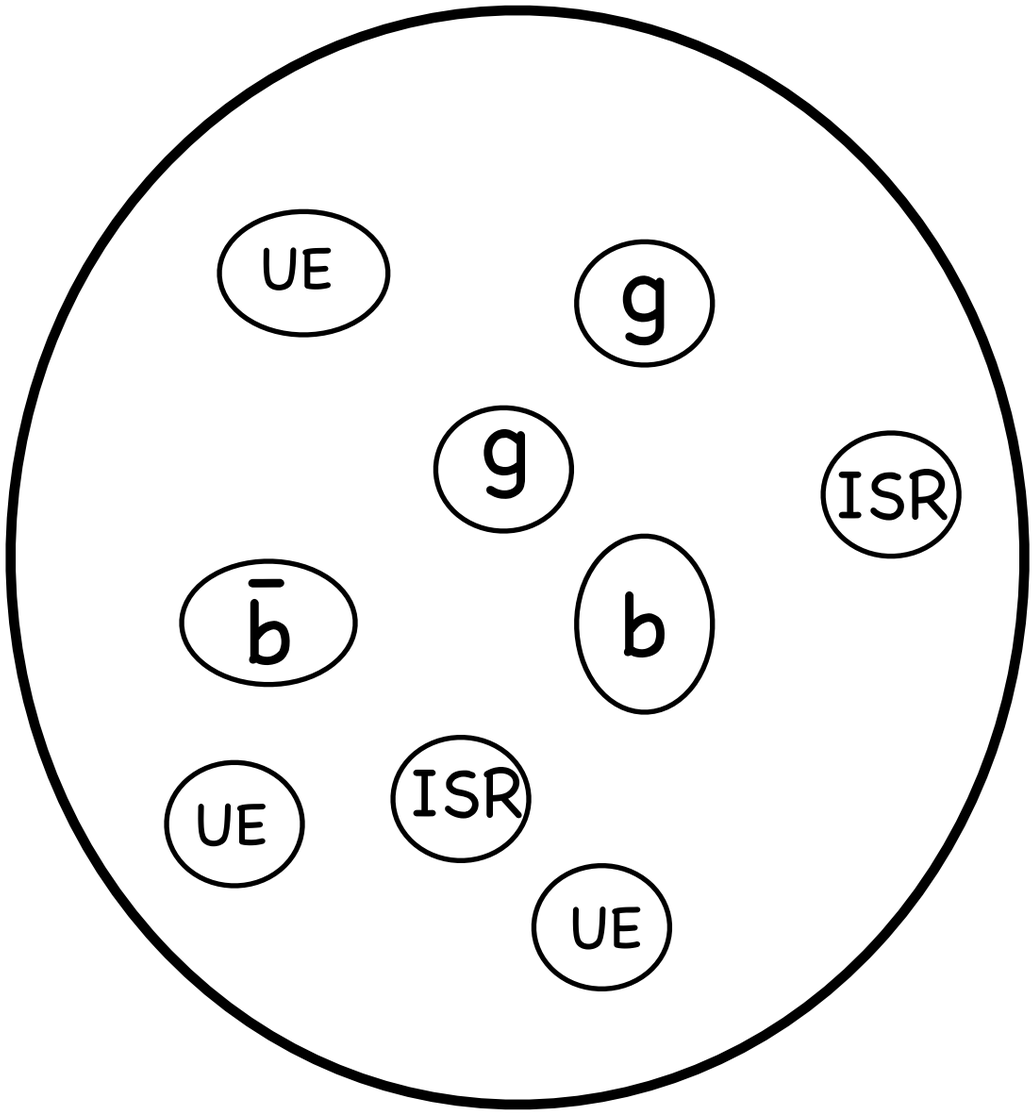

microjets
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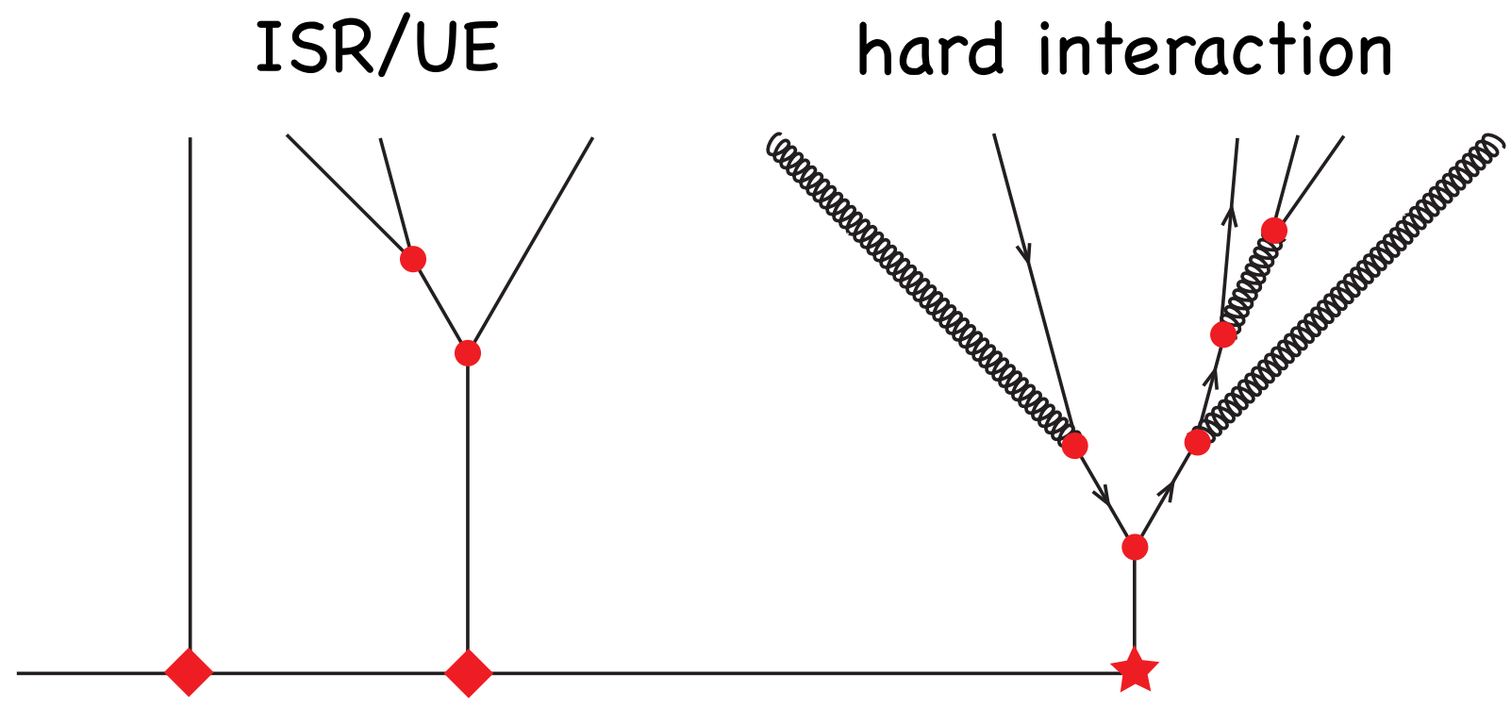

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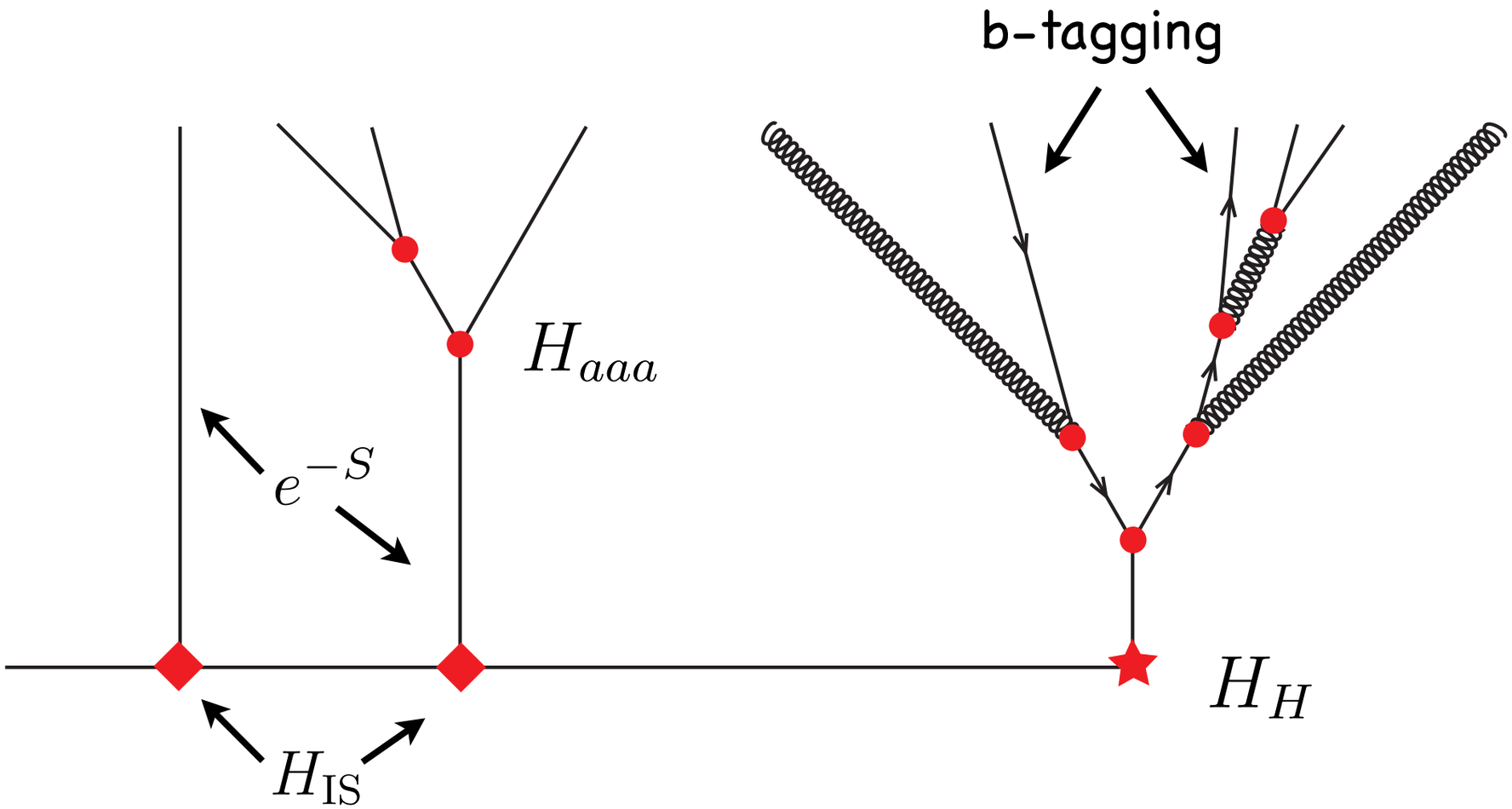


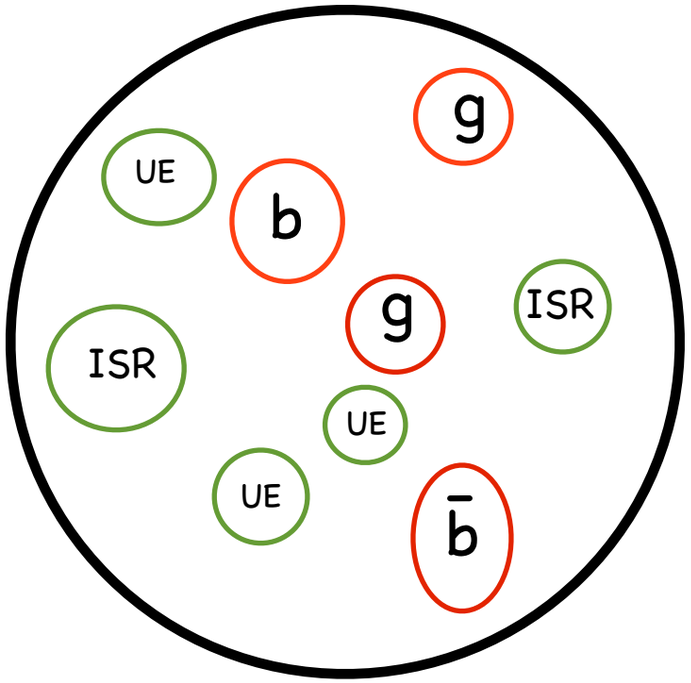
Want to convert the shower history into analytic expression

→ Feynman Rules for Shower Deconstruction

$$\chi(\{p,t\}_N) = \frac{P(\{p,t\}_N|\mathrm{S})}{P(\{p,t\}_N|\mathrm{B})} = \frac{\sum_{\rm histories} H_{ISR} e^{-S_{I1}} \ldots \sum_{\rm histories} H_H e^{-S_{s1}} H^s_{bg} e^{-S_{s2}} \ldots}{\sum_{\rm histories} H_{ISR} e^{-S_{I1}} \ldots \sum_{\rm histories} H_{gbb} e^{-S_{b1}} H^b_{bg} e^{-S_{b2}} \ldots}$$

χ is the one analytic function to discriminate signal from background

(for more detail see 1102.3480)



$$Q^2 = \left(\sum_{i \in \text{fat jet}} \vec{p}_{T,i} \right)^2 + \left(\sum_{i \in \text{fat jet}} p_i \right)^2$$

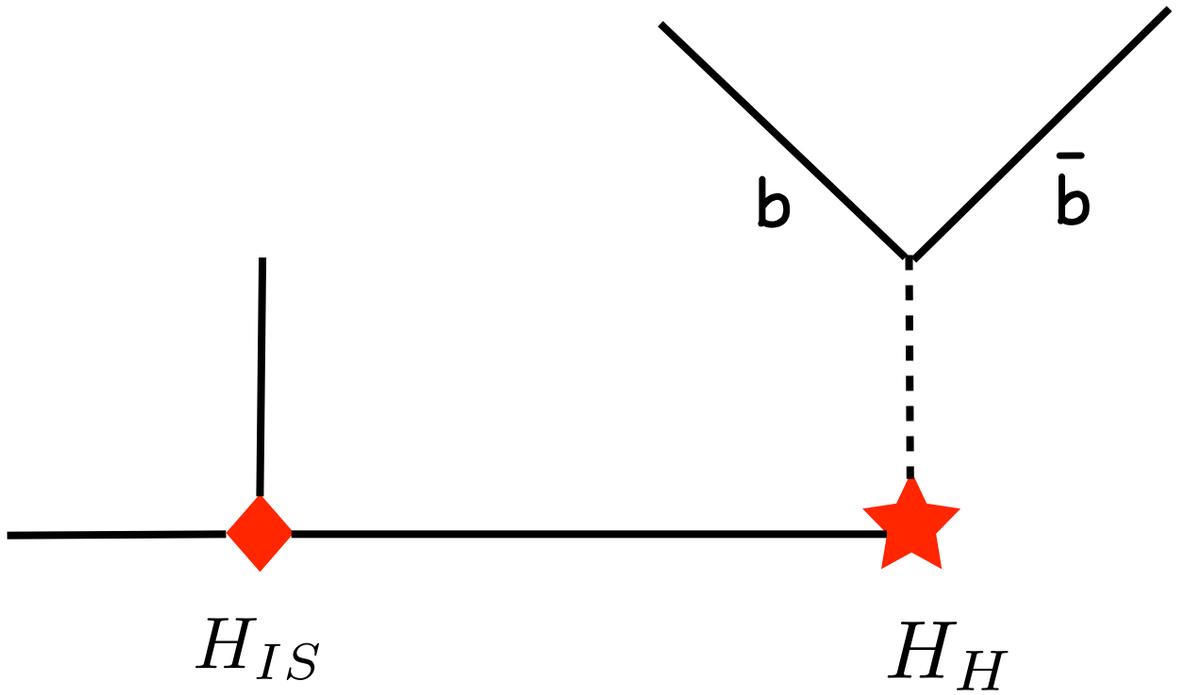
$$H_a = N_{\text{pdf}} \left(\frac{p_{T,\text{min}}^2}{k_0^2} \right)^{N_{\text{pdf}}} \frac{1}{k_0^2} \, \Theta(k_{T,\text{I}}^2 < Q^2/4)$$

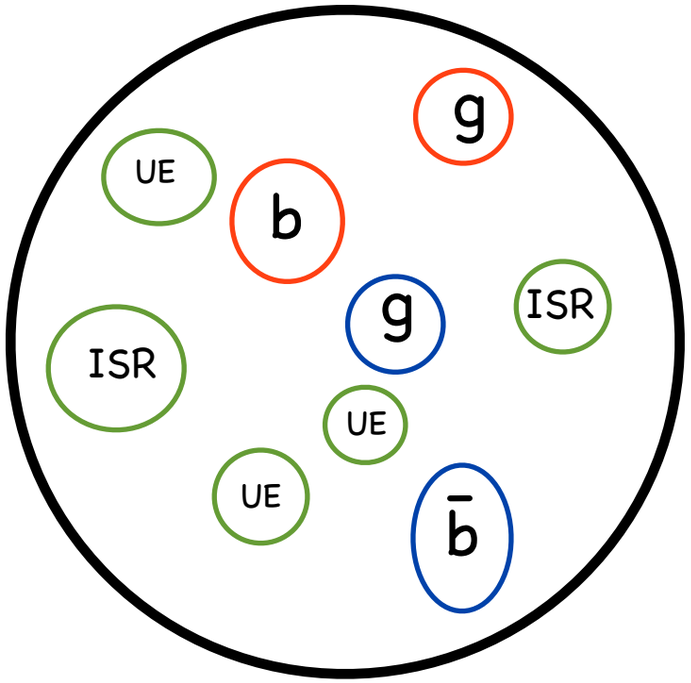
ISR vs Hard scale cut

$$H_H = N_{\text{pdf}} \left(\frac{p_{T,\text{min}}^2 + m_H^2}{k_H^2 + m_H^2} \right)^{N_{\text{pdf}}} \frac{1}{k_H^2 + m_H^2} \, \Theta(k_{T,\text{I}}^2 < Q^2/4)$$

$$H_{\text{IS}} = \frac{C_{\text{A}}}{2} \, \frac{\alpha_{\text{s}}(k_J^2 + \kappa_{\text{p}}^2)}{k_J^2 + \kappa_{\text{p}}^2} \, \frac{1}{(1 + c_R \, k_J/Q)^{n_R}} + \frac{c_{\text{np}} (\kappa_{\text{np}}^2)^{n_{\text{np}}-1}}{[k_J^2 + \kappa_{\text{np}}^2]^{n_{\text{np}}}}$$

(fitted to Pythia8)

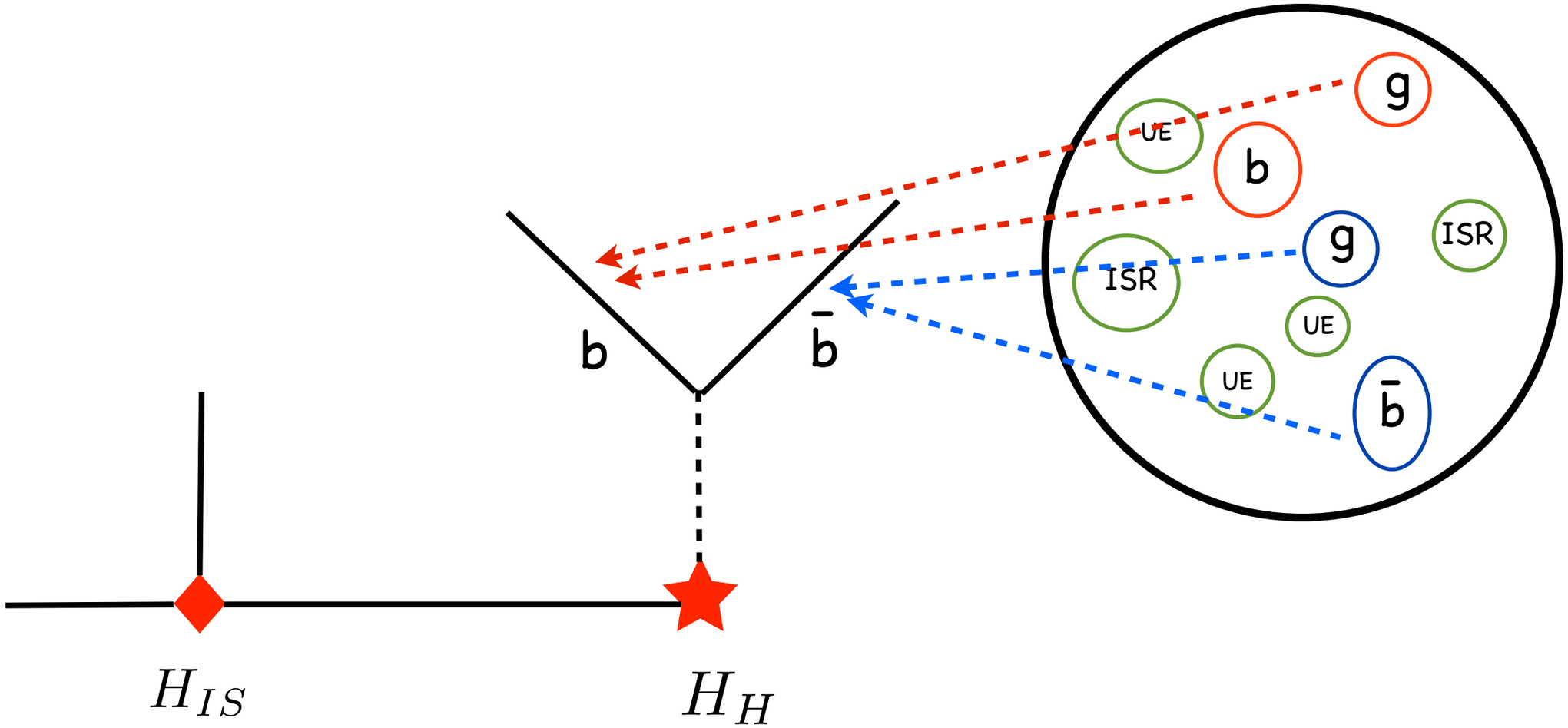




Higgs has to decay:

$$He^{-S} = \frac{4}{(\sqrt{2}-1)\pi} \frac{\Theta(|m_{b\bar{b}} - m_H| < \Delta m_H)}{4 m_H \, \Delta m_H} \qquad \Delta m_H = 10 \text{ GeV}$$

$$\int dm_{b\bar{b}}^2 \, d\Delta y \, d\Delta\phi \sum_s J_0 H e^{-S} = 1$$



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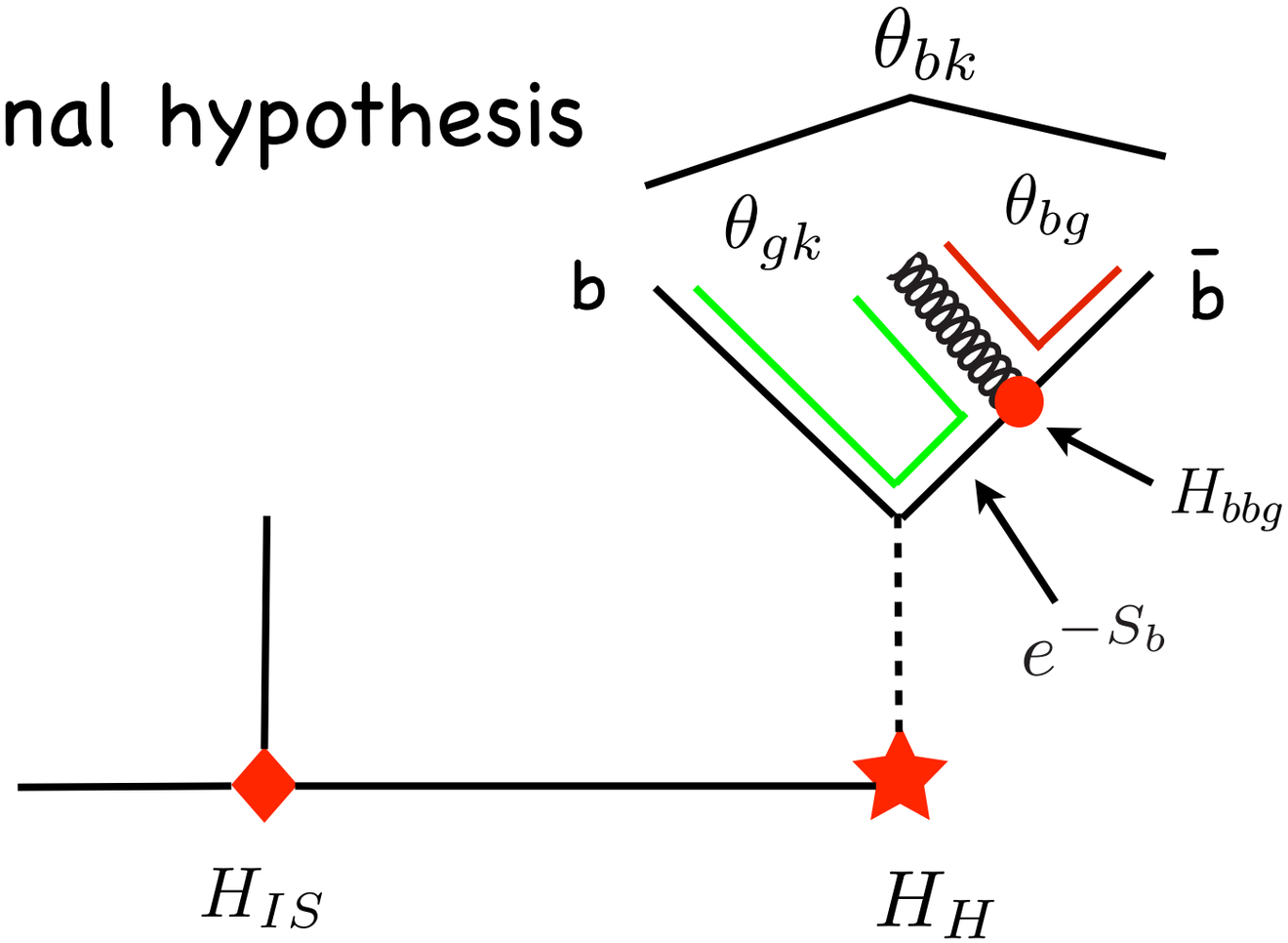
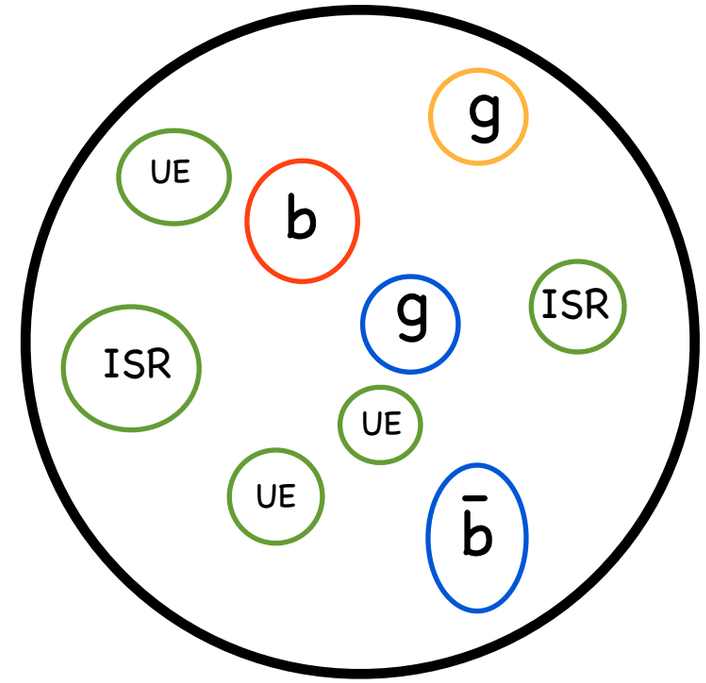
Signal hypothesis





b-quarks radiate gluons

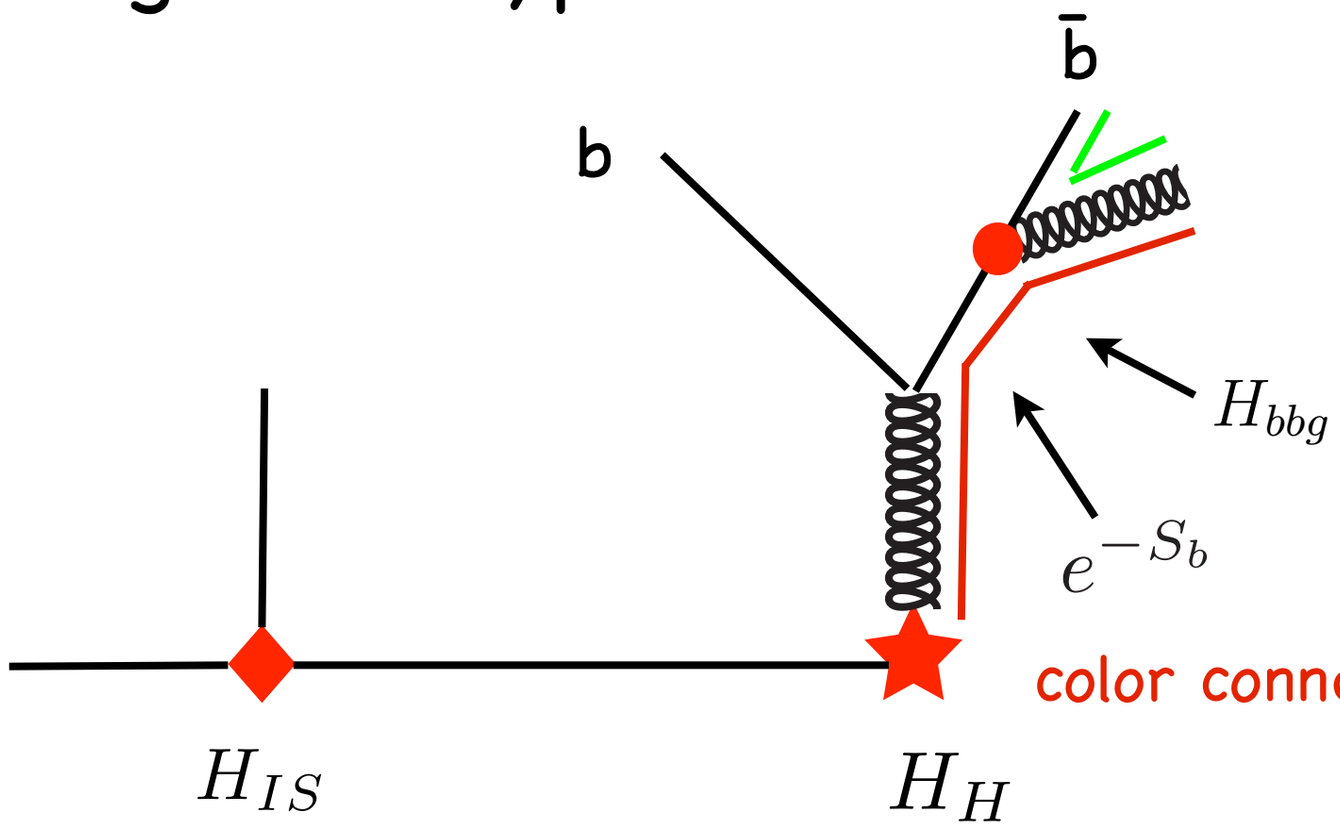
See Dave's talk

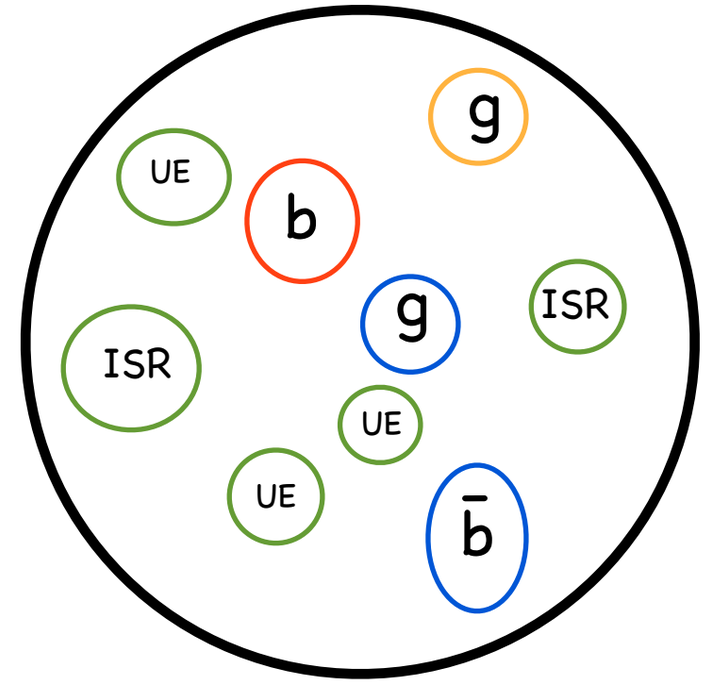
$$\int d\mathcal{P} = \int d\mu_J^2 \int d\Delta\phi \int d\Delta y \sum_s J\, H e^{-S}$$

$$S \approx \int d\bar{\mu}_J^2\, \Theta(\mu_J^2 < \bar{\mu}_J^2) \int d\Delta\bar{y} \int d\Delta\bar{\phi} \sum_{\bar{s}} J(\bar{p}_A, \bar{p}_B)\, H(\bar{p}_A, \bar{p}_B)\, \Theta(\{\bar{p}_A, \bar{p}_B\} \in \text{fat jet})$$

$$H_{bbg} = H_{\bar{b}g\bar{b}} = \frac{C_{\mathrm{A}}\alpha_{\mathrm{s}}(\mu_J^2)}{2}\, \frac{1}{\mu_J^2}\, \frac{k_J^2}{k_b k_g}\, \frac{\theta_{bk}^2}{\theta_{gb}^2 + \theta_{gk}^2}\, \Theta(k_g < k_b)\, \Theta\left(2\,\frac{\mu_J^2}{k_J} < \frac{\mu_K^2}{k_K}\right)$$

Background hypothesis





color connected partner outside fat jet

b-quarks radiate gluons

See Dave's talk

$$\int d\mathcal{P} = \int d\mu_J^2 \int d\Delta\phi \int d\Delta y \sum_s J\, H e^{-S}$$

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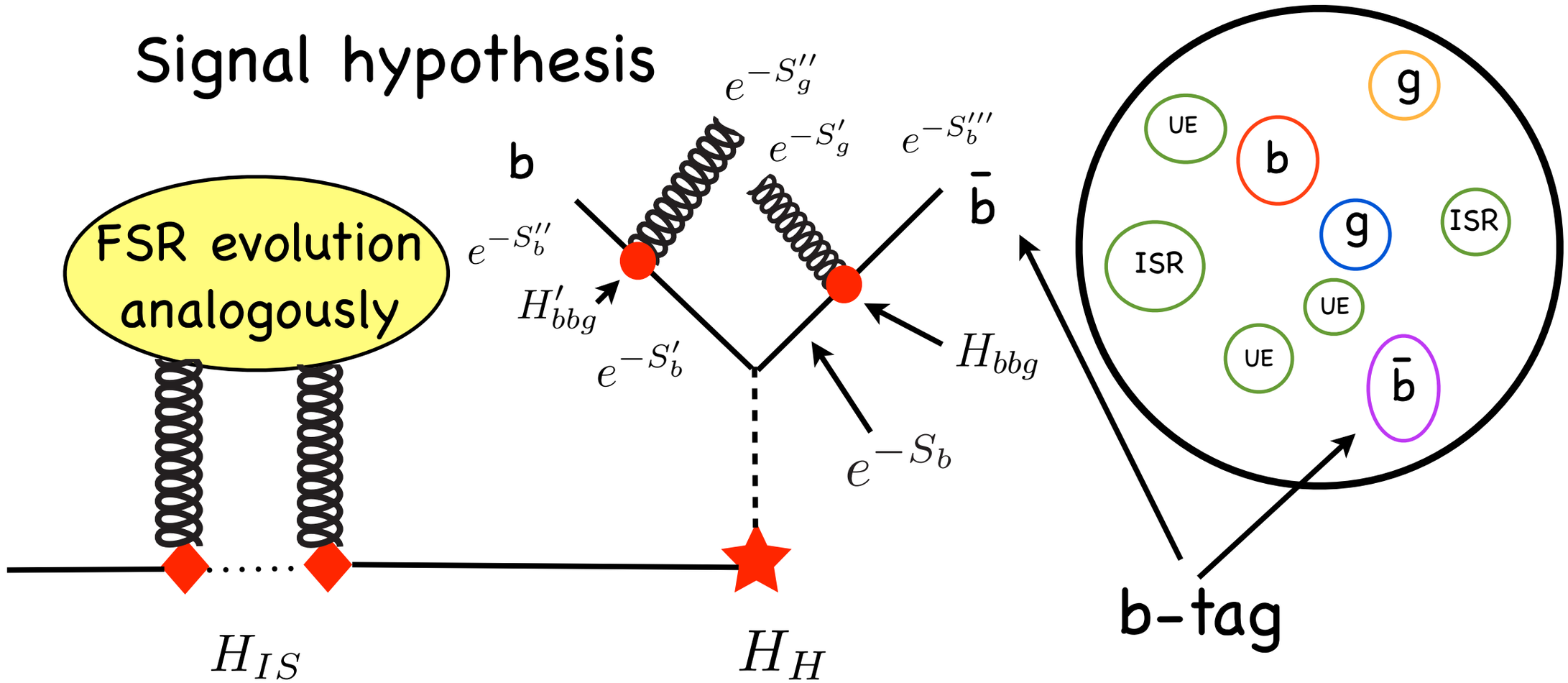
Signal hypothesis



Wrapping up all factors gives weight for shower history

$$\chi = \frac{\sum_{ISR/Hard}\left(\sum_i \mathrm{ISR_i} \times \sum_j \mathrm{Signal_j}\right)}{\sum_{ISR/Hard}\left(\sum_i \mathrm{ISR_i} \times \sum_j \mathrm{Backg_j}\right)}$$

Here $\mathrm{Signal_1 = H_H H_{split} e^{-S_{split}} H_{bbg} e^{-S'_b} e^{-S'''_b} e^{-S'_g} H'_{bbg} e^{-S''_b} e^{-S_b} e^{-S''_g}}$

Event selection cuts

- Cluster hadrons to 'detector cells' 0.1 x 0.1, ET > 0.5 GeV
- lepton pT > 15 GeV
- two hardest leptons mZ +- 10 GeV
- at least 1 fat jet (anti-kT, R=1.2, pT>200 GeV)

Normalize signal/background cross section
to the NLO results obtained from MCFM

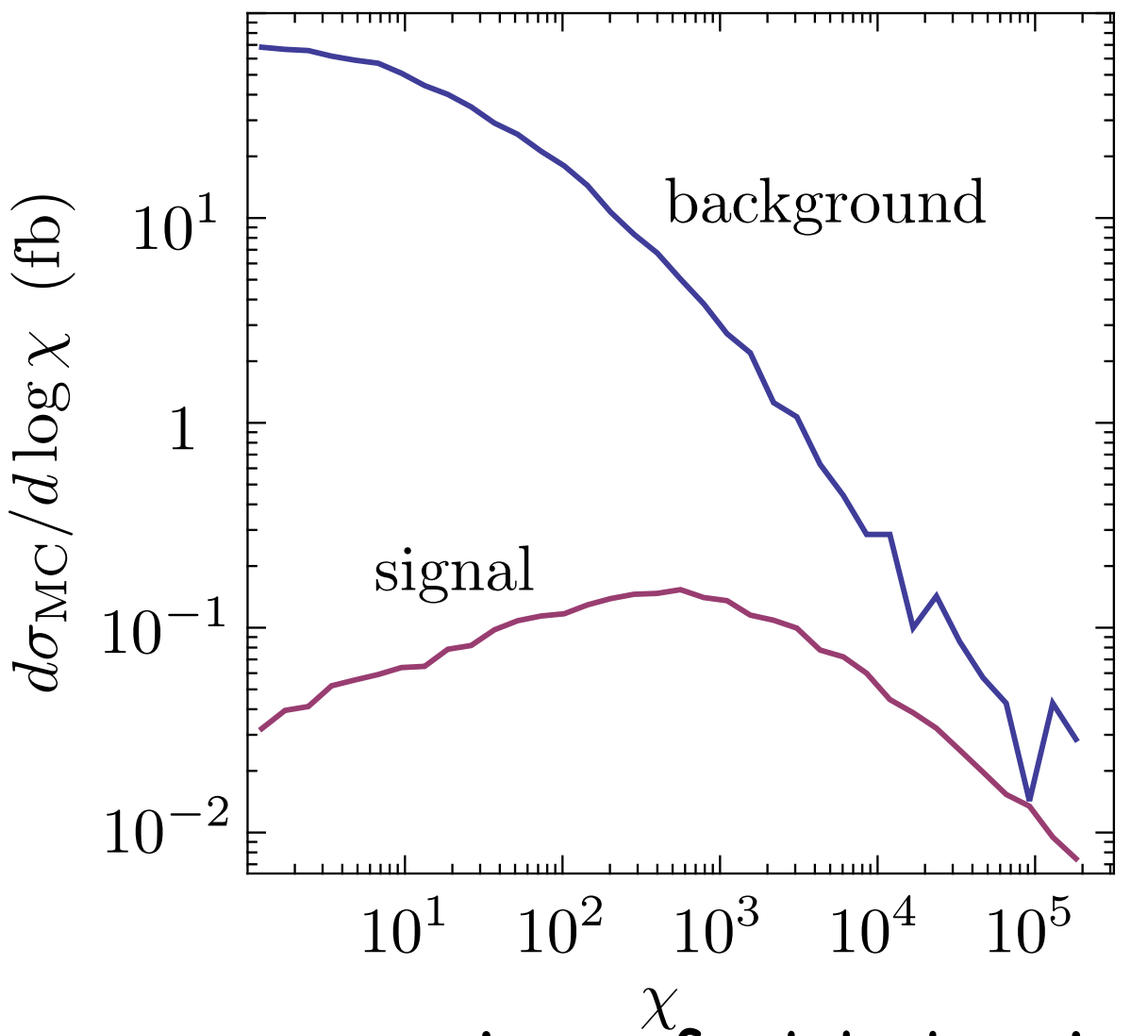
$$\sigma_{\mathrm{MC}}(\mathrm{S}) = 1.48 \text{ fb}$$

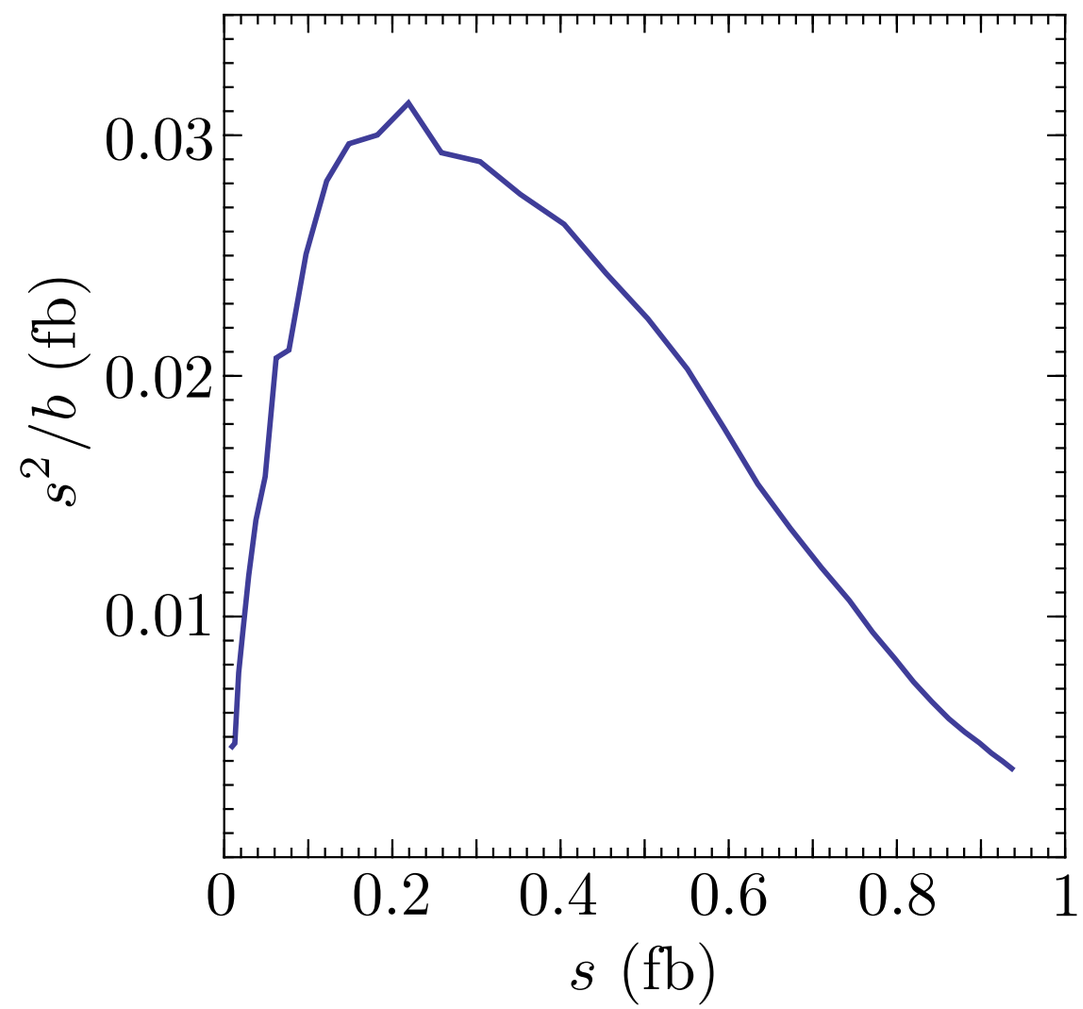
$$\sigma_{\mathrm{MC}}(\mathrm{B}) = 2610 \text{ fb}$$

$$\frac{\sigma_{\mathrm{MC}}(\mathrm{S})}{\sigma_{\mathrm{MC}}(\mathrm{B})} = \frac{1}{1760}$$

Results of shower deconstruction (SD)

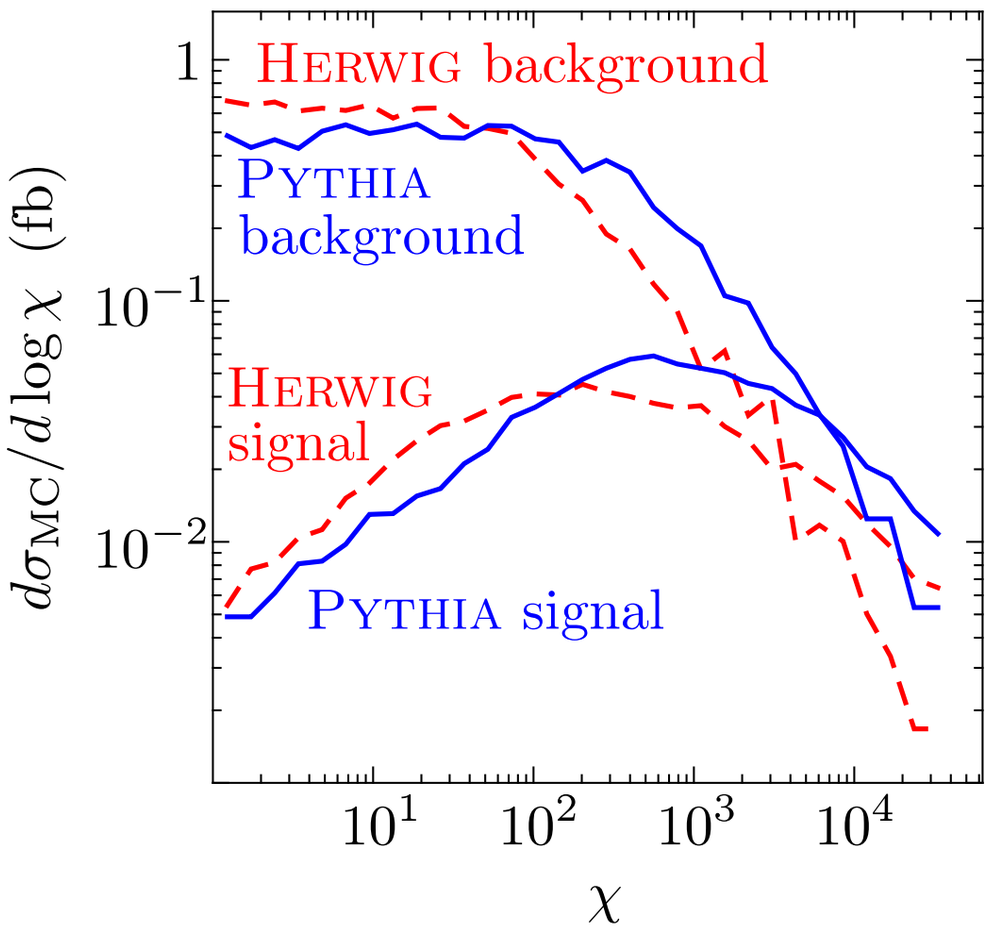
$$\chi(\{p,t\}_N) = \frac{P(\{p,t\}_N|\mathrm{S})}{P(\{p,t\}_N|\mathrm{B})}$$

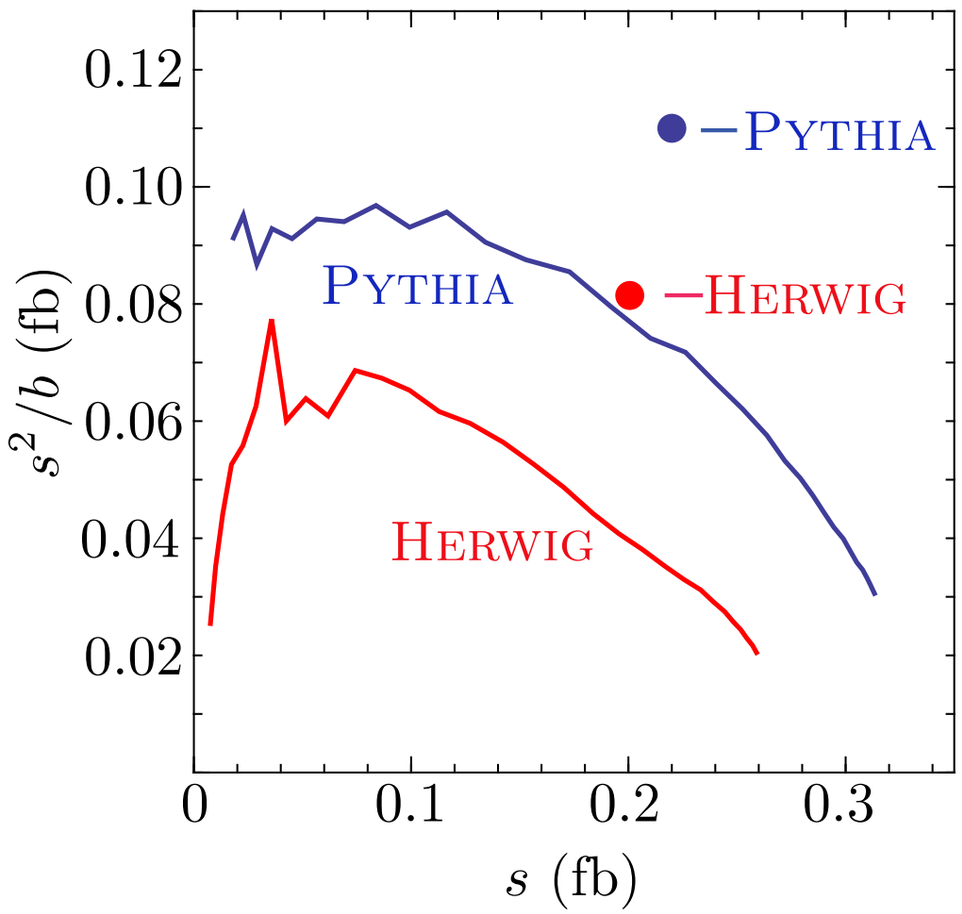




imperfect b-tagging no b-tag required

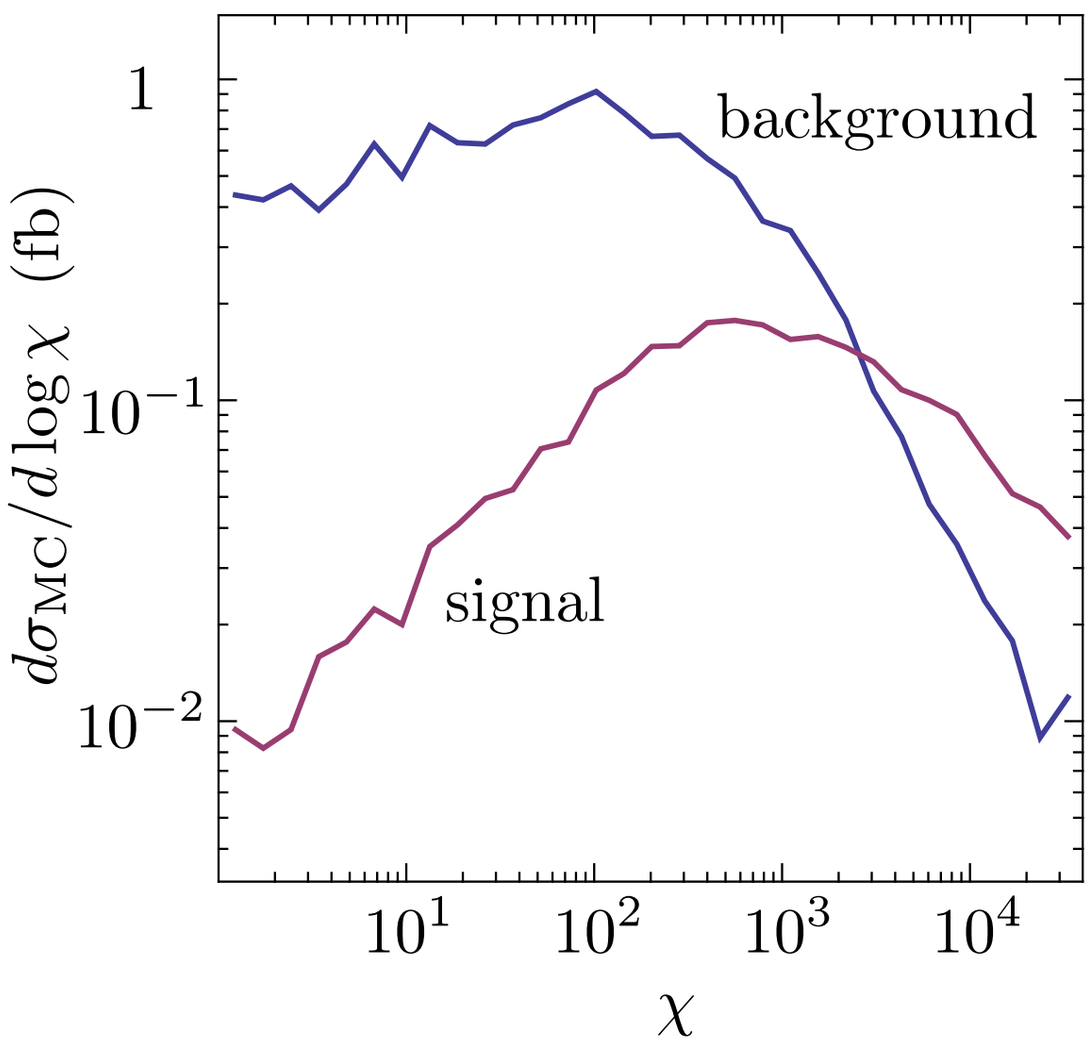
imperfect b-tagging but 2 b-tagged microjets

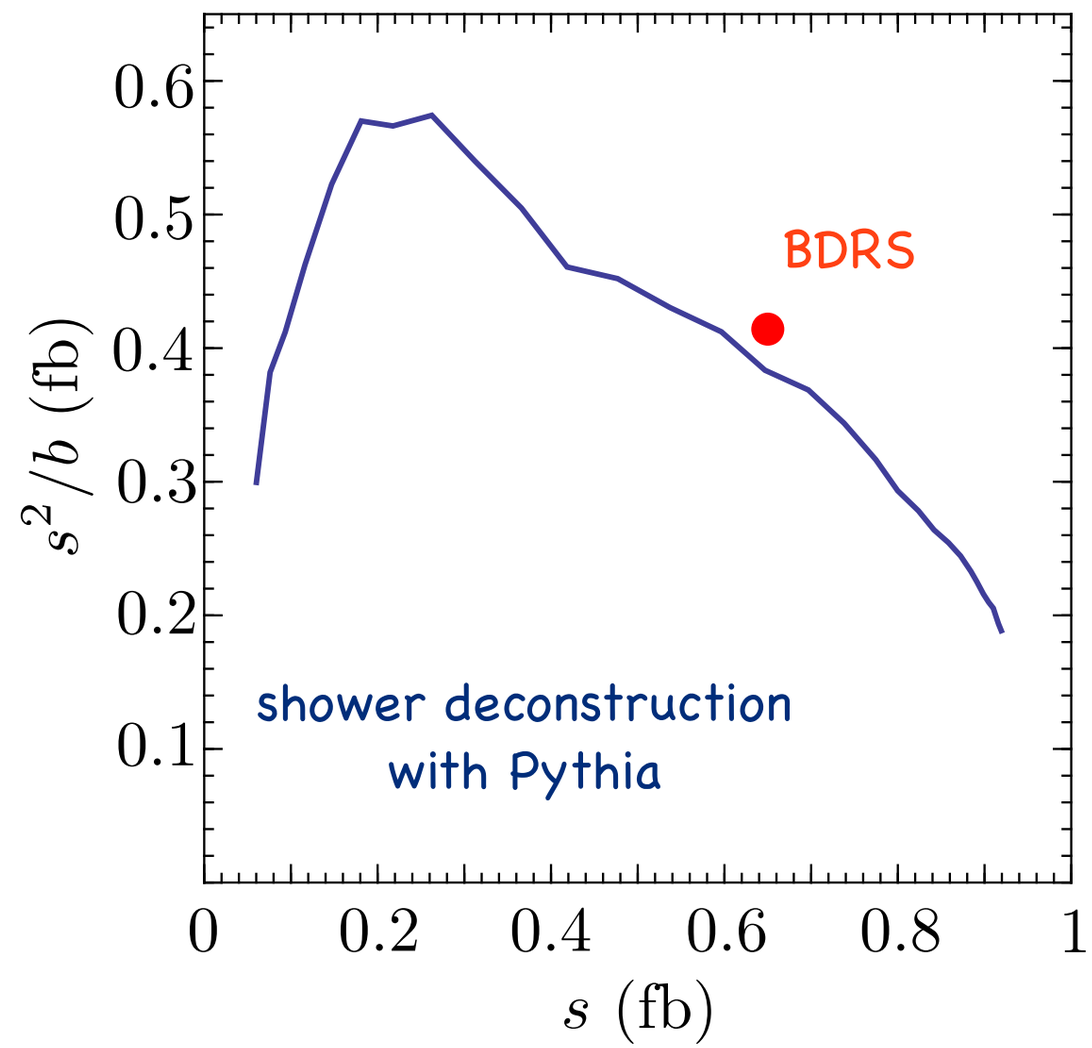




- In simple HZ final state not as good as BDRS
- SD performs comparable for Herwig++ and Pythia

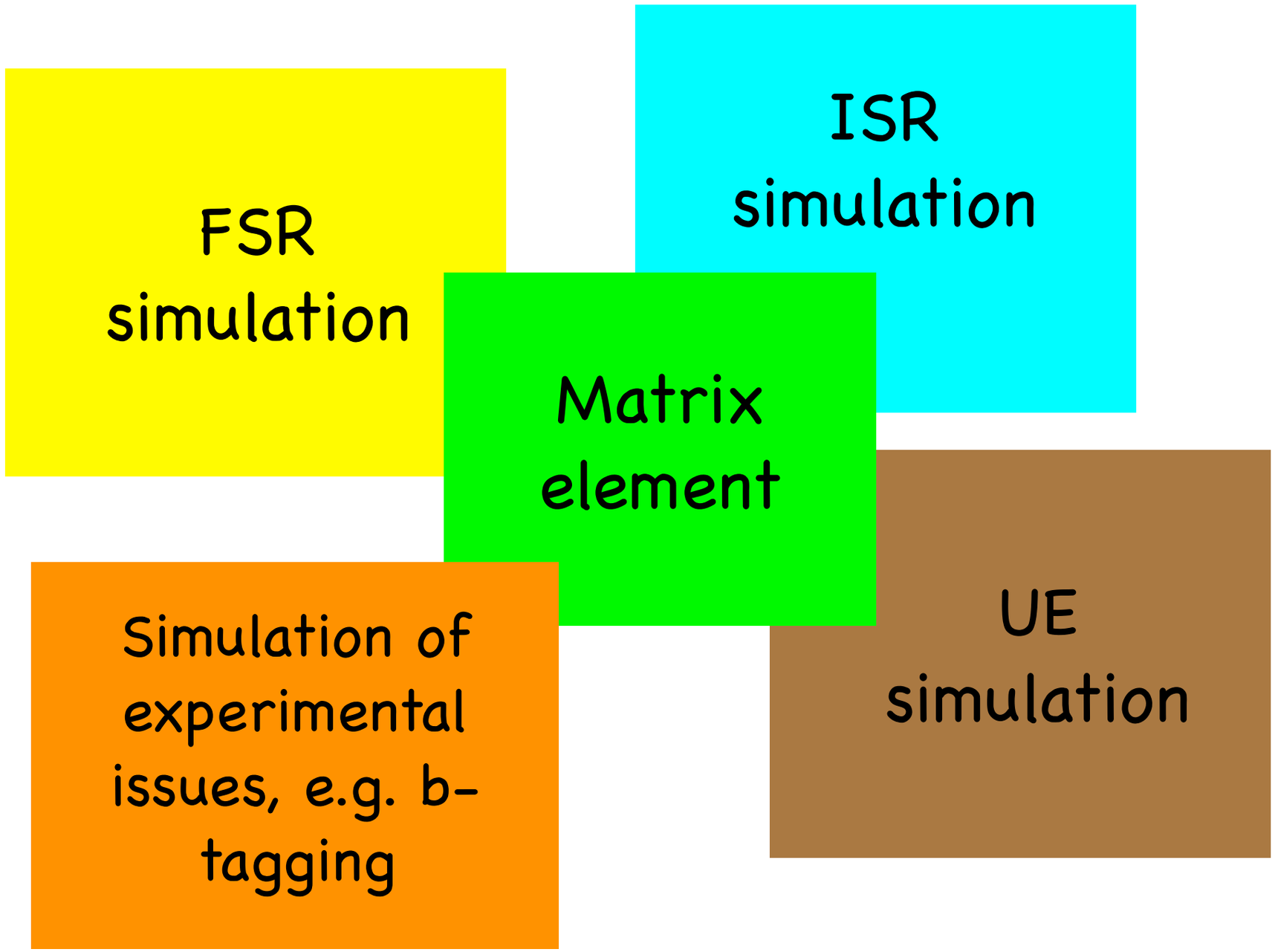
perfect b-tagging 2 b-tagged microjets





- Profits more from information than BDRS, e.g. b-tagging

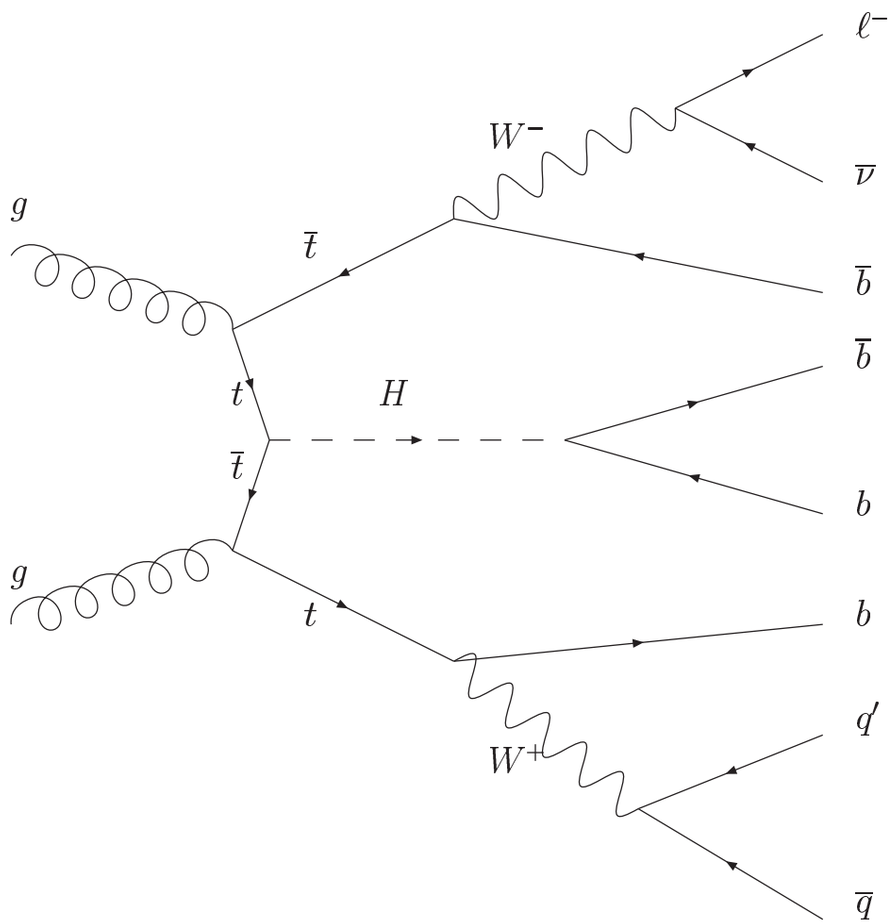
Lots of room for improvement:

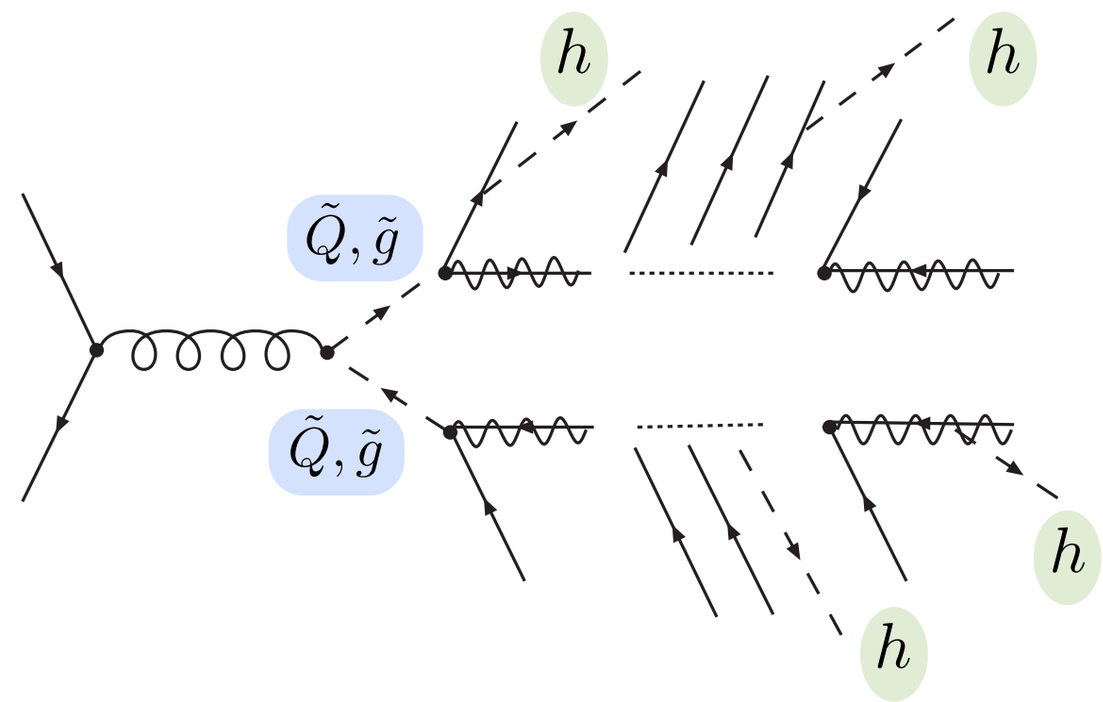


Modular build -> improvements are additive

Targeted scenarios:

- Busy final states -- e.g. tth, susy cascades





- Difficult processes with low stat. significance

Conclusions

- SD realization of 'maximal information approach'
- In simple HZ final state not as good as BDRS
- Theoretical Systematic uncertainty similar to BDRS
- Profits more from information than BDRS, e.g. b-tagging
- Might be useful for busy final states
- Modular set-up -> parts can be improved independently
- Inclusion of light quarks + collinear limit close to finalization