Collider Phenomenology on the Grid

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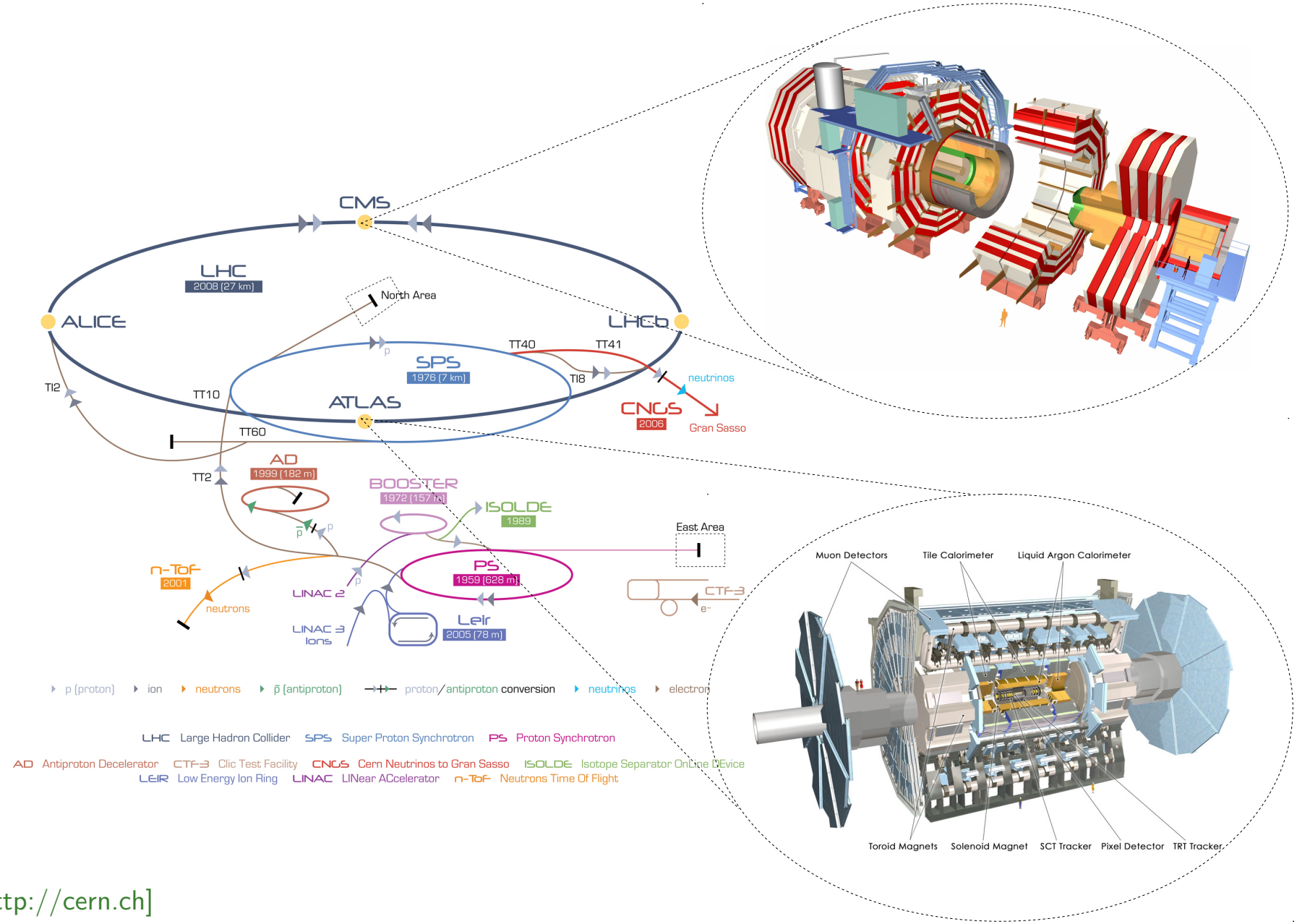
SLAC

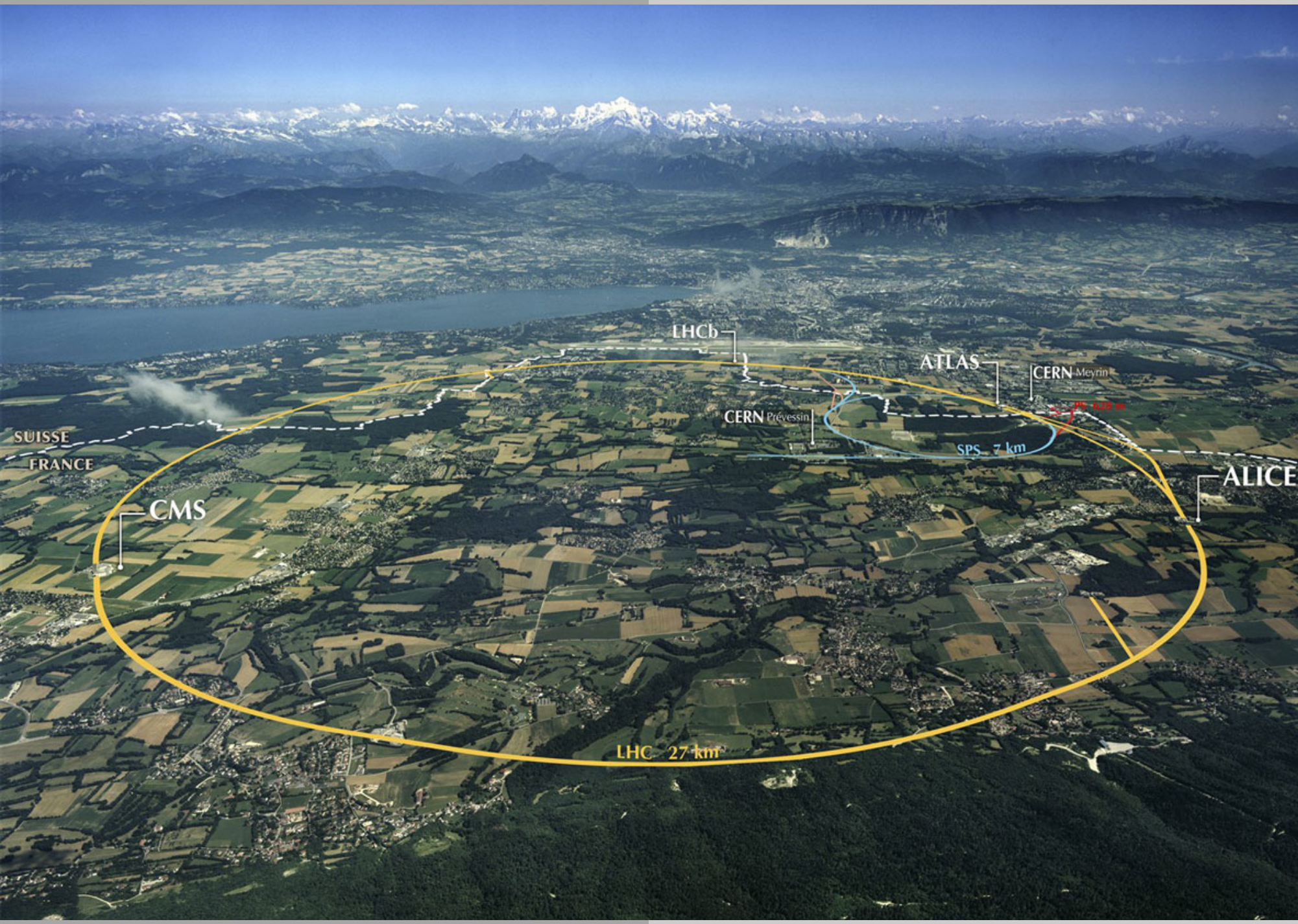
OSG All Hands Meeting

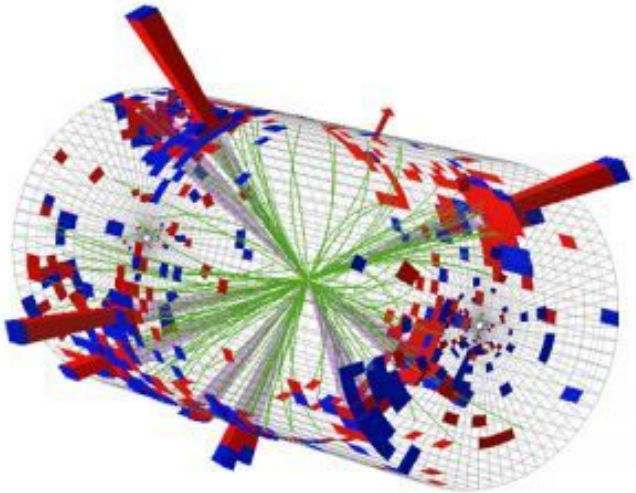
SLAC, 04/09/14

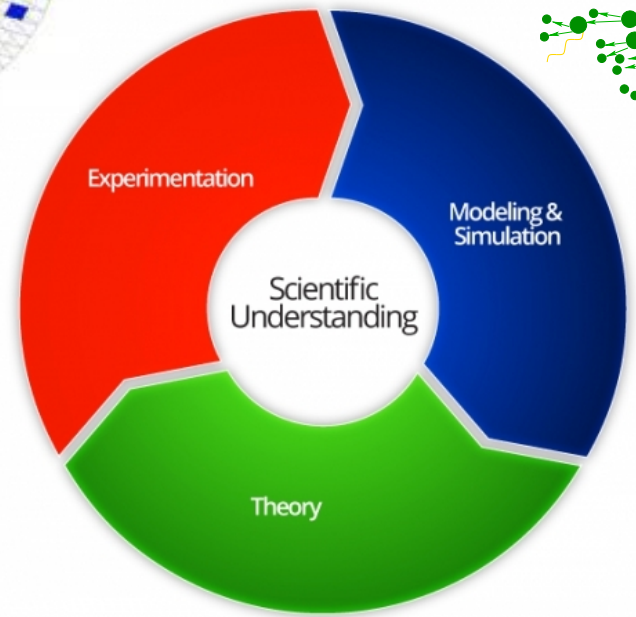
The Large Hadron Collider (LHC)

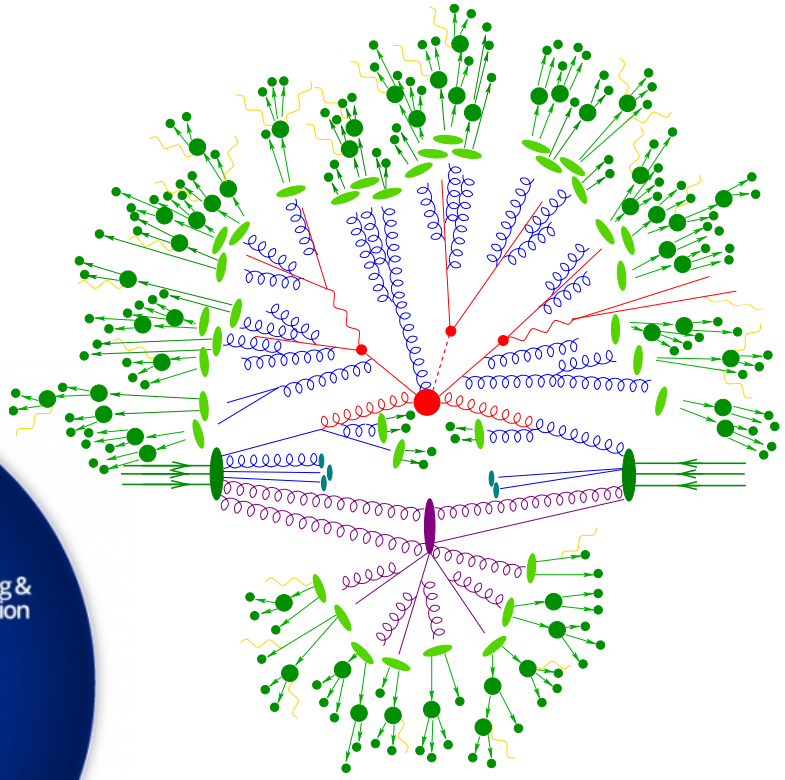


[http://cern.ch]


LHCb
ATLAS
CERN Meyrin
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
ALICE
CMS
LHC 27 km

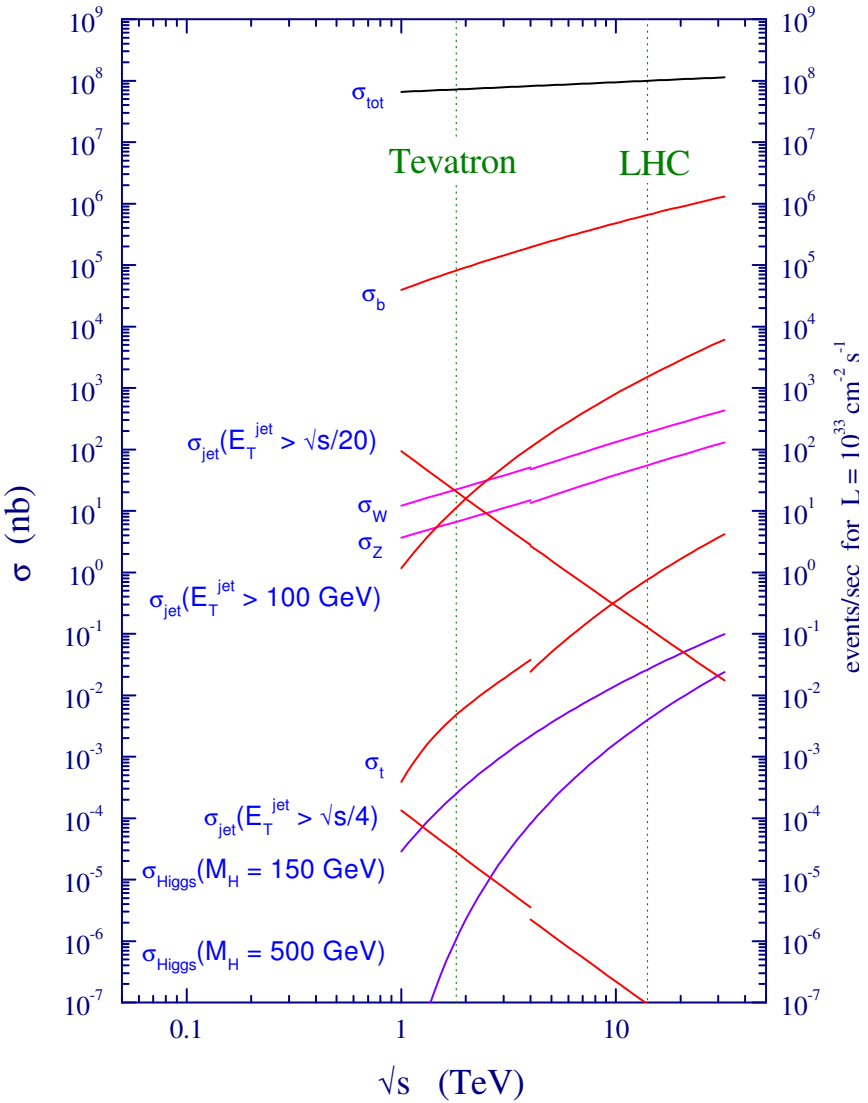




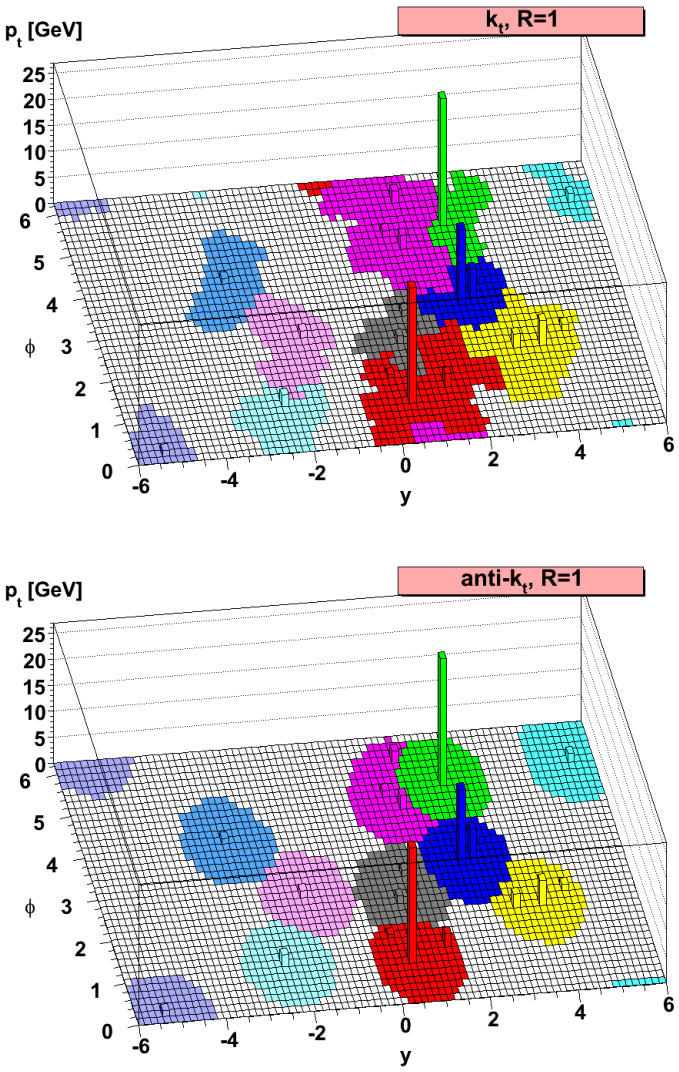


$$\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + i \bar{\psi} \not{D} \psi + h.c.$$

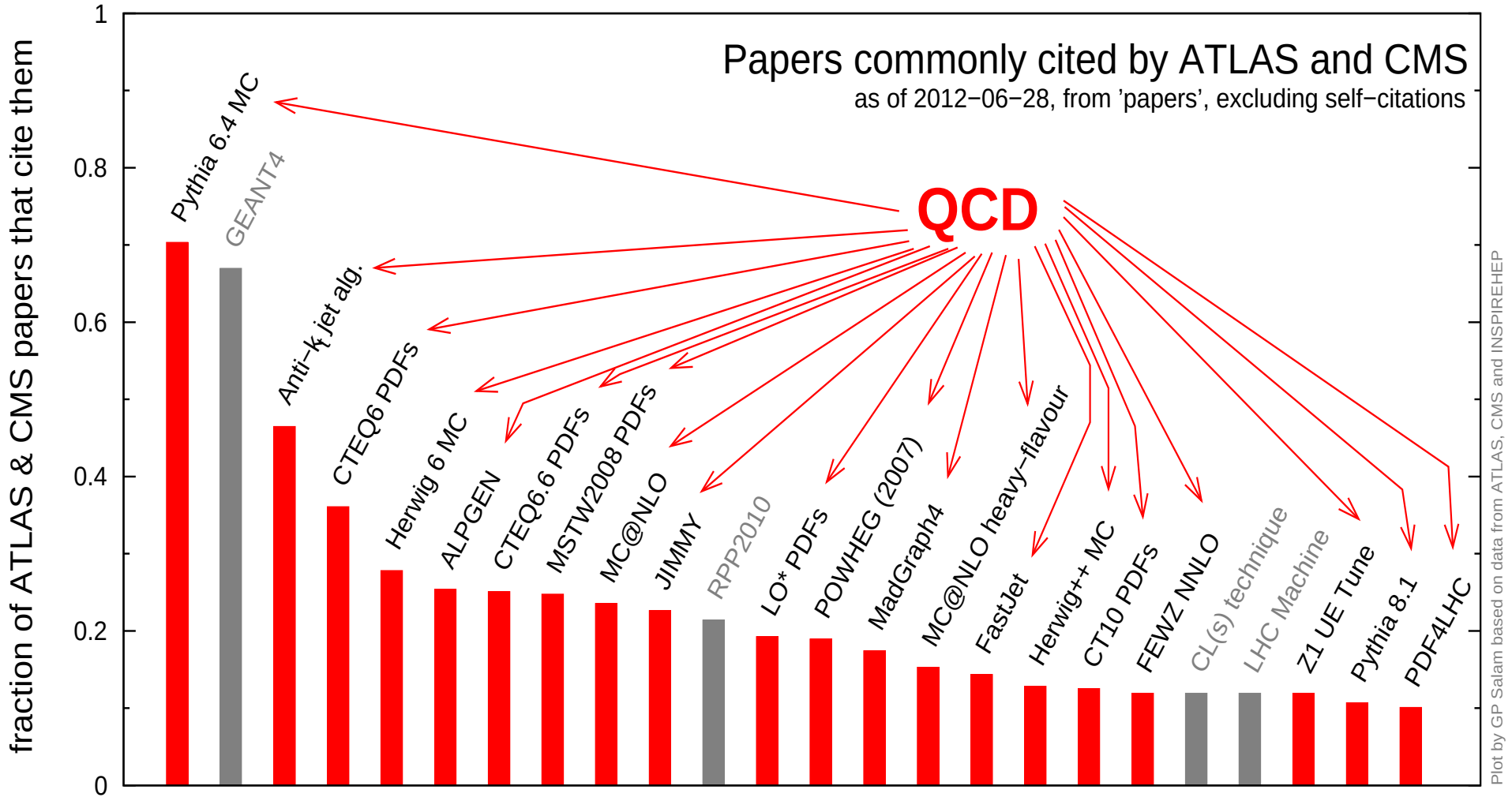
QCD Jets at the LHC



[Campbell,Huston,Stirling] RPP70(2007)89



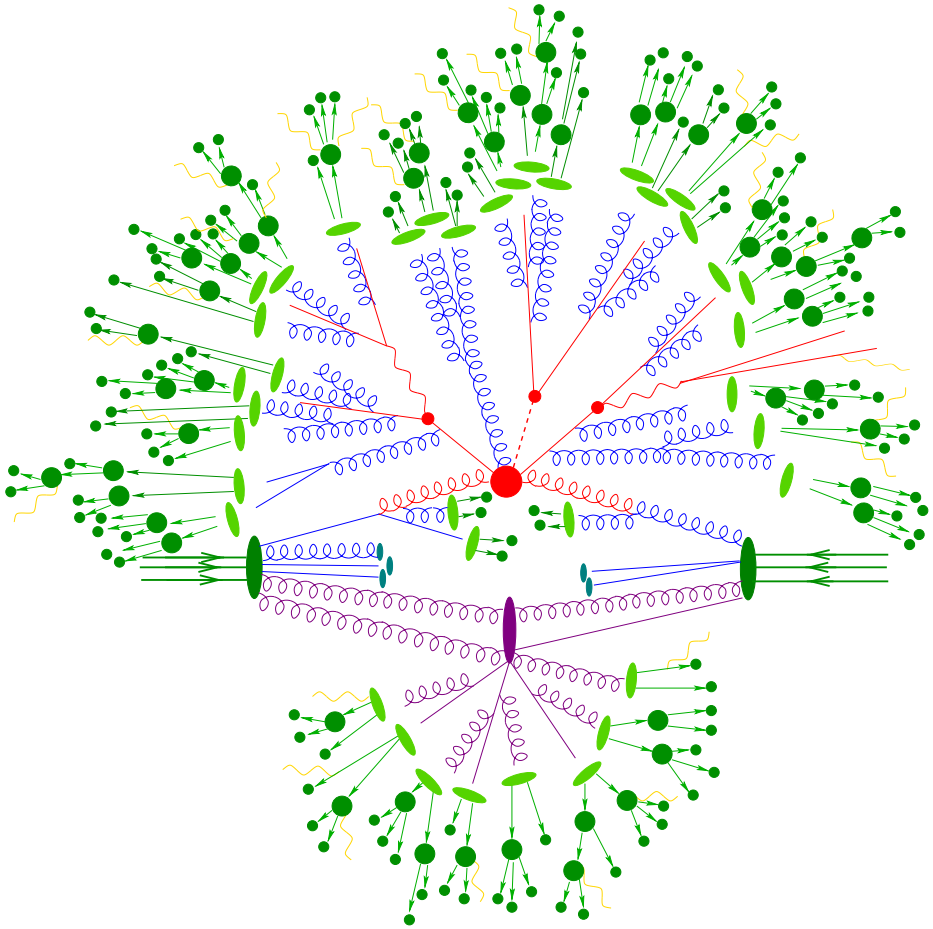
[Cacciari,Salam,Soyez] JHEP04(2008)063



[G.P. Salam, La Thuile 2012]

Simulation Cookbook

1. Matrix Element (ME) generators
   simulate "hard" part of scattering
2. Parton Showers (PS)
   produce Bremsstrahlung
3. Multiple interaction models
   simulate "secondary" interactions
4. Fragmentation models
   "hadronize" QCD partons
5. Hadron decay packages
   simulate unstable hadron decay
6. YFS generators
   produce QED Bremsstrahlung



Why use OSG?

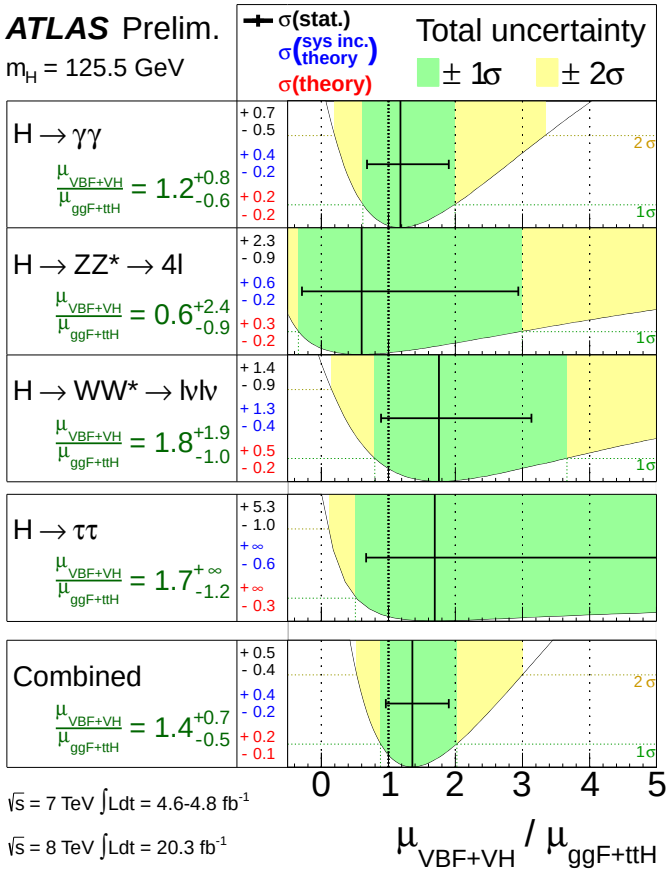
- LHC final states typically very complex (lots of jets!)
  interesting signals small and in tricky corners of phase space
  $\rightarrow$ Need many events to simulate backgrounds accurately $\mathcal{O}(10M)$
- Precise theoretical predictions needed to extract physics parameters
  $\rightarrow$ Simulation of one event can take anywhere from 10ms to 100s
- Theory uncertainty estimates mandatory to control systematics
  $\rightarrow$ Multiplies computational effort by factor of $\mathcal{O}(1-10)$

A single high-precision MC prediction costs $\mathcal{O}(250k)$ CPU hours

Simulation of Standard Model Higgs-Boson Production

Why interesting?

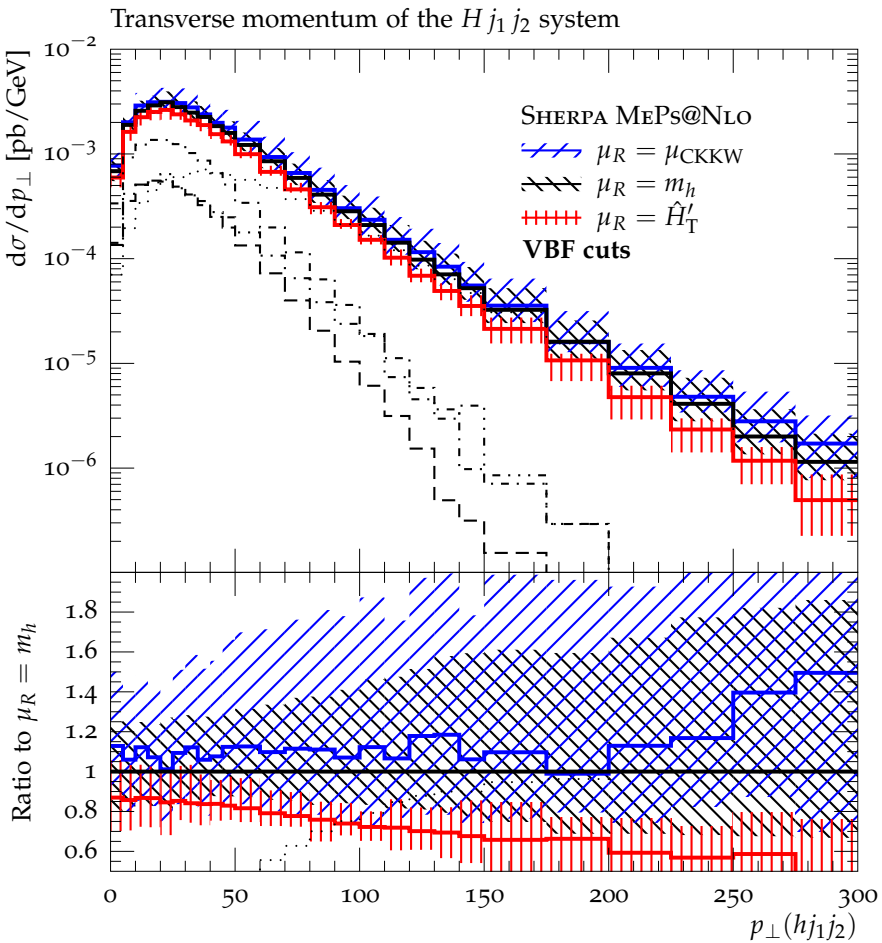
- Only new particle discovered at LHC so far!
- Need to know whether SM Higgs or not
- Gluon fusion (GGF) Higgs+jets production background to Vector Boson Fusion (VBF)
- Large QCD uncertainties in GGF

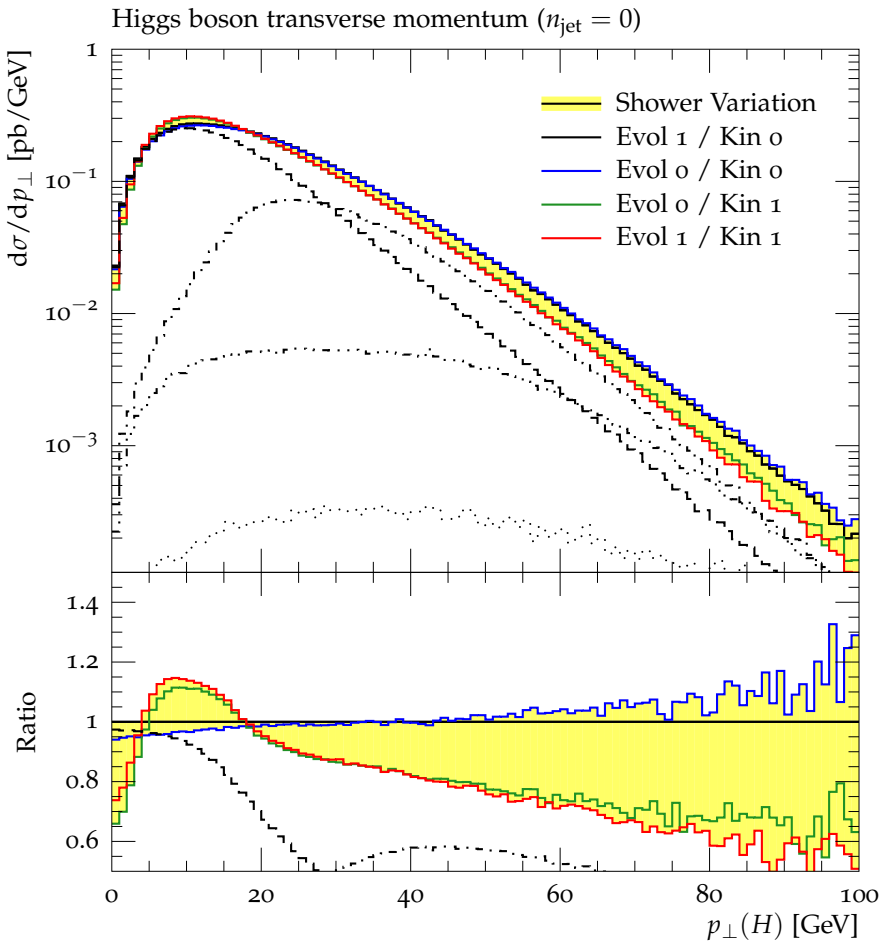


[ATLAS] ATLAS-CONF-2014-009

Simulation of Standard Model Higgs-Boson Production

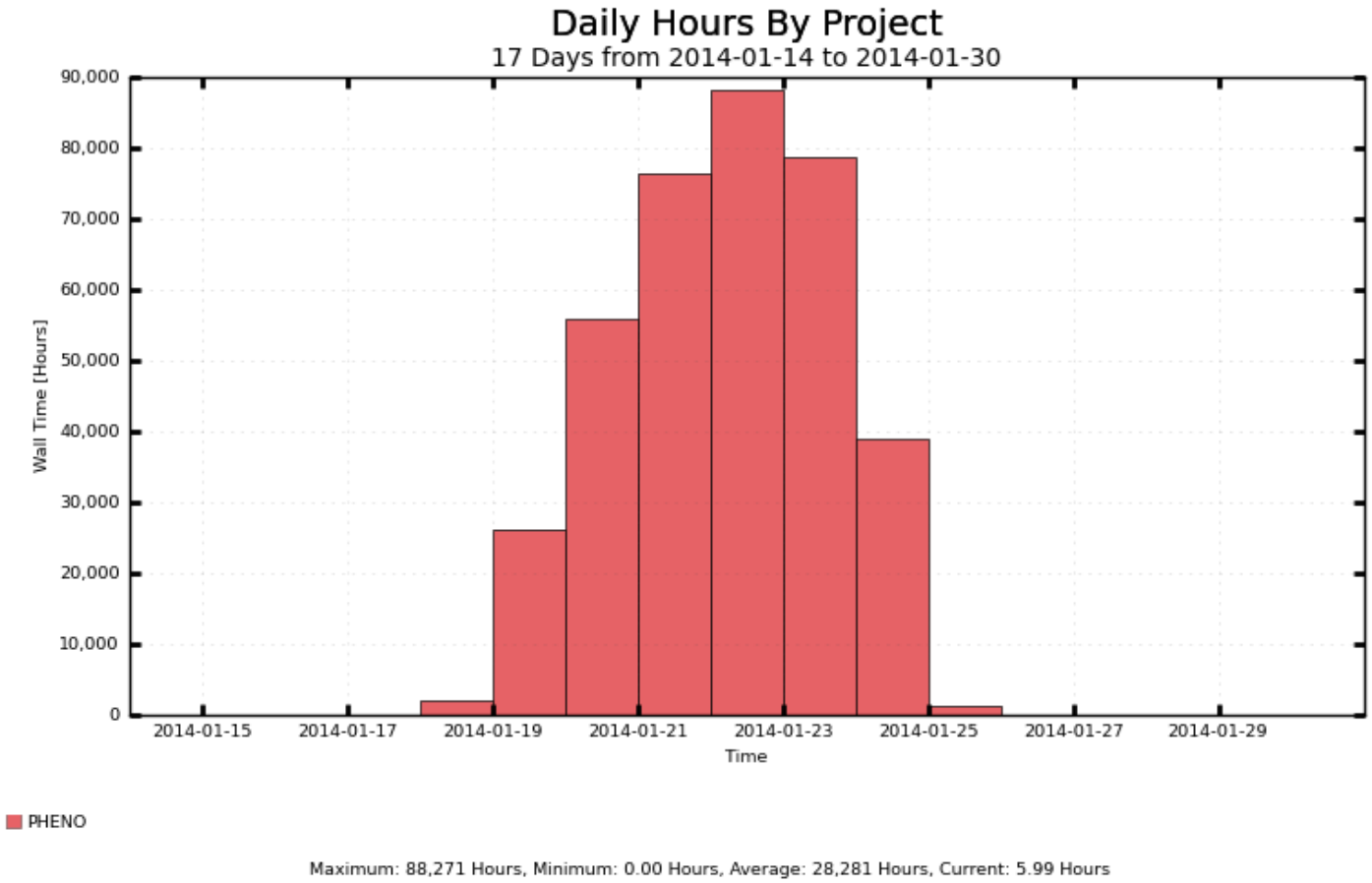
[Krauss,Schönherr,SH] arXiv:1401.7971





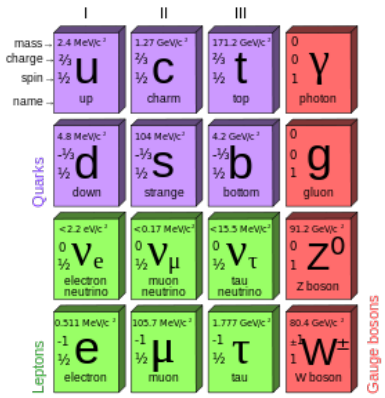
- Combines NLO QCD calculations for $pp \to h + 0, 1\&2$-jet plus 3-jet at LO
- Three different functional forms of scale + individual uncertainty estimates
- Resummation uncertainty remains in jet-vetoed region relevant for VBF

Computational Cost



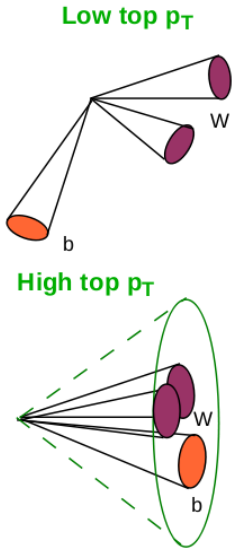
- ∼481k hours worth of CPU time in 6+x days
- No hiccups

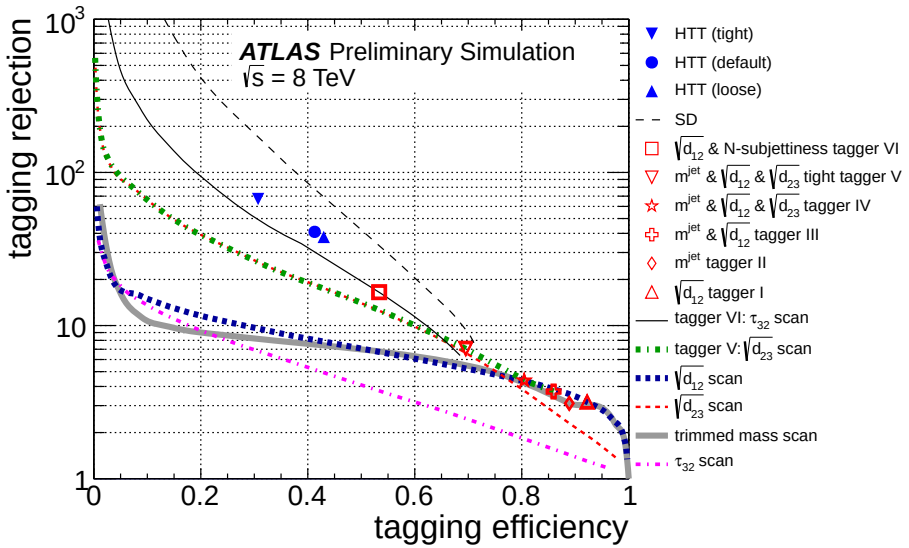
Simulation of SM Top Quark Pair Production



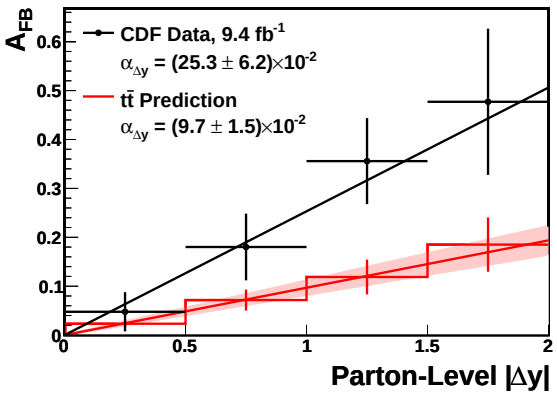
Why interesting?

- Top quark is heaviest particle in Standard Model
- Special role among quarks → does not hadronize!
- Decay distinguished from QCD jet BG by substructure
- Important background to most searches for new physics
- Large unexplained forward-backward asymmetry at CDF / DØ





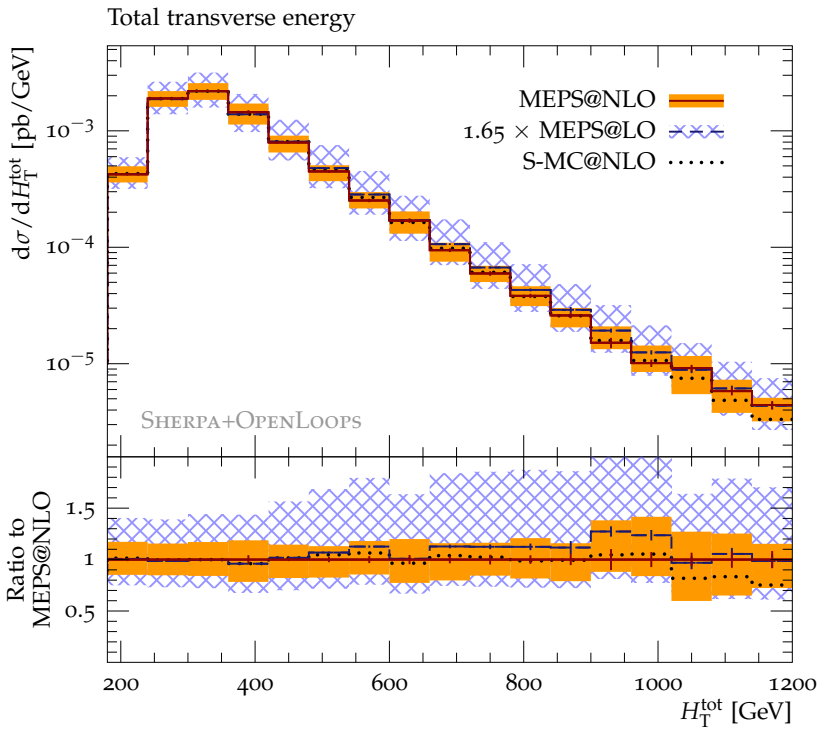
[ATLAS] ATLAS-CONF-2014-003

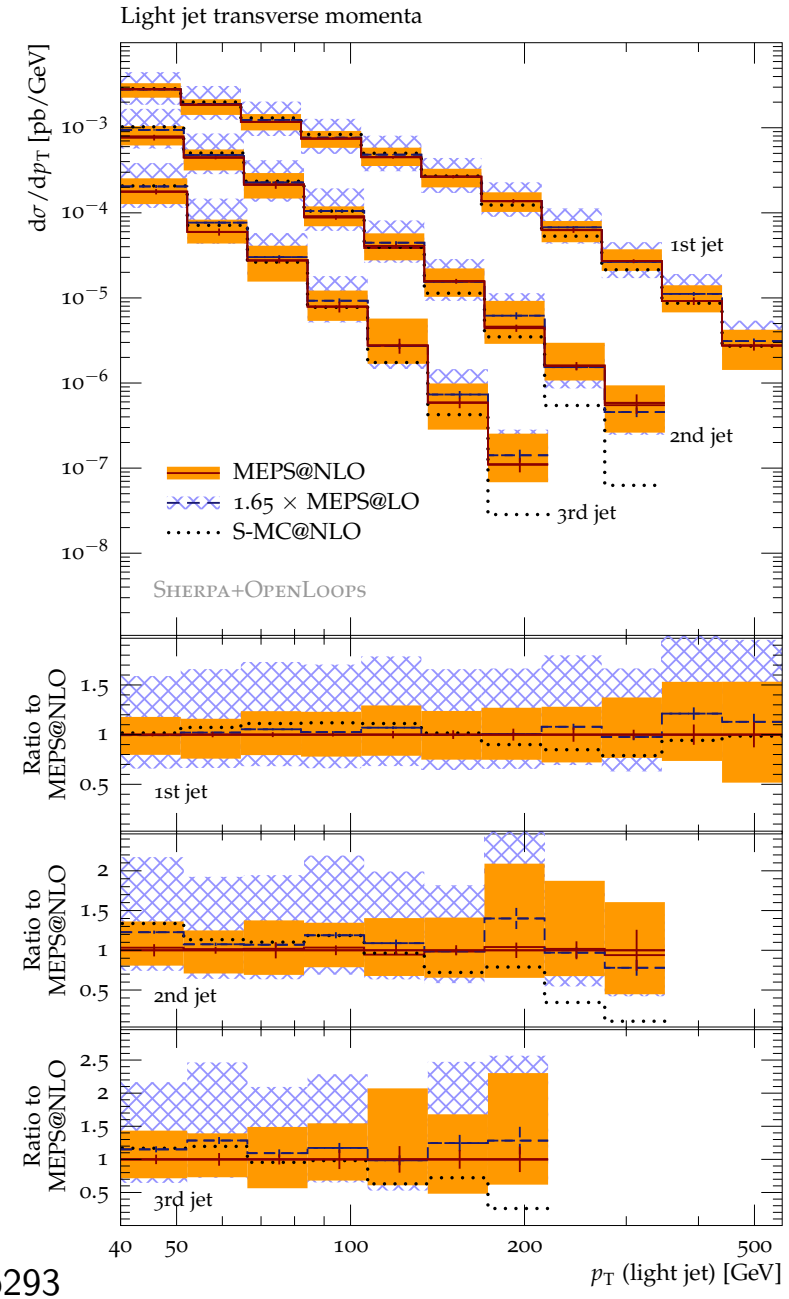


[CDF] PRD87(2013)092002

Simulation of Top Quark Pairs

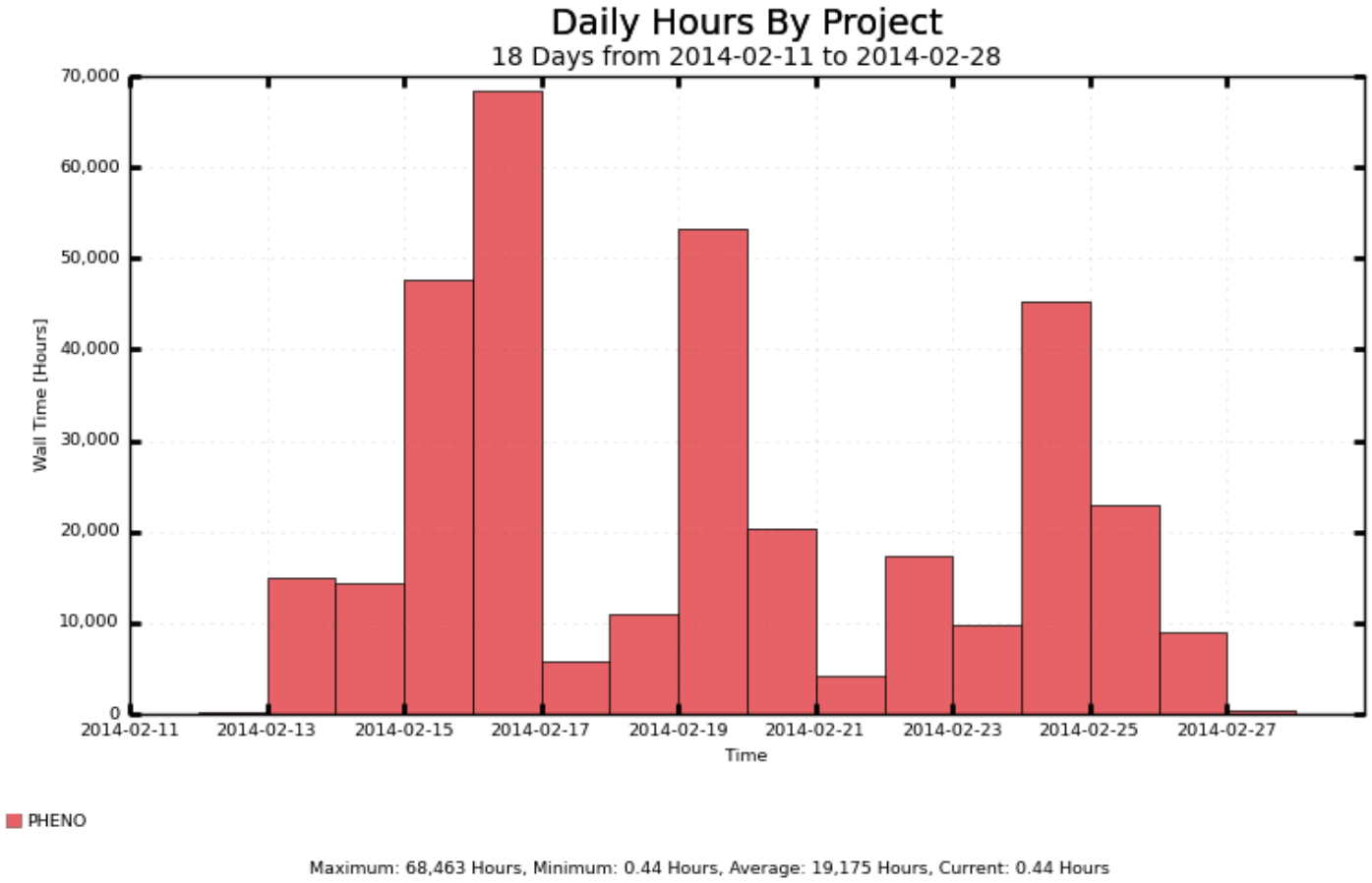
- First matched/merged sim for $t\bar{t}$+2j full result has $t\bar{t}$+0,1,2j@NLO, 3j@LO
- Largely reduced theory uncertainty for both for measurement (p_T, N_{jet}) and BSM search (H_T) observables





[Krauss,Maierhöfer,Pozzorini,Schönherr,Siegert,SH] arXiv:1402.6293

Computational Cost



- ∼345k hours worth of CPU time in 14+x days
- Badly adjusted CPU time limit (user end) → needed manual intervention

The Code Suite

- Event generator → **Sherpa** `http://www.sherpa-mc.de`
- Analysis suite → **Rivet** `http://rivet.hepforge.org`
- GGF 2-jet virtual corrections → **MCFM** `http://mcfm.fnal.gov`
- $t\bar{t}$+0,1,2-jet virtual corrections → **OpenLoops** `PRL108(2012)111601`

User Experience

- Tried pre-staging but code small enough to be sent with job input
  → allows rapid turnaround in development, big plus!
- HTPC working (using custom-compiled MPICH2, sent with job)
  → may allow larger simulations in future
- Some simulations currently memory-bound
  → not enough (known) high-mem nodes to run VBF efficiently

Summary

- OSG allowed us to produce scientifically relevant results
  in very short time with state-of-the art tools
- Since our codes are publicly available
  we believe that users will benefit from this experience
- OSG needs to attract more attention in the pheno community
  examples using common tools and hands-on sessions may help

Big thanks to Marko Slyz, Tanya Levshina, Mats Rynge and Gabriele Garzoglio
for the (often out-of-hours) support and help in getting things to work!