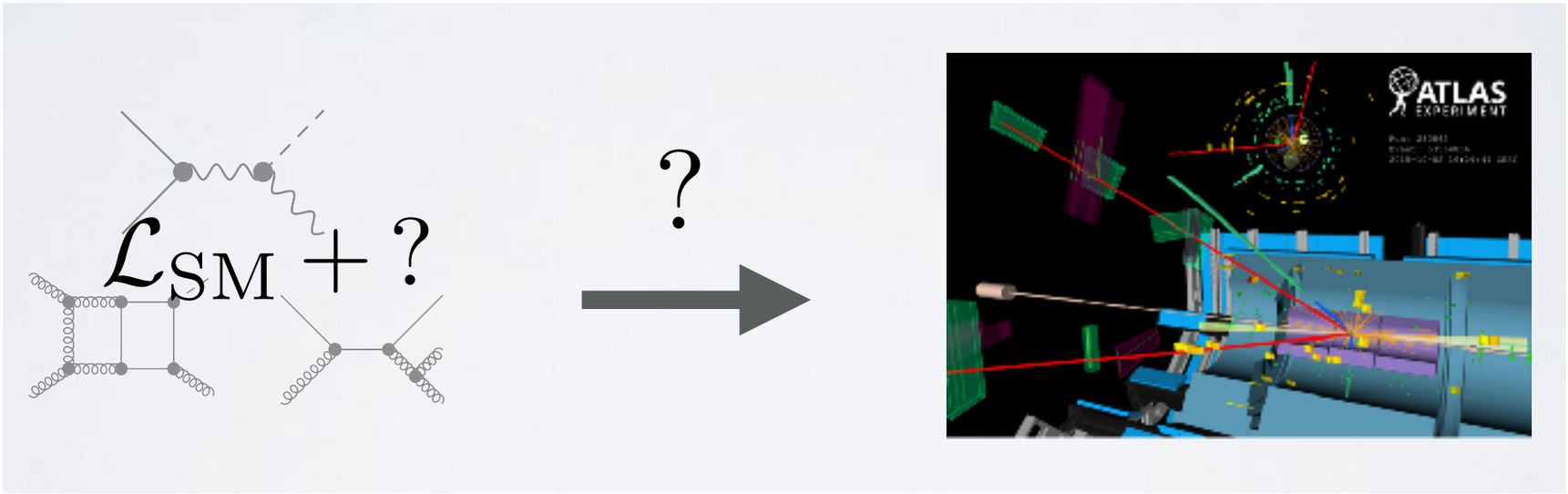
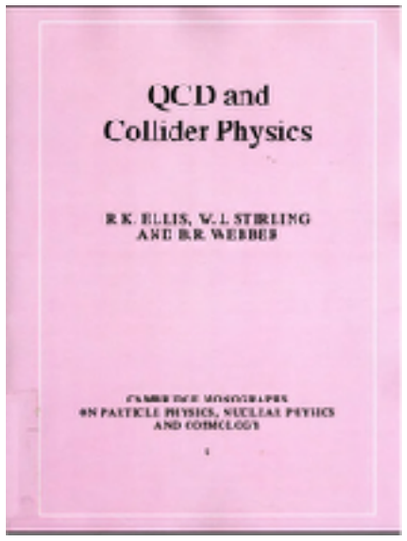
Collider Phenomenology

Lucian Harland-Lang, University of Oxford

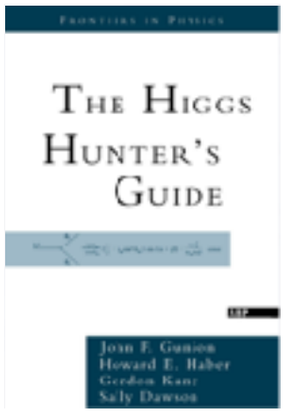


Background Reading

- Ellis, Stirling, Webber, "QCD and Collider Physics", aka "The Pink Book".



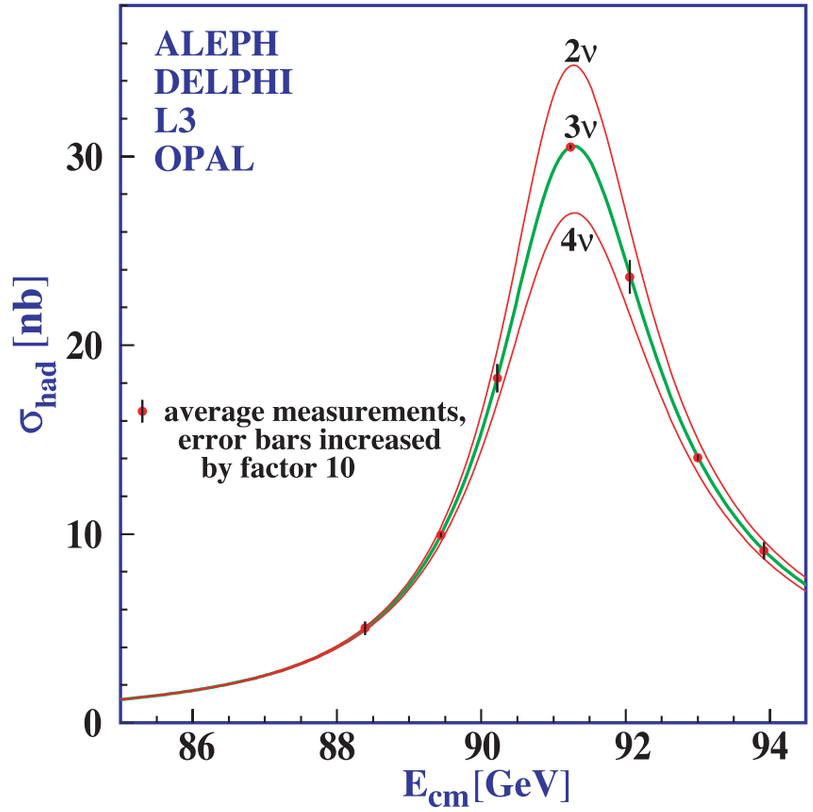
- Gunion, Kaber, Kane, Dawson, "Higgs Hunter's Guide"



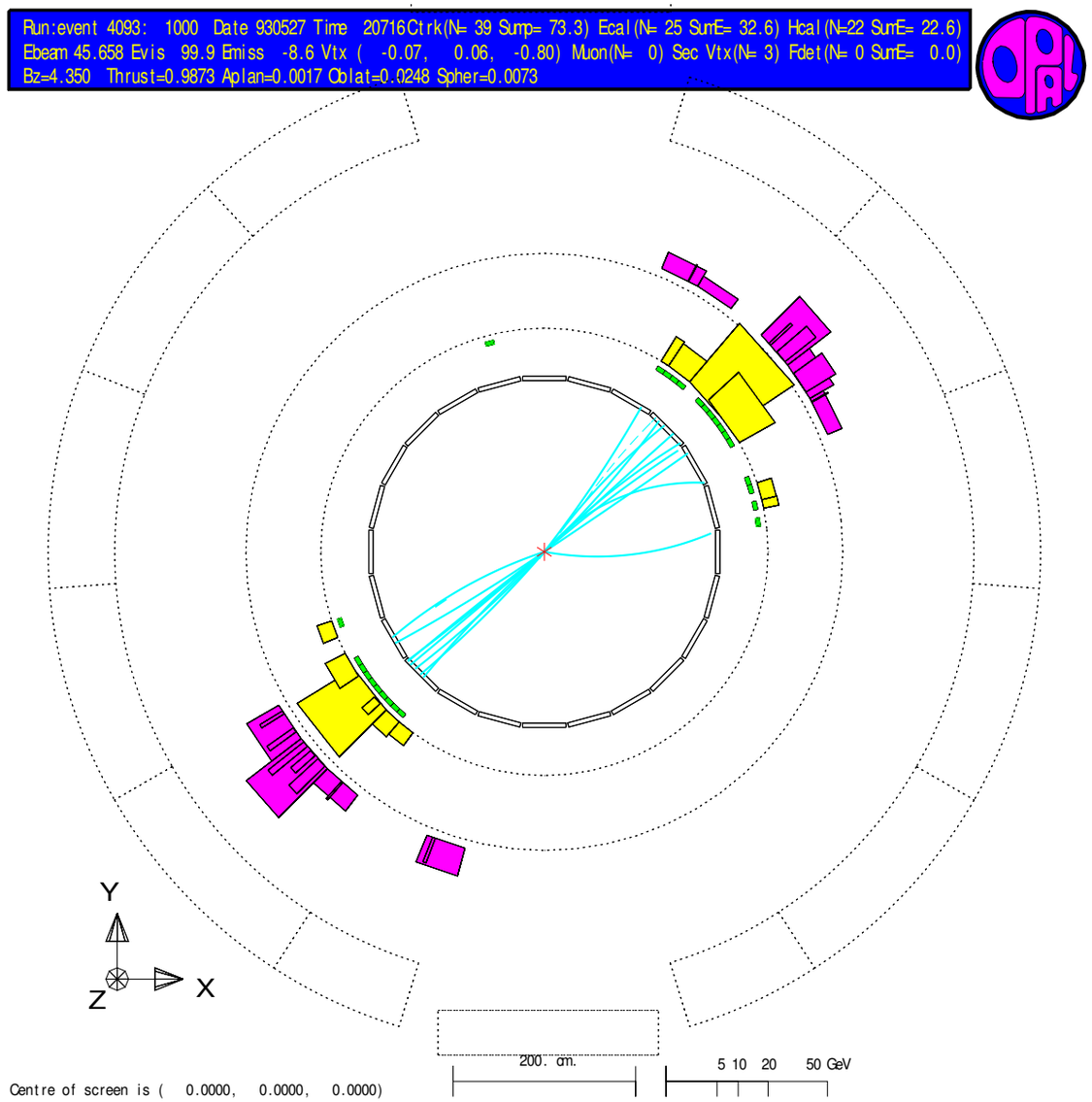
- Many nice review/lecture notes online: hep-ph/0011256, http://cds.cern.ch/record/454171, arXiv:1011.5131, arXiv:0906.1833, hep-ph/0505192, arXiv:1709.04533, arXiv:1312.5672…

Purpose of Slides

- Lecture notes will be given on board, but see online notes for more detail (will not cover everything there).
- These slides: plots that I cannot draw easily on the board (in many cases borrowed from Simon Badger).
- May update throughout the week.



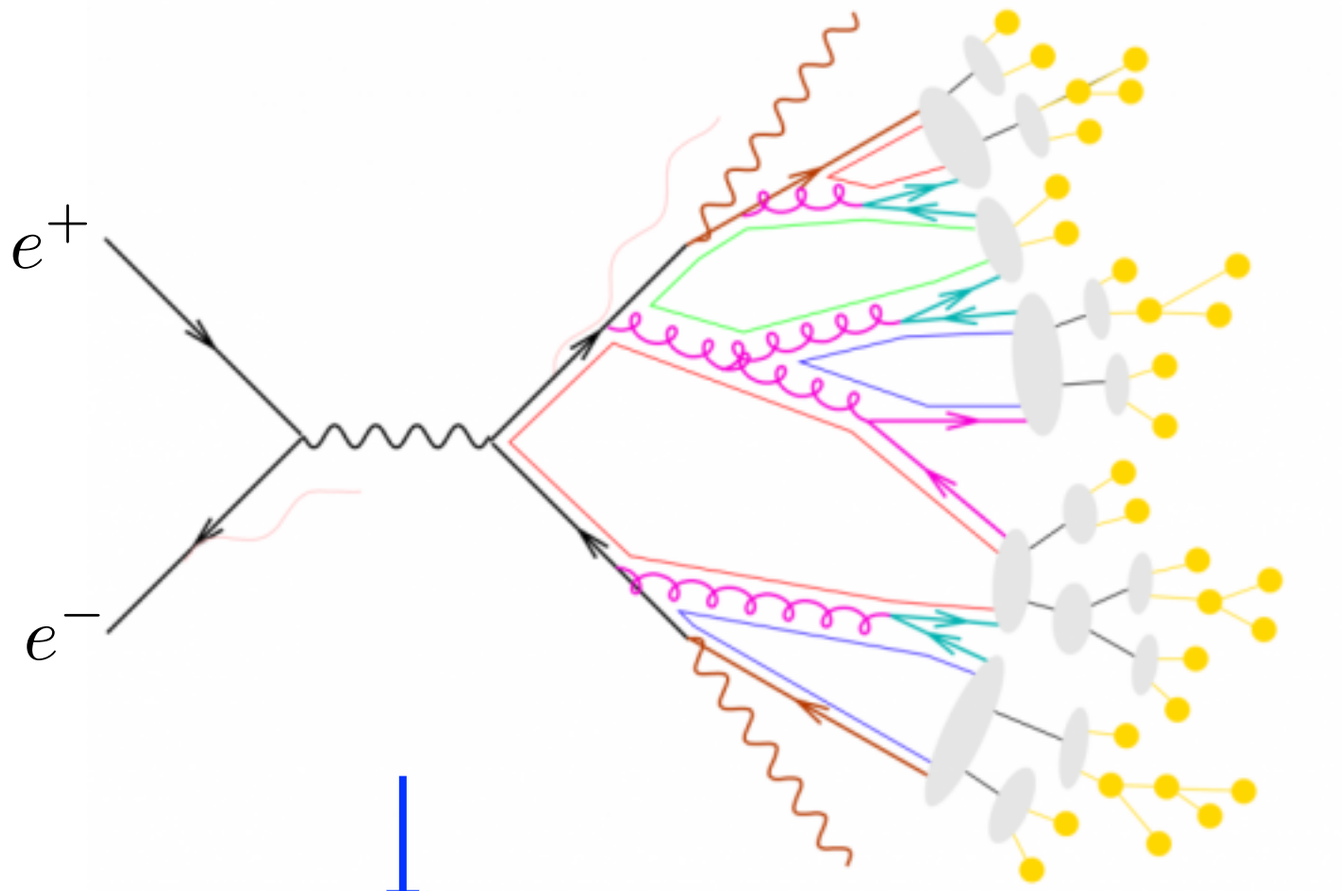
(2-jet) Event Display



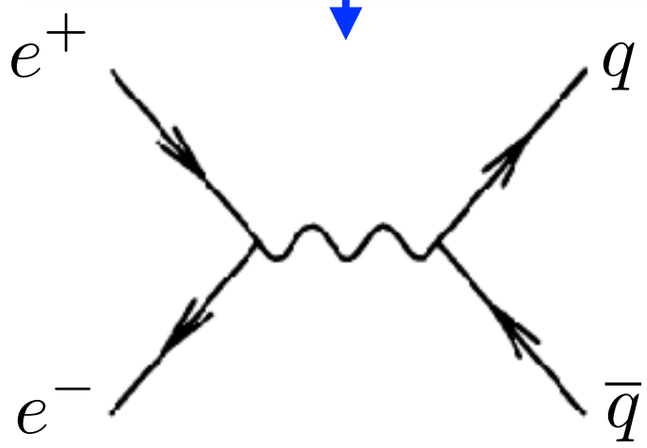
- Example event display from e^+e^- collisions.

R(hadrons/muons)

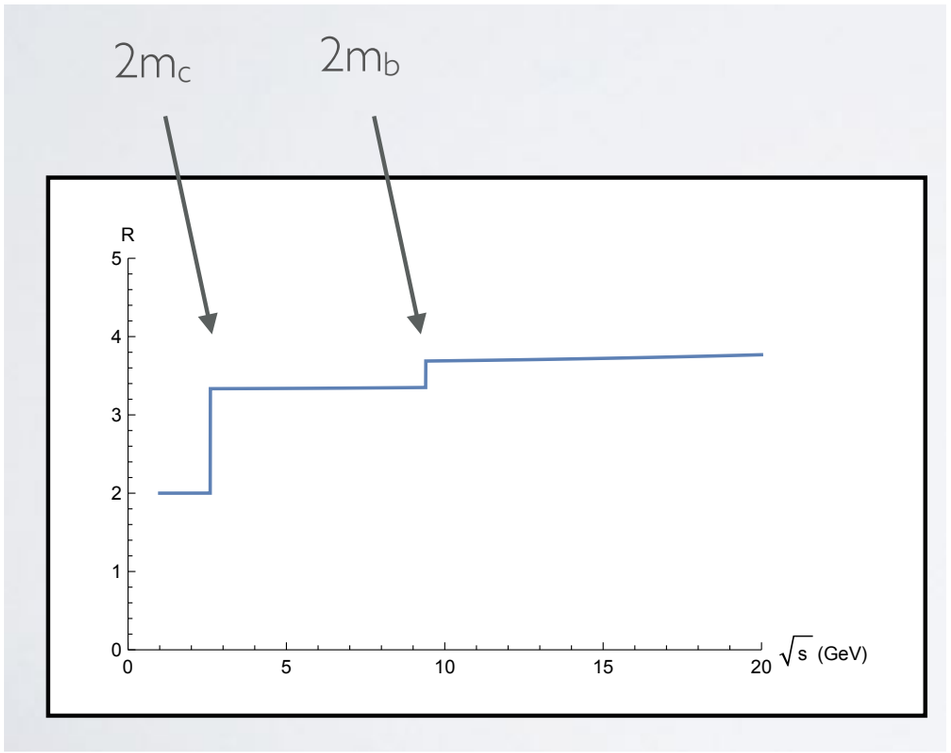
Full Event



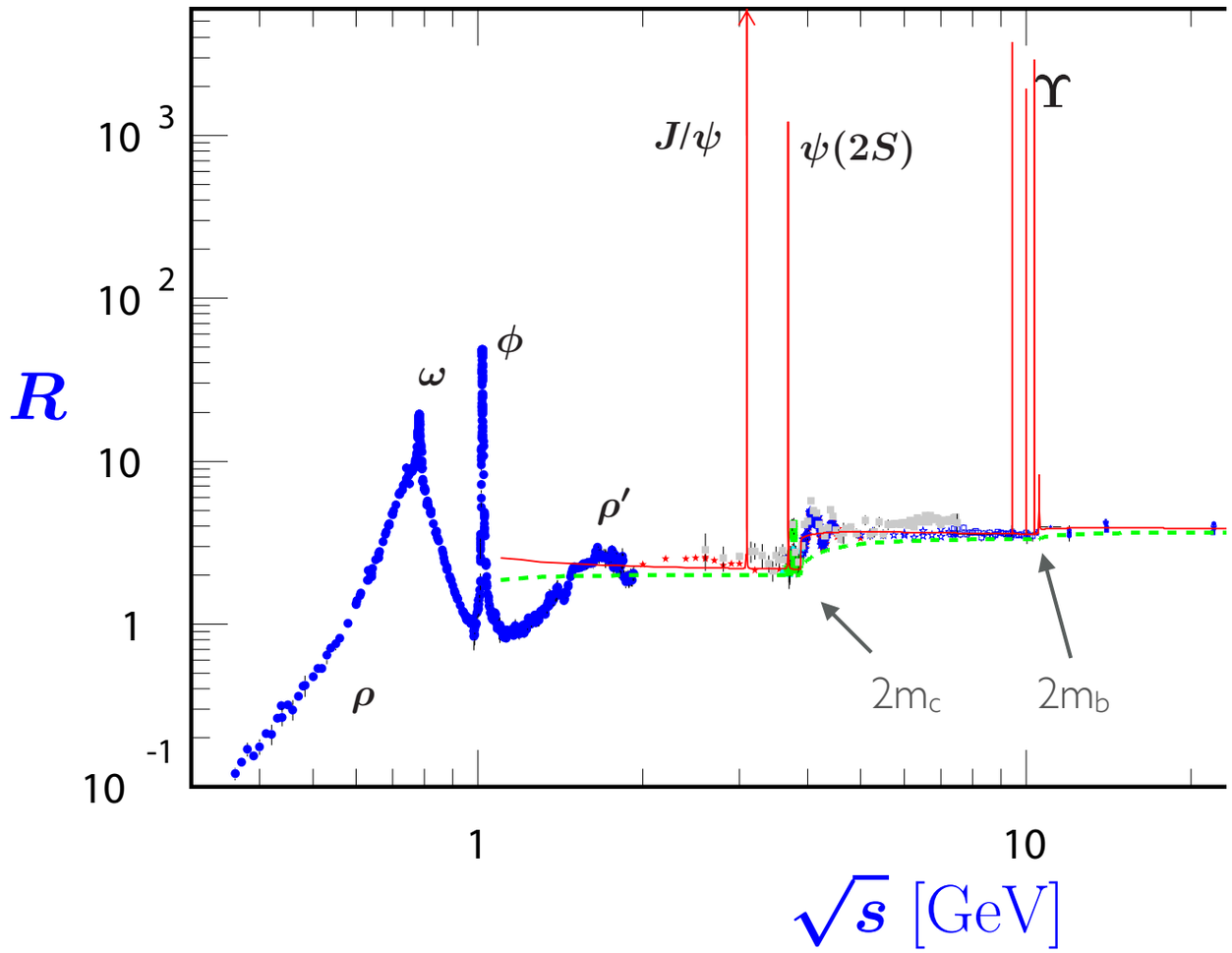
LO parton-level cross section



R(hadrons/muons)

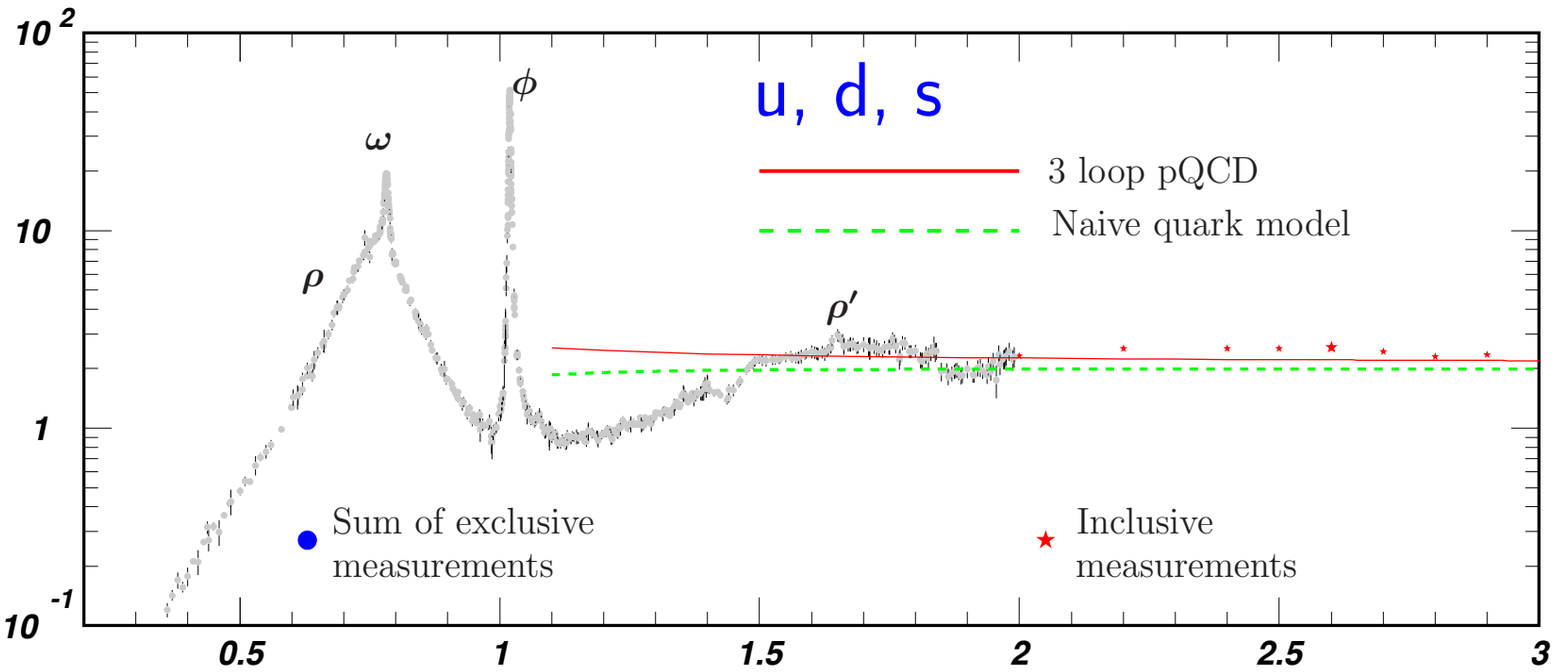


(Approx.!)
Theory

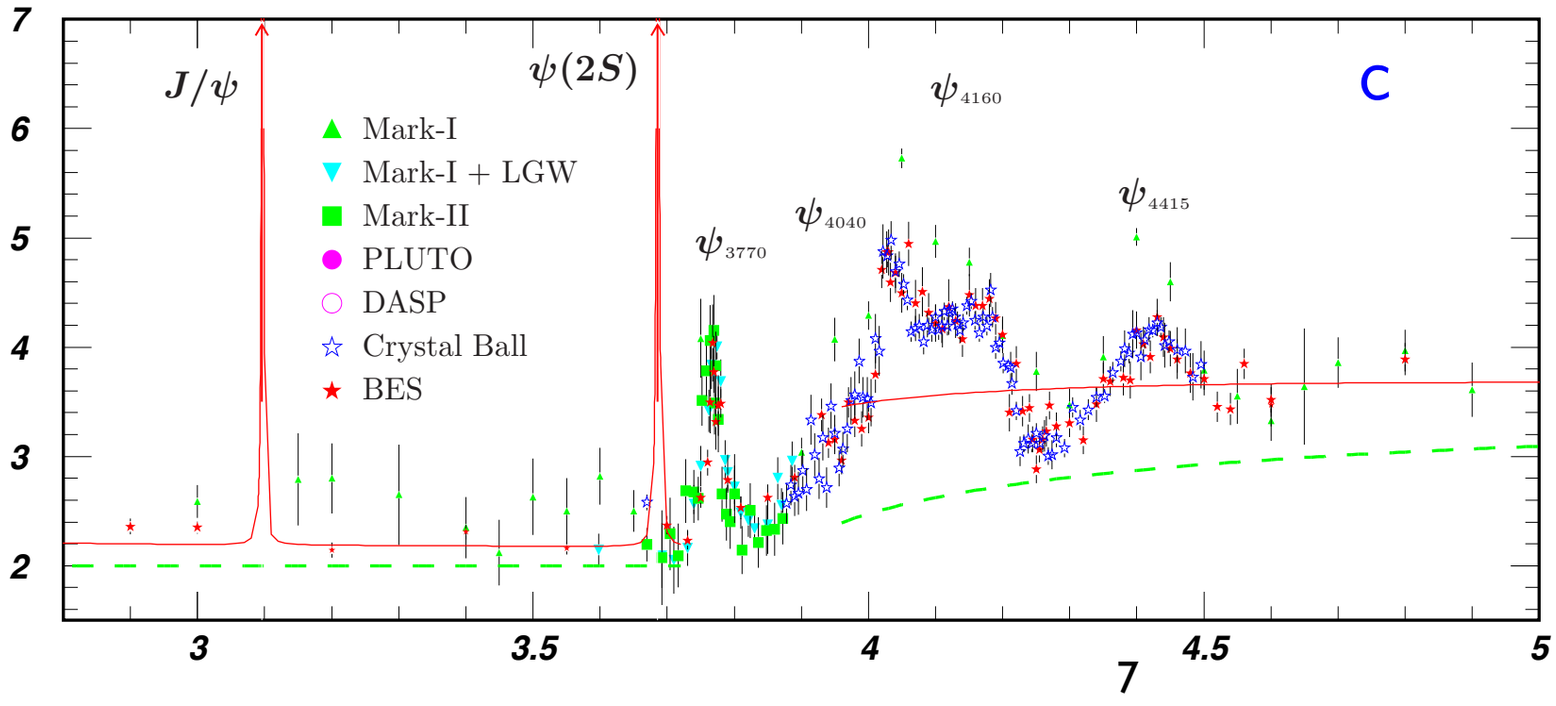


Data

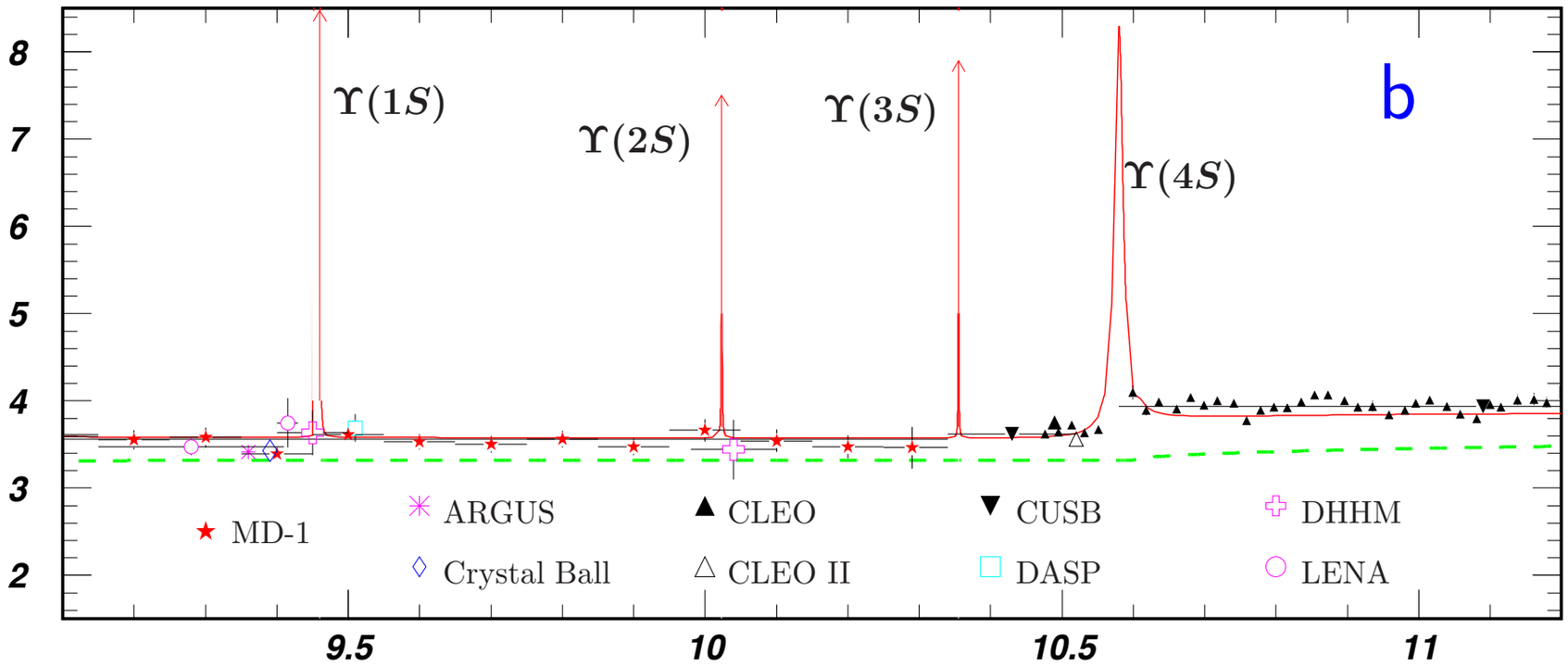
R(hadrons/muons) - Closer Look



$$R = \sum_q e_q^2 N_c = \underbrace{\underbrace{\underbrace{N_c\left(\frac{4}{9}+\frac{1}{9}+\frac{1}{9}\right.}_{u,d,s}+\frac{4}{9}}_{u,d,s,c}+\left.\frac{1}{9}\right)}_{u,d,s,c,b} .$$



R(hadrons/muons) - Closer Look



$$R = \sum_q e_q^2 N_c = \underbrace{\underbrace{\underbrace{N_c\left(\frac{4}{9} + \frac{1}{9} + \frac{1}{9}\right.}_{u,d,s} + \frac{4}{9} + \left.\frac{1}{9}\right)}_{u,d,s,c}}_{u,d,s,c,b} .$$

- Data from last three slides:

Mark I/II @ SLAC (1974-1975)

PLUTO @ DESY (1974-1982)

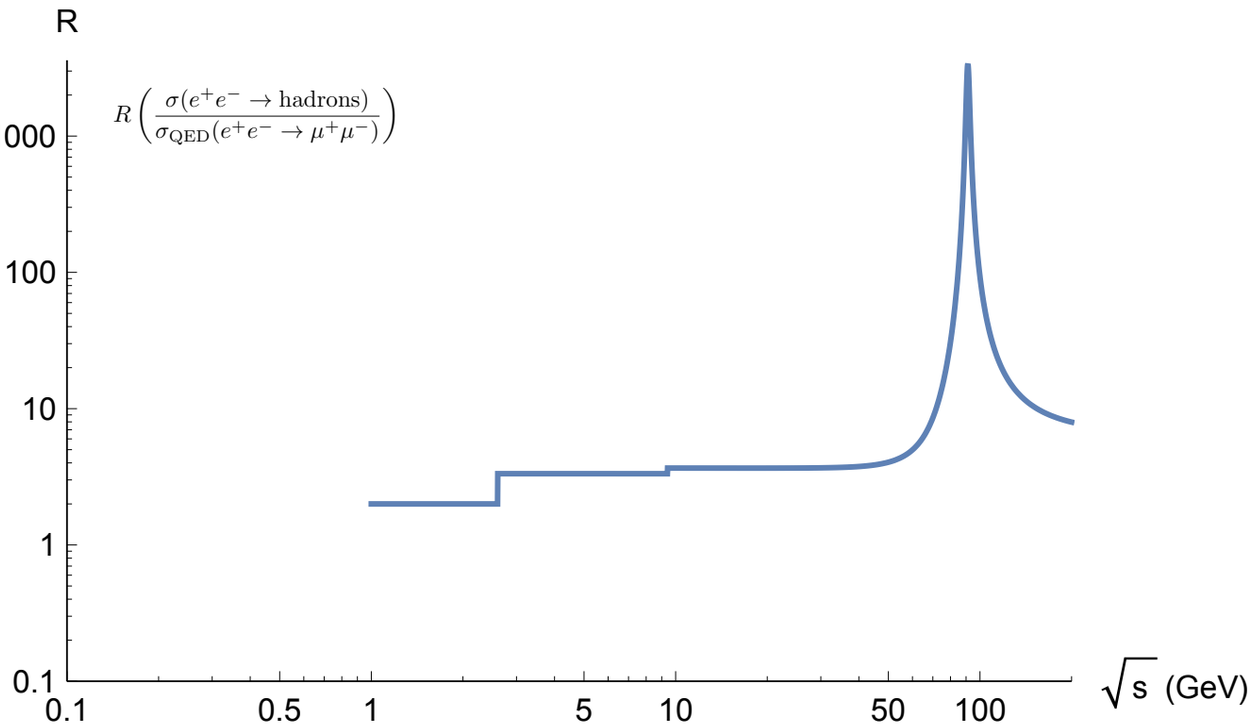
w/ DORIS I/II and PETRA

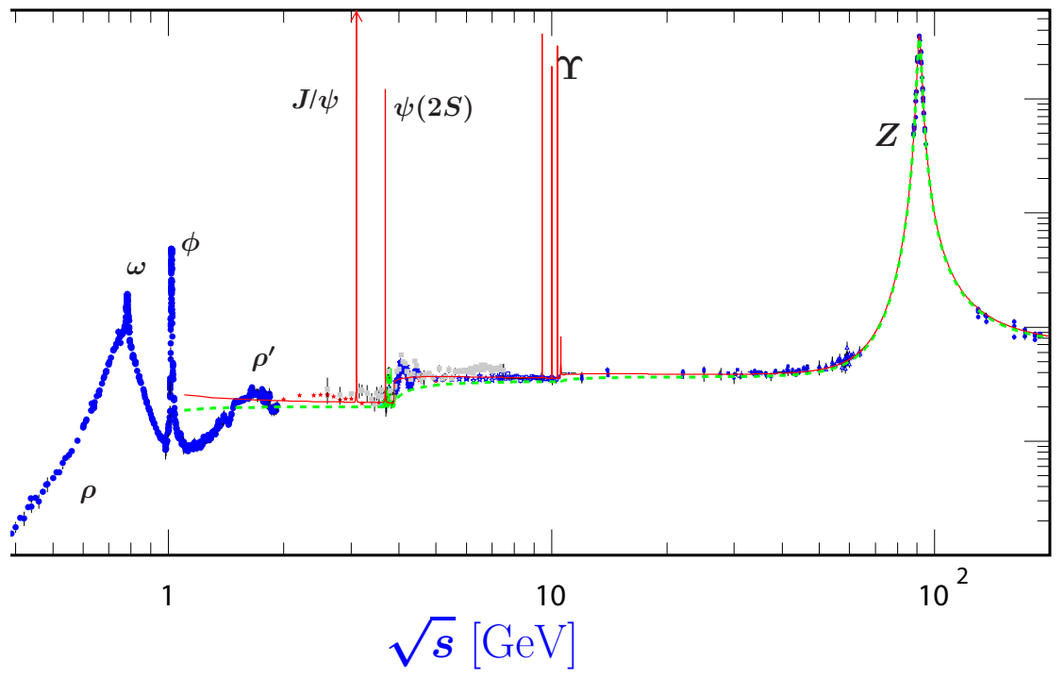
DASP @ DESY (1974-1982)

w/ DORIS I

BES @ BEPC (1995-)

R(hadrons/muons) - up to Z peak

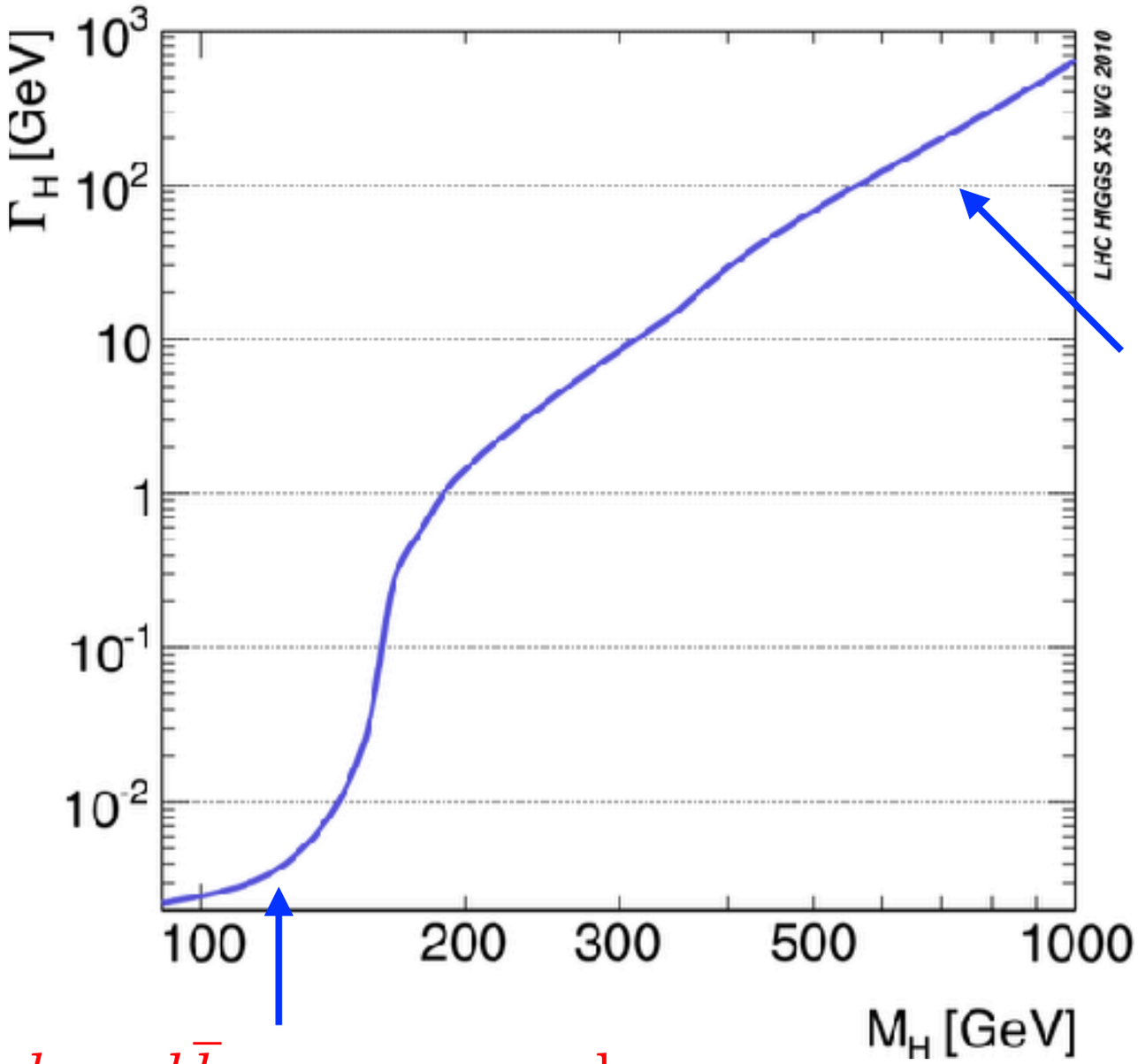




(Approx.!) Theory

Data

Higgs Width



$h \to WW(ZZ)$: broad peak

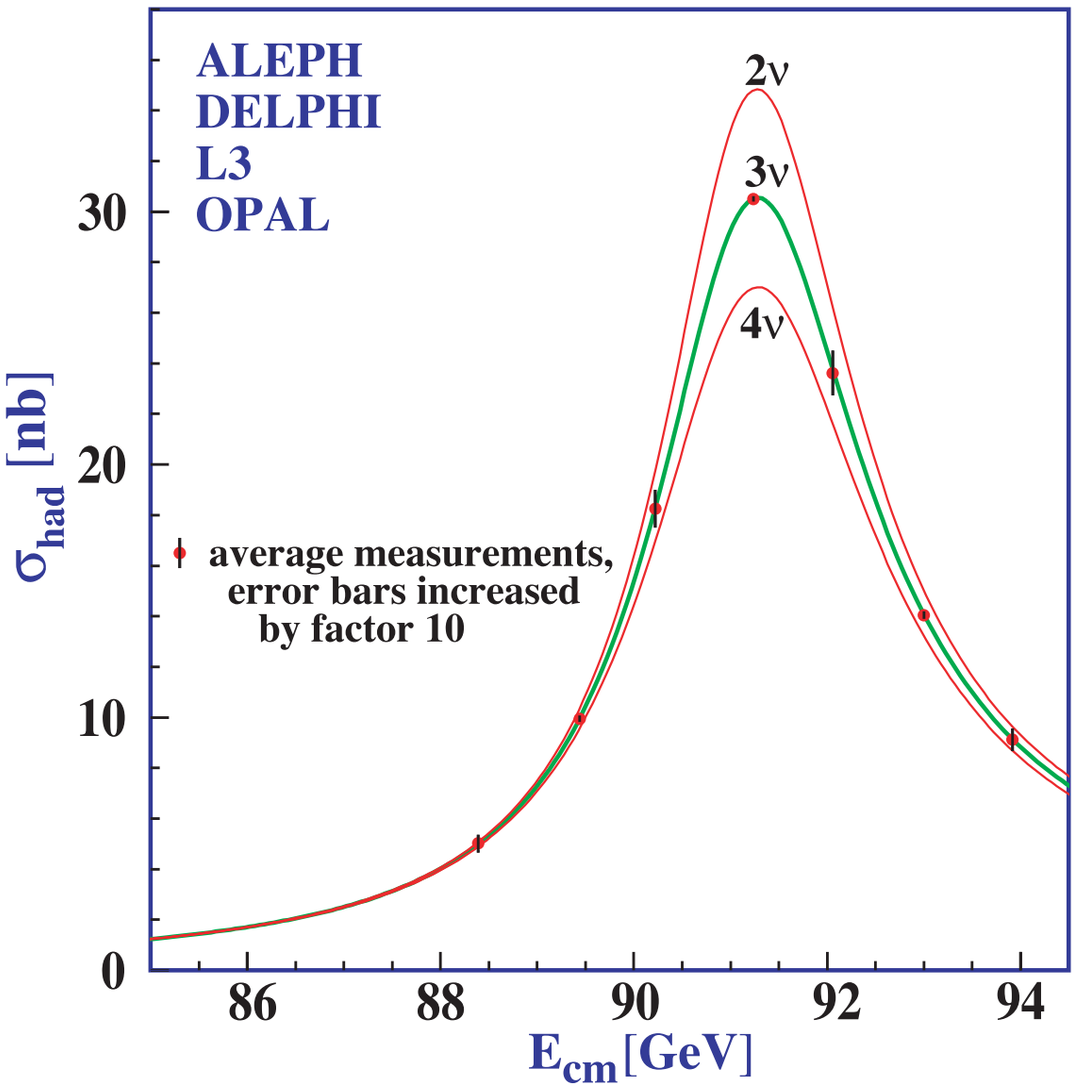
$h \to b\bar{b}$: narrow peak

Sigma(hadronic) - Z peak

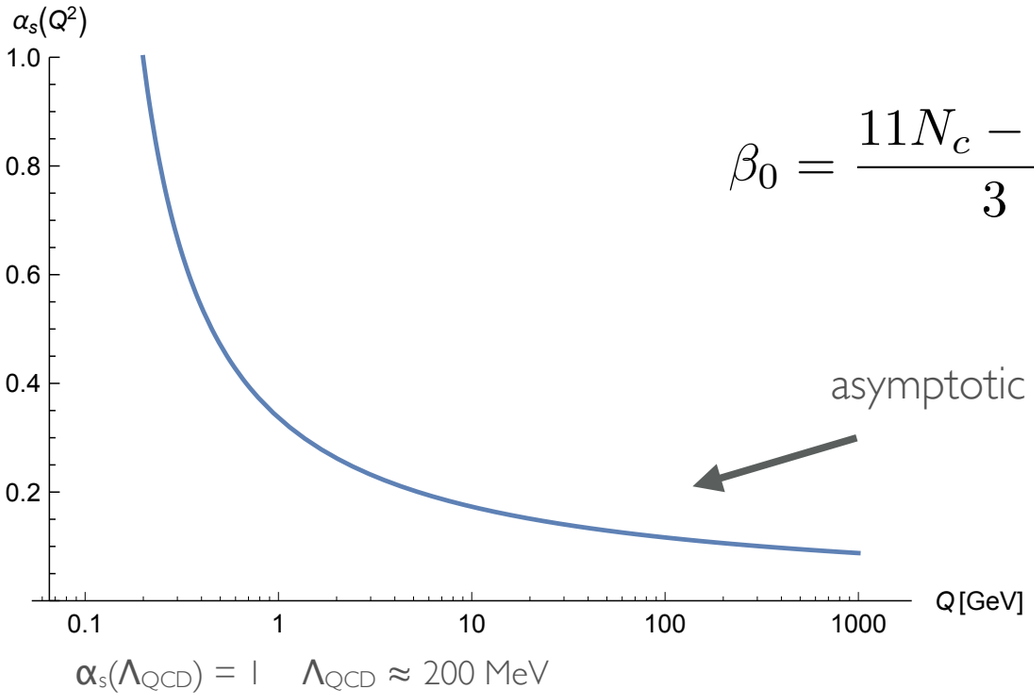
$$\sigma_Z \sim \frac{s^2}{(s - m_Z^2)^2 + m_Z^2 \Gamma_Z^2}$$

$$Z \to \nu\overline{\nu} + \cdots$$

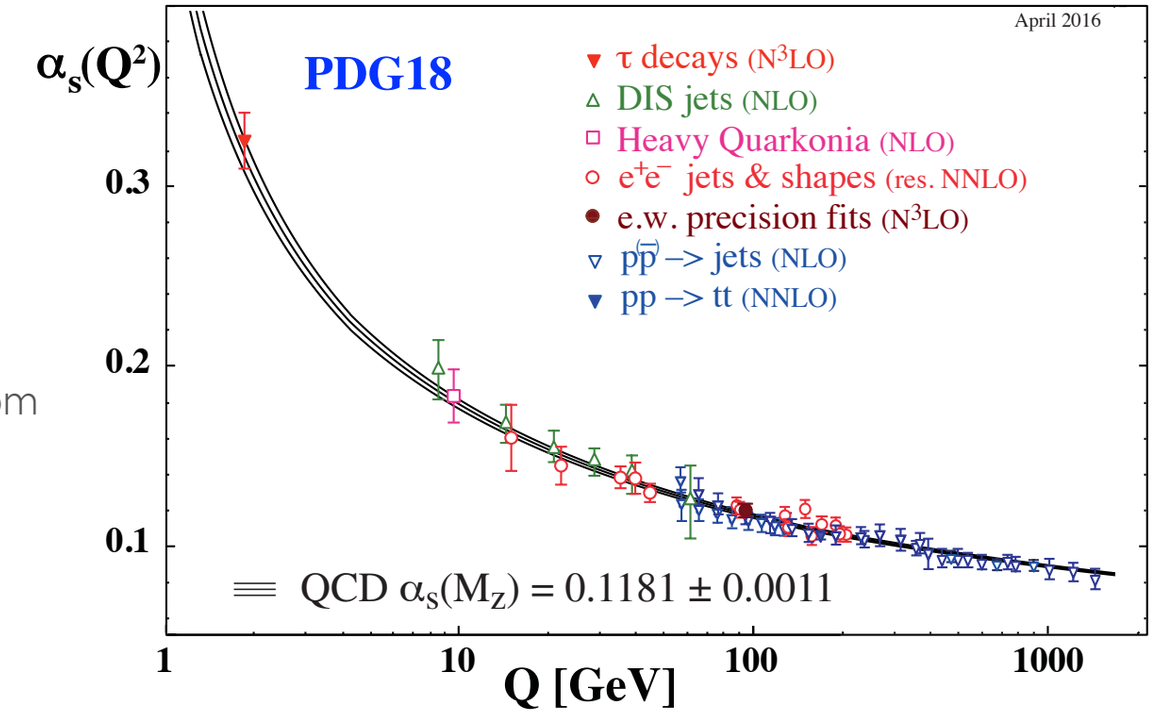
- Clear evidence for 3 light neutrino families ($2m_\nu < M_Z$).



Running (Strong) Coupling



$$\beta_0 = \frac{11N_c - 2N_f}{3}$$

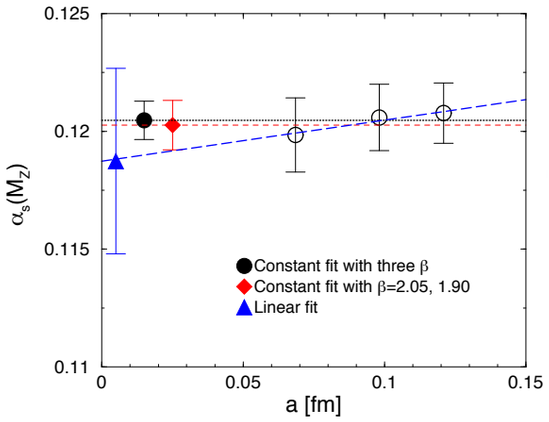


(Approx.!) Theory

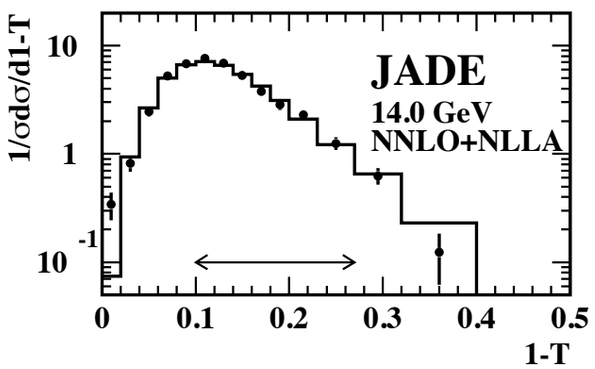
Data + Theory

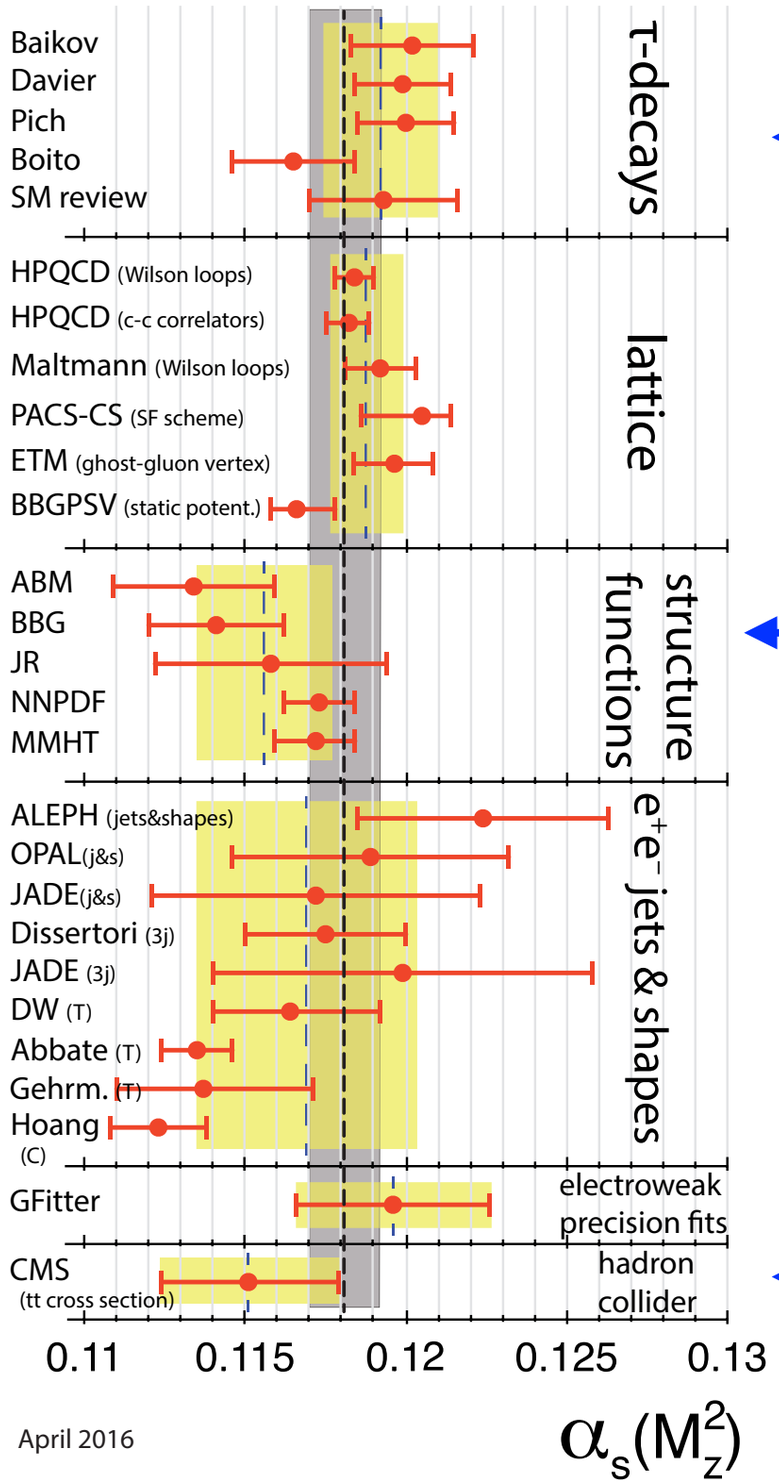
Strong Coupling Determination

arXiv:0906.3906



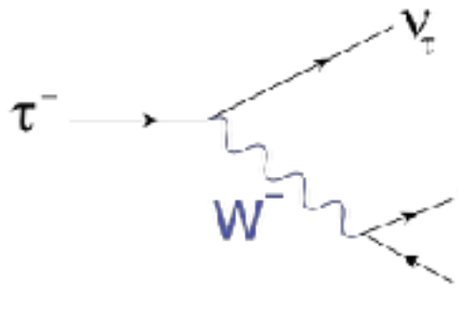
arXiv:0810.1389

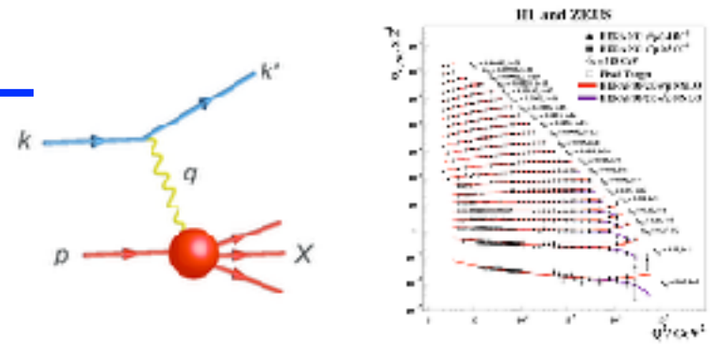




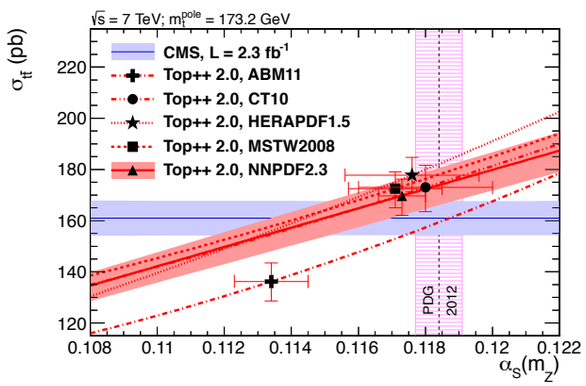
April 2016

$$R_\tau \equiv \frac{\Gamma[\tau^- \to \text{hadrons}\,\nu_\tau(\gamma)]}{\Gamma[\tau^- \to e^-\overline{\nu}_e\nu_\tau(\gamma)]}$$





arXiv:1307.1907

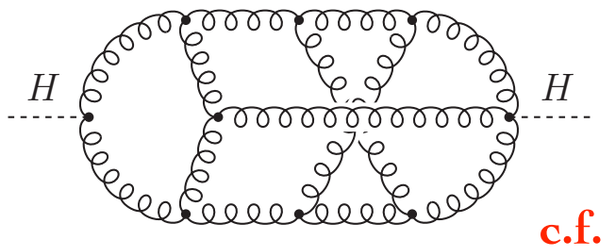


$$\alpha_s(M_Z^2) = 0.1181 \pm 0.0011$$

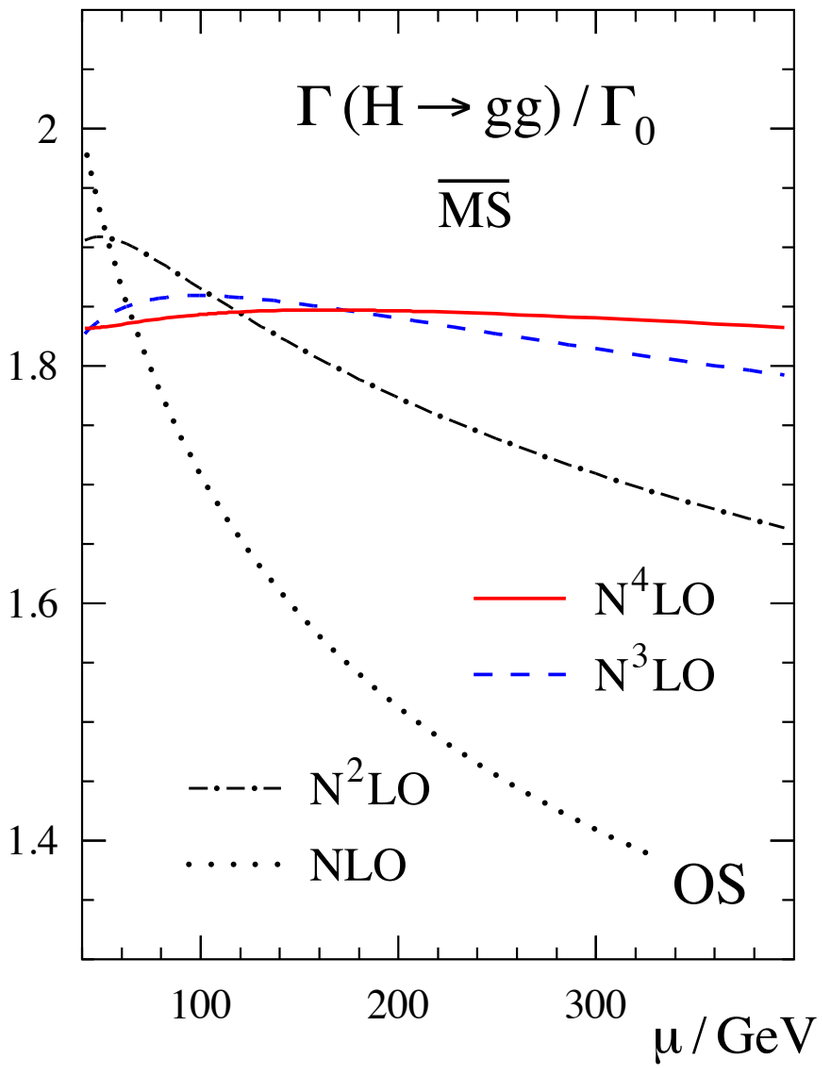
Renormalization Scale Dependence

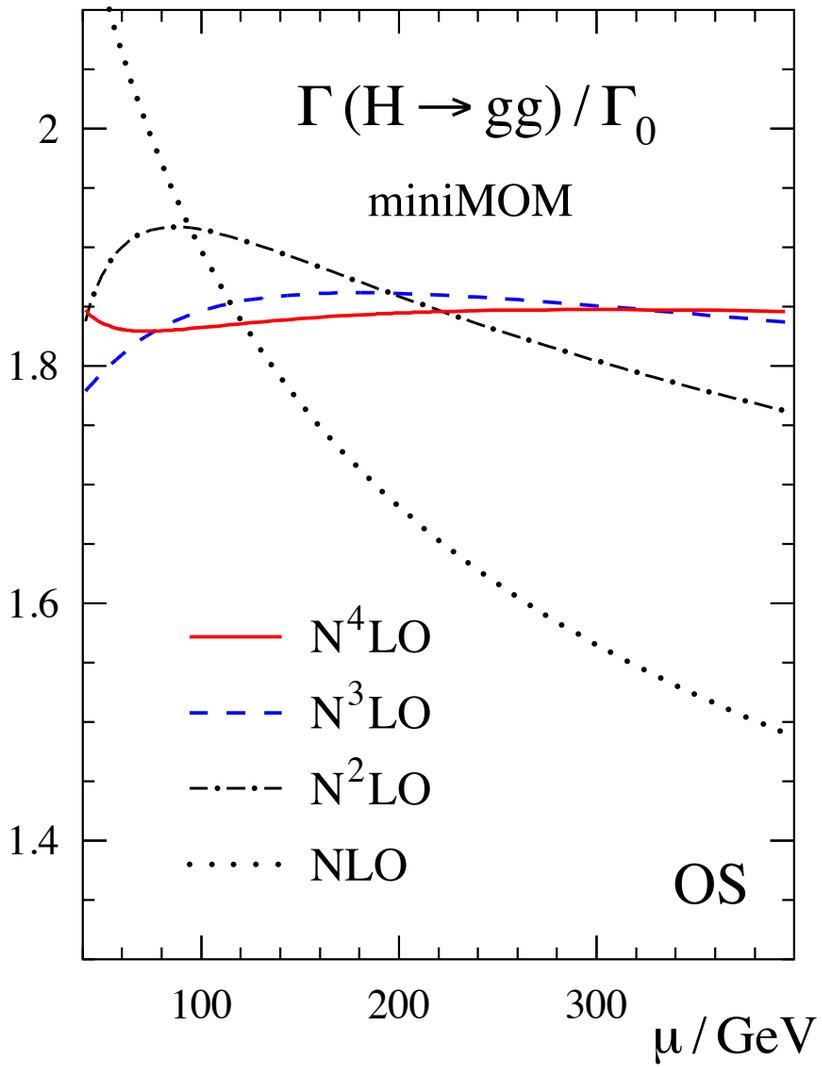
- Two nice recent examples from **arXiv:1707.01044**:

Up to $O(\alpha_S^4)$ corrections to $H \to gg$:



c.f. optical theorem



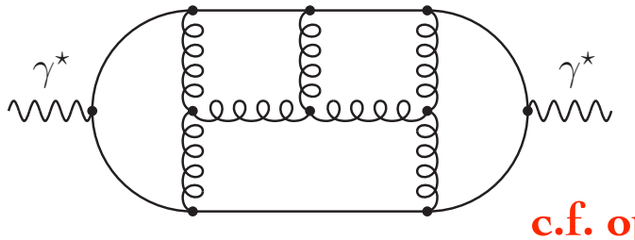


- Decreasing dependence on μ_R and scheme with increasing order.

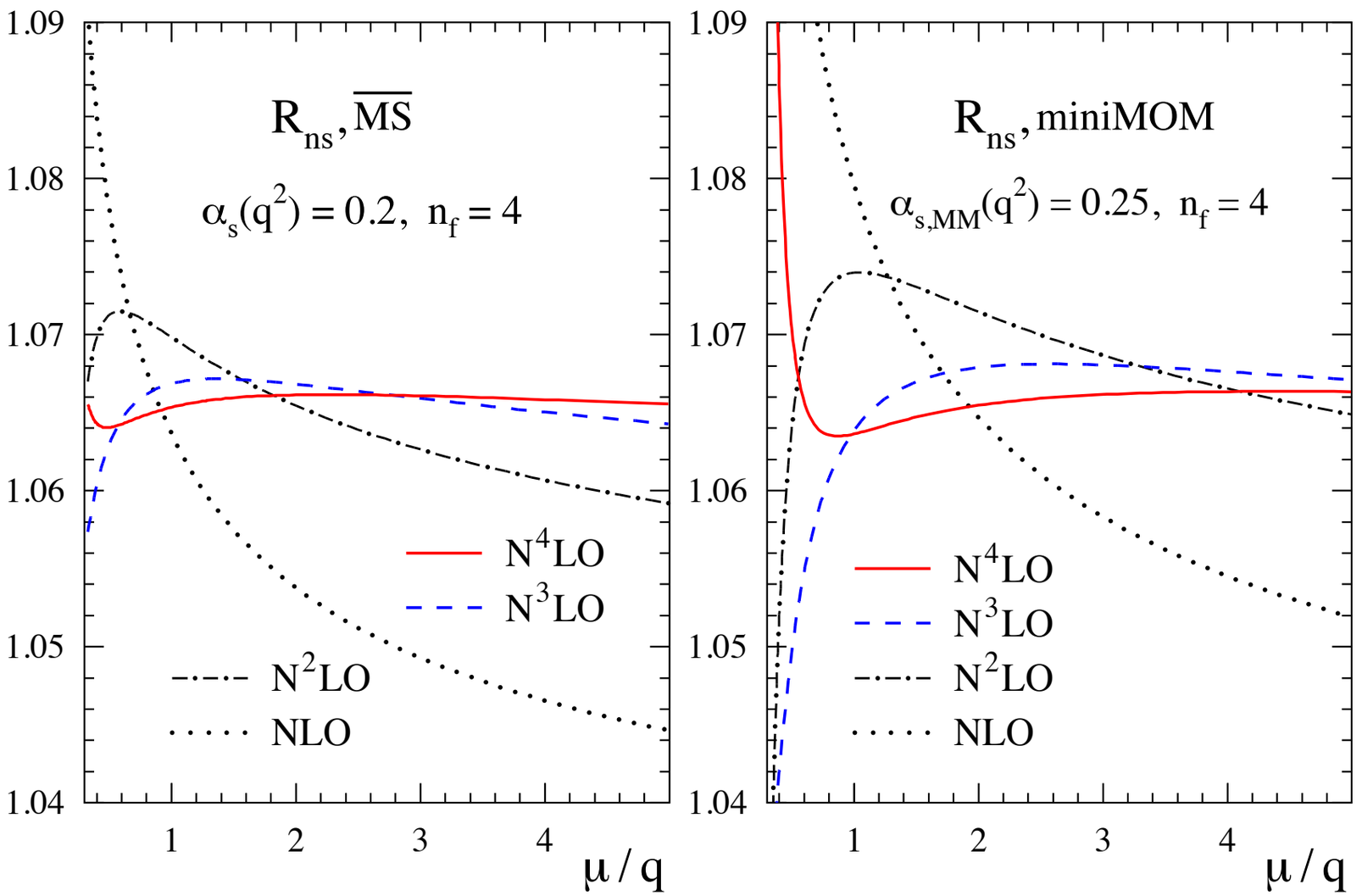
Renormalization Scale Dependence

- Two nice recent examples from **arXiv:1707.01044**:

Up to $O(\alpha_S^4)$ corrections to R(hadrons/muons):



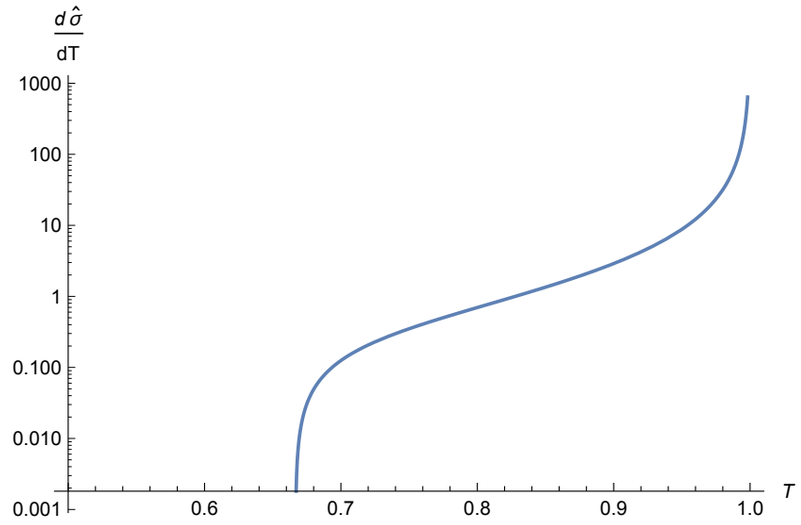
c.f. optical theorem



- Decreasing dependence on μ_R and scheme with increasing order.

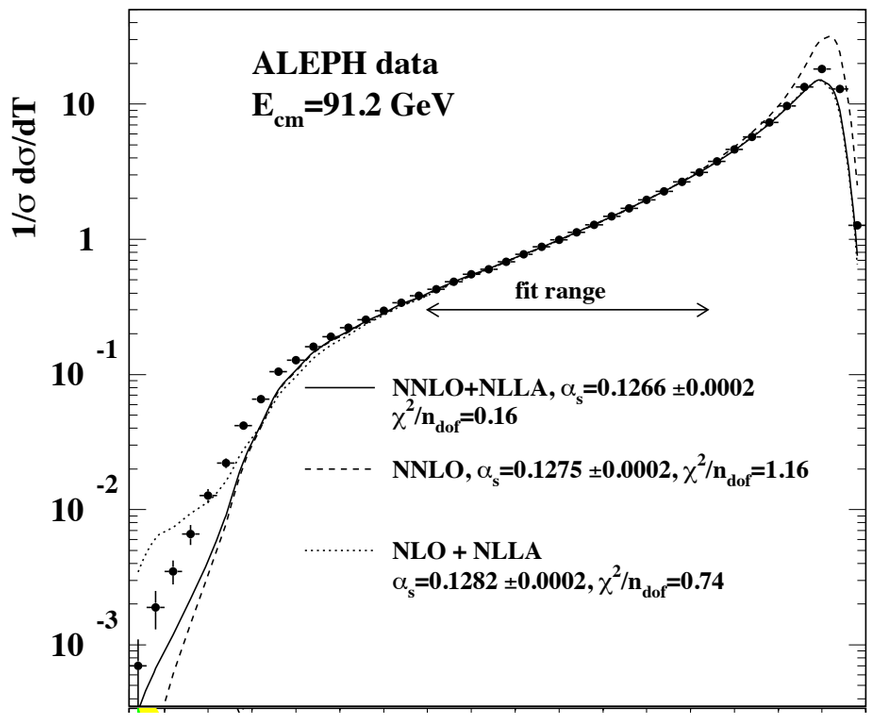
Thrust

- Basic (LO in QCD) expectation:



- Modern (NNLO in QCD + NLL resummation) result vs. data.

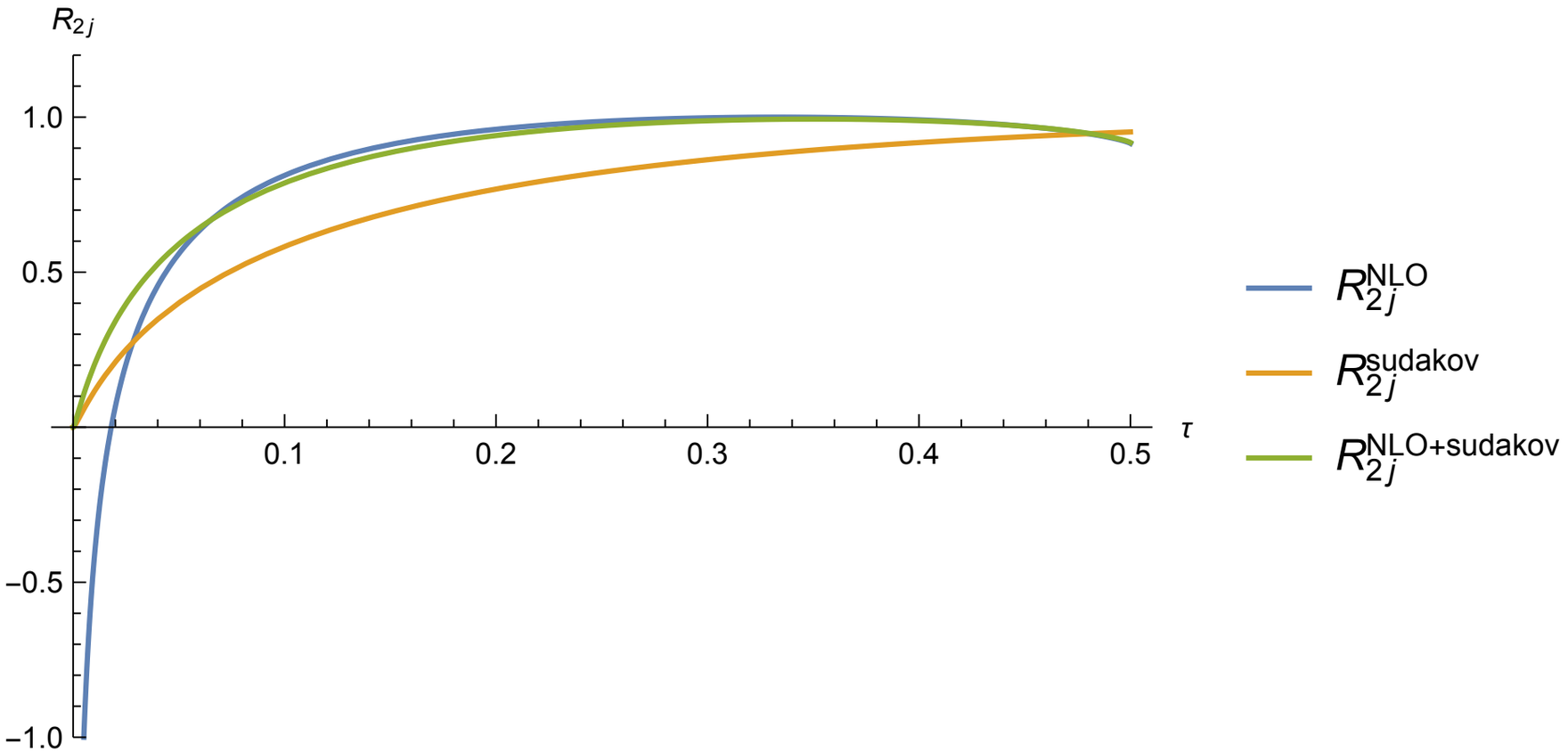
arXiv:0906.3436



- Nice description. Sensitive to (colour/spin) nature of gluons.

Thrust - Resummed Prediction

- Impact of resummation: including Sudakov form factor.



Resummation - Z transverse momentum

$$\sigma \sim \ln\left(\frac{p_{\perp}^{Z}}{M_Z}\right)$$