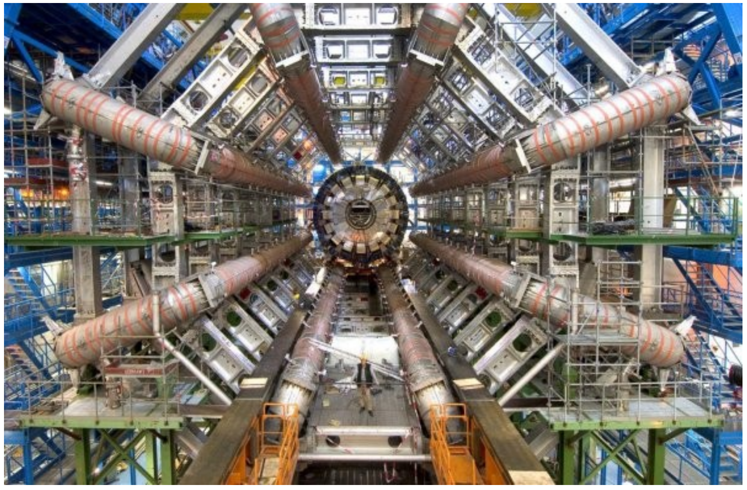
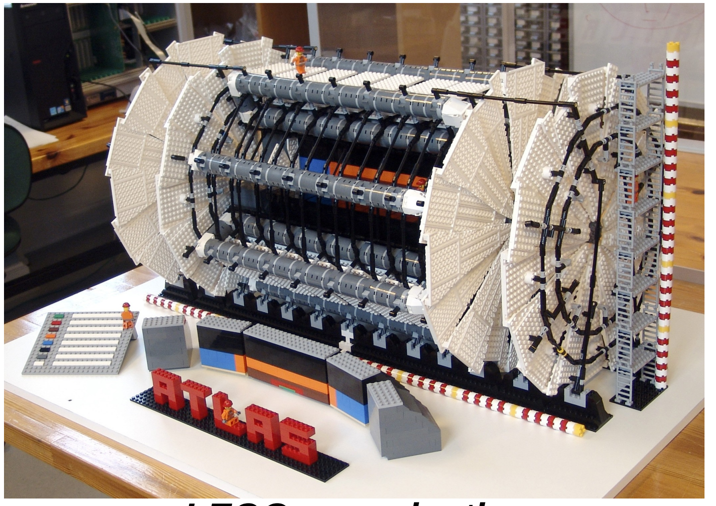
Particle Physics Research Center on ATLAS Experiment



Marcella Bona

Queen Mary University of London



LEGO reproduction

Launch of the School of Physics and Astronomy
Queen Mary, University of London

January 31st, 2012

the five Ws (and one H)

but not quite as many bosons..
at least at the moment..

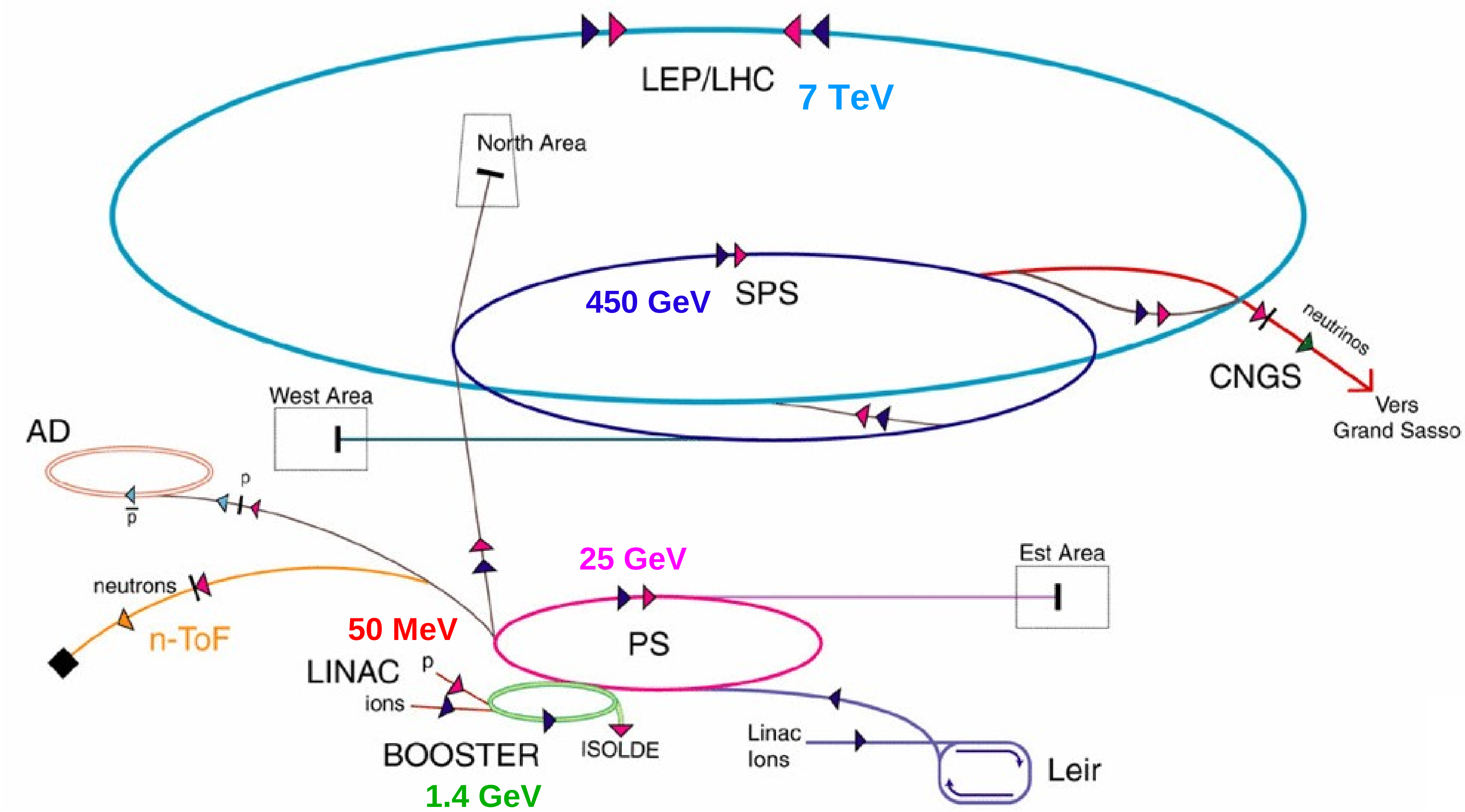
- ***Who*: the PPRC ATLAS group**
- ***What*: the ATLAS experiment**
- ***Where*: the Large Hadron Collider**
- ***When*: since 2009..**
- ***Why*: to rediscover the Standard Model and find the Higgs and New Physics**
- ***How*: 7TeV proton-proton collisions**

ATLAS EXPERIMENT

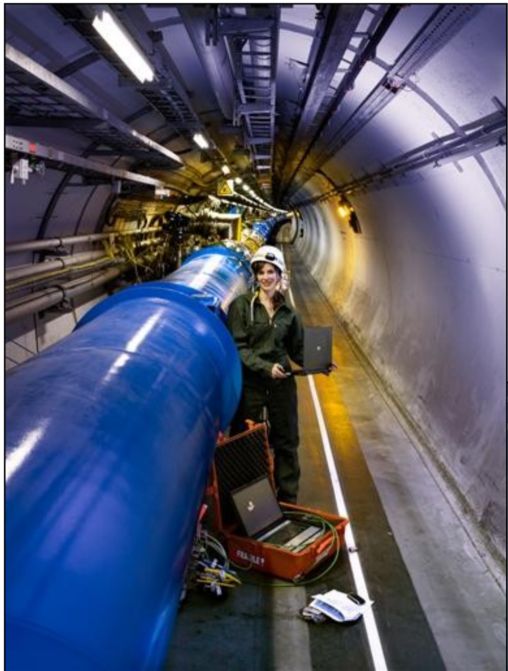
A Toroidal LHC Apparatus

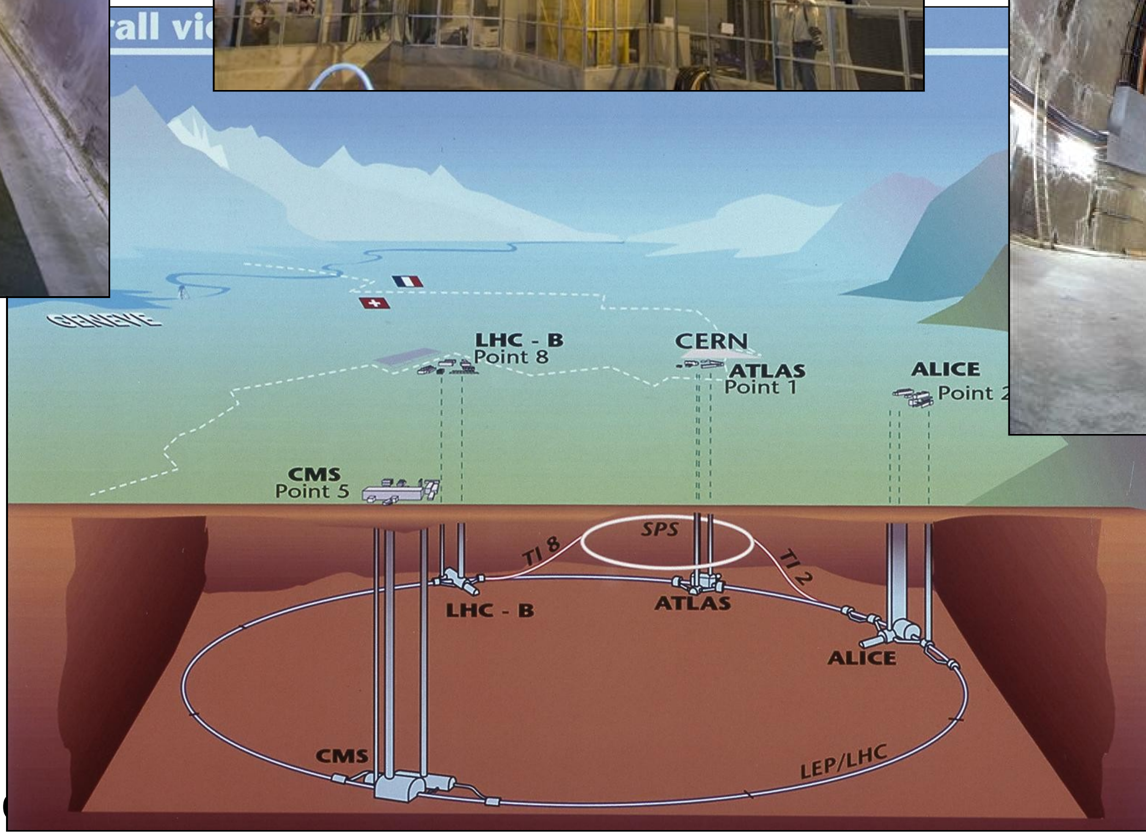
Where: the LHC @ CERN

1232 superconducting dipole magnets (bending the beam)
392 quadrupoles (focusing the beam)
8 accelerator cavities per beam



Where: the LHC machine – the magnets



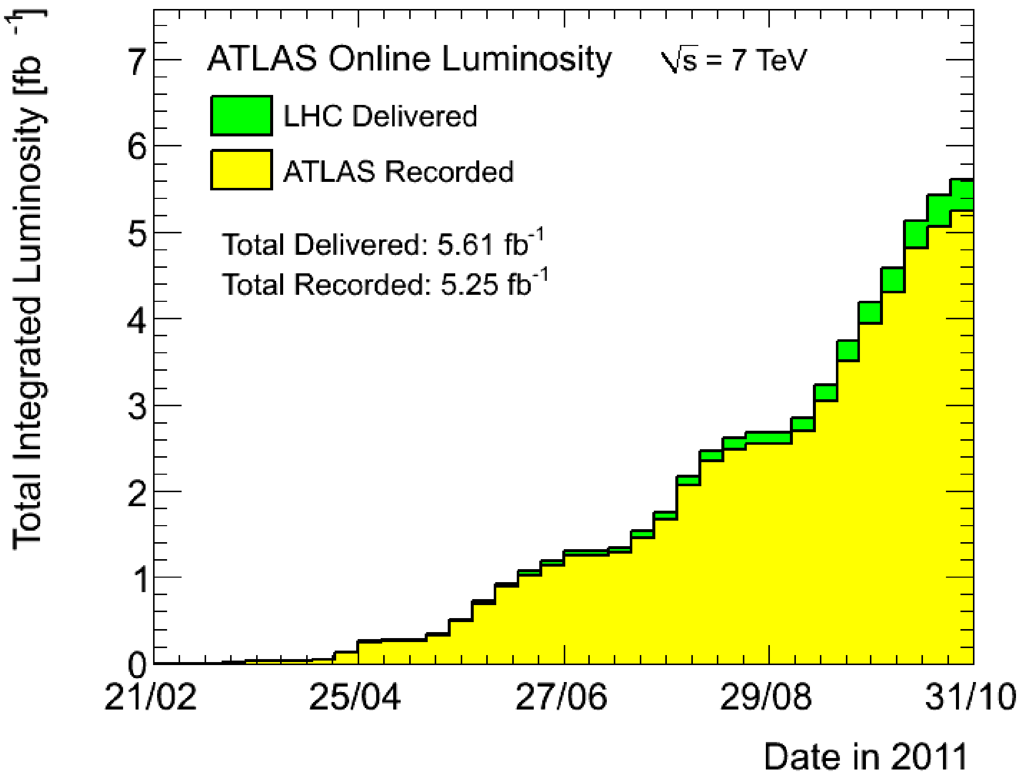


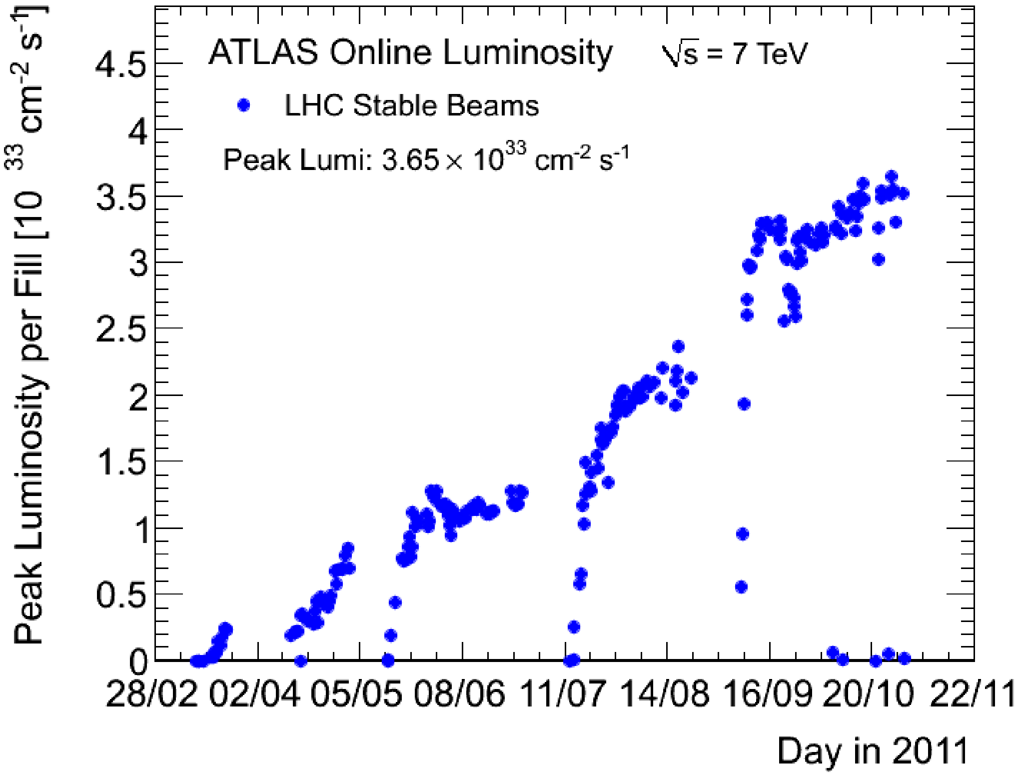
How: beams and collisions at the LHC

http://www.atlas.ch/multimedia/di-jet-event.html

When: accumulated data sample

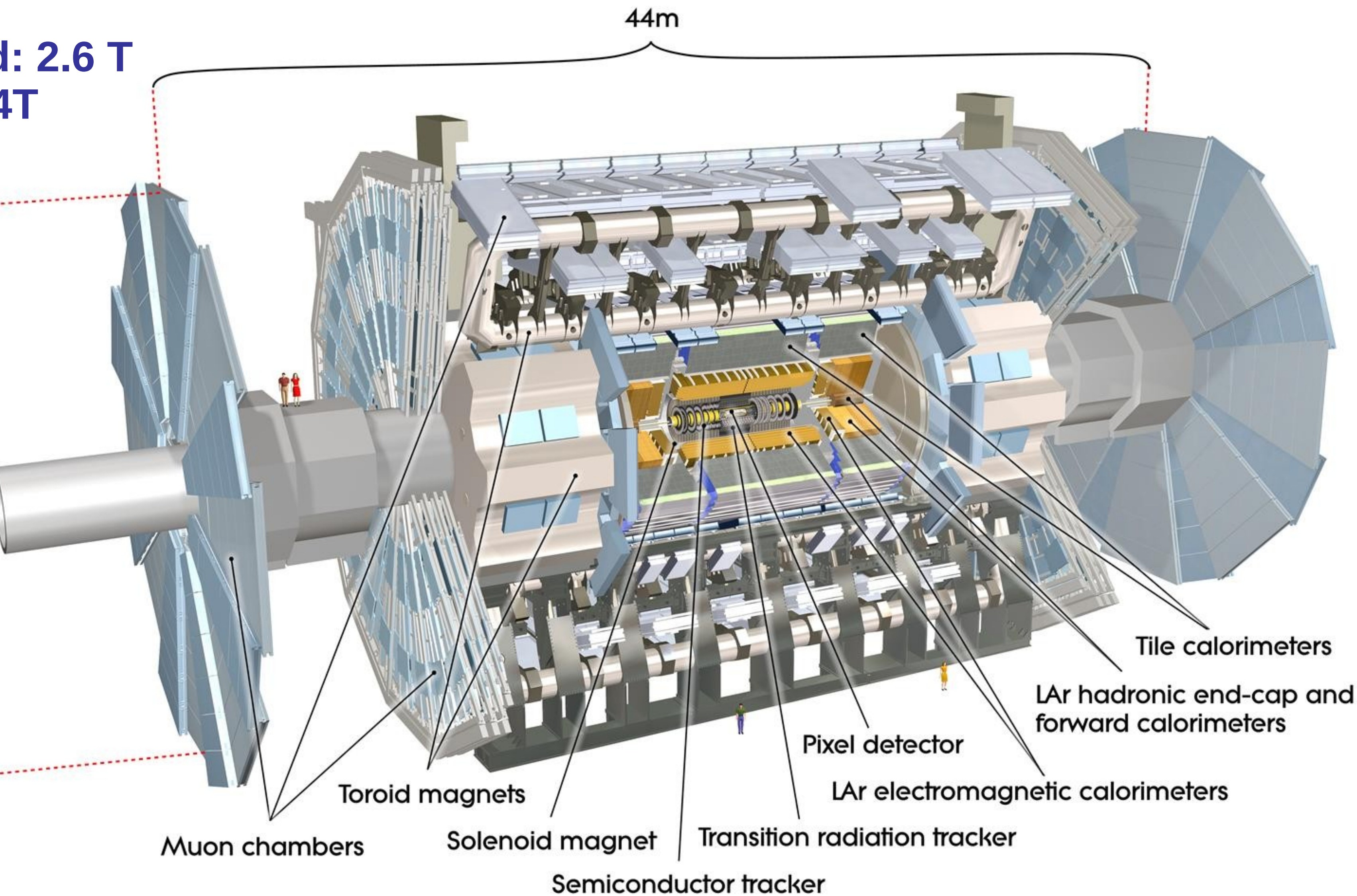
Integrated luminosity recorded by ATLAS in 2009-2011: 5.24 fb^{-1}





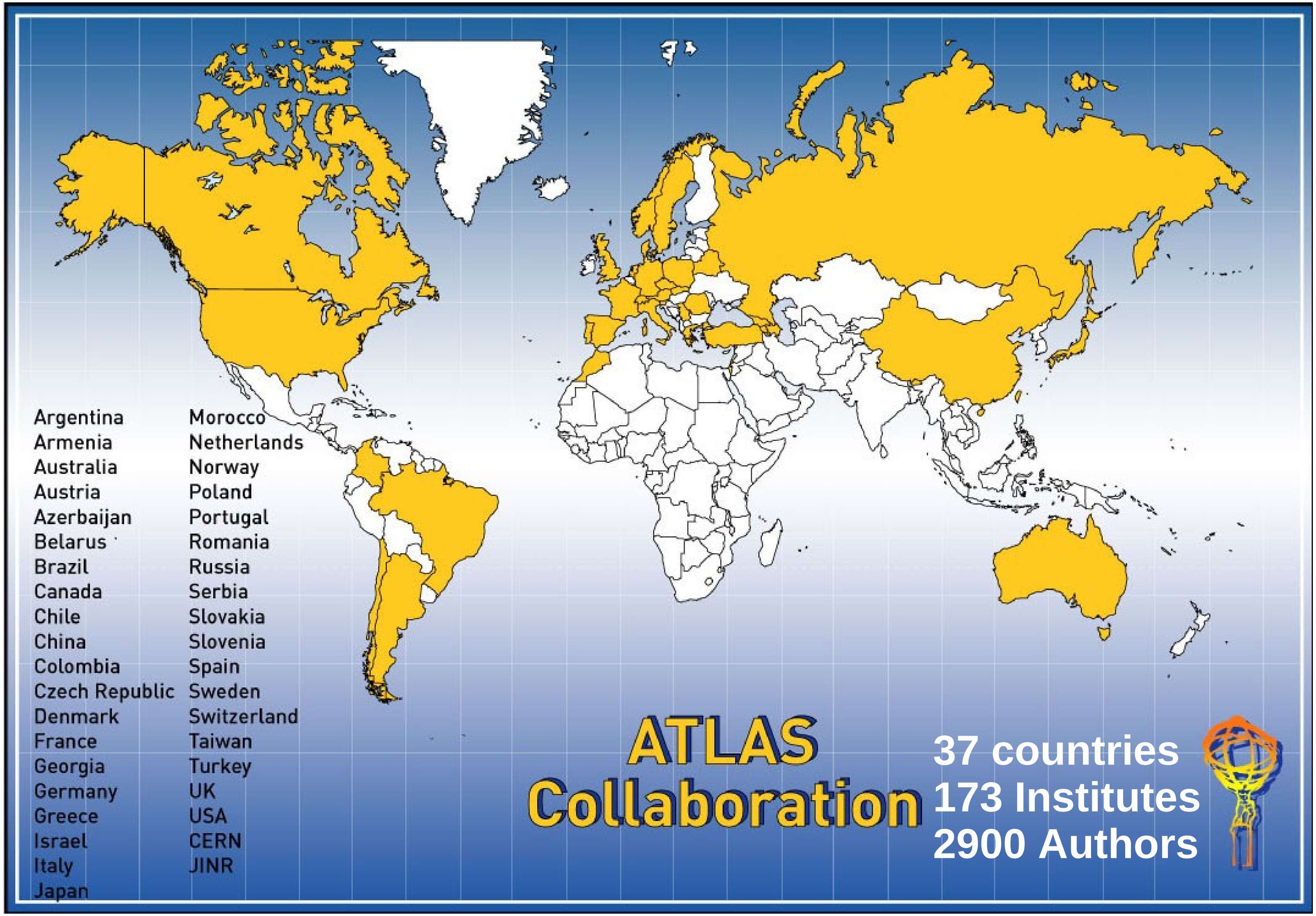
Where: ATLAS detector

Solenoid field: 2.6 T
Toroid field: 4T
7000 Tonnes

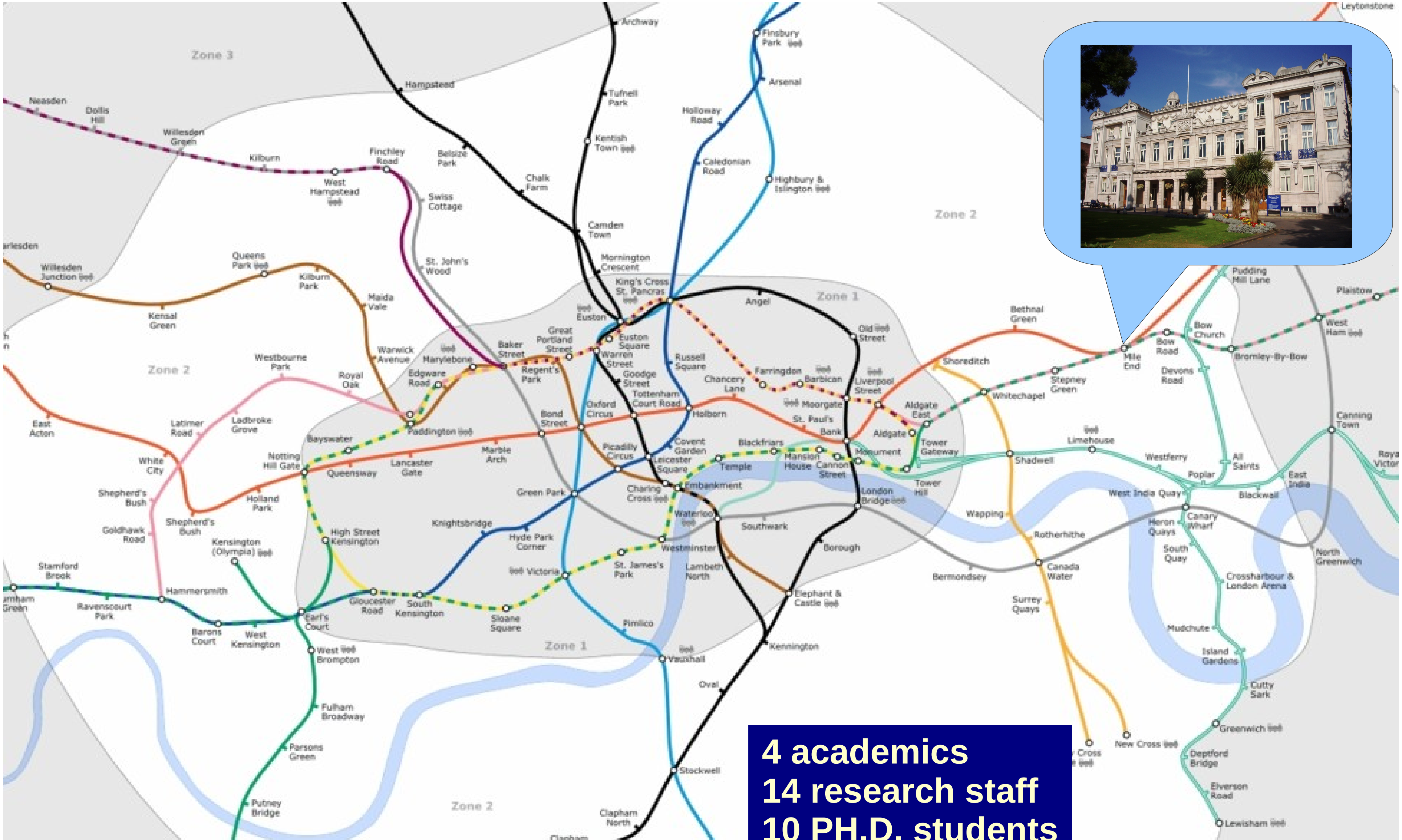


7300 Tonnes

Who: ATLAS Collaboration

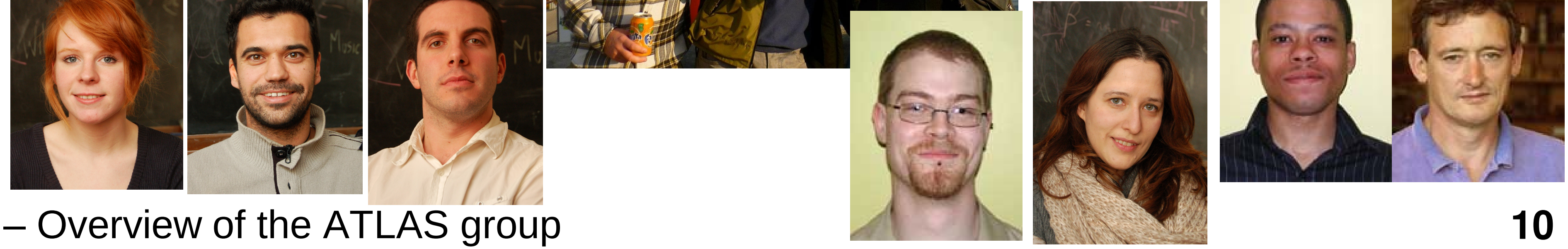


Who: PPRC ATLAS group



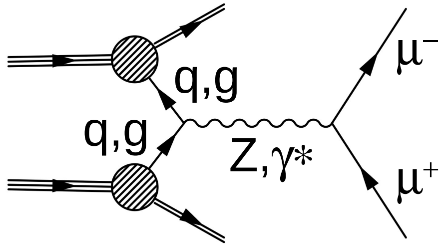
4 academics
14 research staff
10 PH.D. students

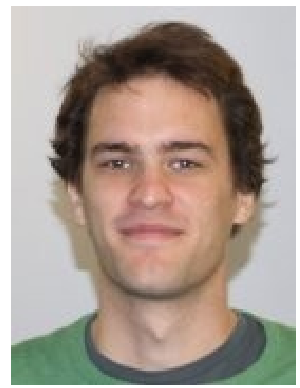
Who: PPRC ATLAS group *and friends*



What: Low Mass Drell-Yan

Eram Rizvi, Elisa Piccaro, Jack Goddard, Rob Hickling





Drell-Yan into two muons: process of quark & anti-quark annihilation and the subsequent decay to muon and anti-muon.

This process is sensitive to the distribution of quarks and gluons inside the proton, and therefore tells us about the dynamics of QCD.

At high energies, this process is one of the main decay mechanisms for some new particles like a heavy Z' boson, or so-called Kaluza-Klein excitations of particles moving in hidden extra-dimensions.

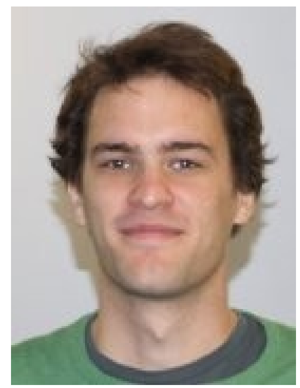
What: Low Mass Drell-Yan

Eram Rizvi, Elisa Piccaro, Jack Goddard, Rob Hickling

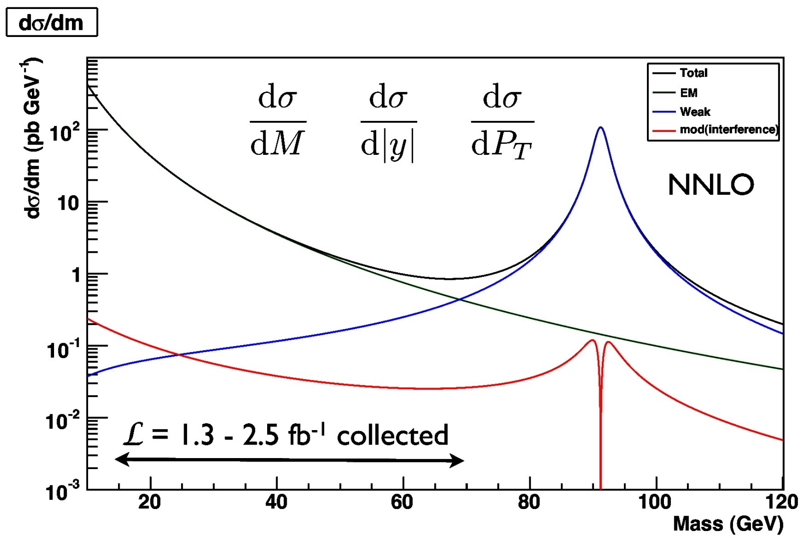
at ATLAS:

- ✔ **Sensitivity to the Parton Density Functions: crucial inputs to all QCD studies**
- ✔ **Cross-section measurement across a large mass spectrum: 12-66 GeV**

$$\sigma_{fid} = \frac{N_{data} - N_{bg}}{C_{SF} * L_{int}}, \quad \sigma = \sigma_{fid} / A_{geo}$$

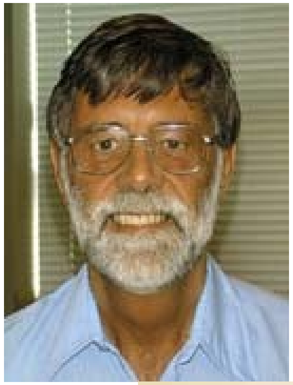


N_{data}: number of events in data
N_{bg}: number of estimated background events (from data-driven techniques)
C_{SF}: correction factor including efficiencies
L_{inc}: integrated luminosity
A_{geo}: detector acceptance



What: Topological Parton Reconstruction

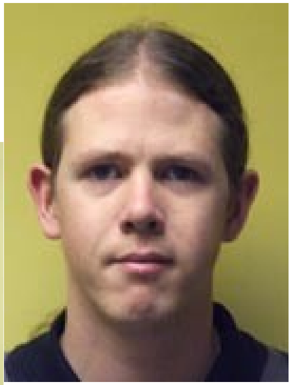
Graham Thomson, Katy Ellis, Tom Macey. John Morris, Dan Traynor



- **TRAPS**
  - **Topological Reconstruction Algorithm for Parton Scatters**
  - **Aim: reconstruct the final state partons in hadron-hadron collisions.**
  - **Usage: fragmentation and structure functions.**

A “top-down” jet-finding-type algorithm which attempts to reconstruct the final state partons exiting the hard interaction: to do this, it needs to isolate:

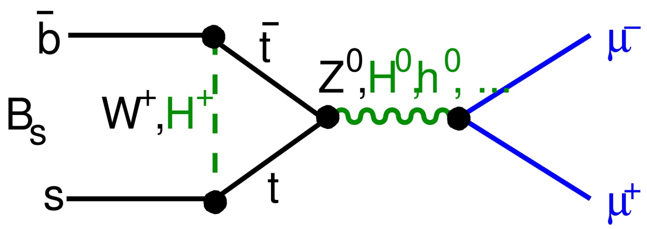
- ✔ 2-jet topologies
- ✔ high transverse momentum: p_T > 100GeV/c

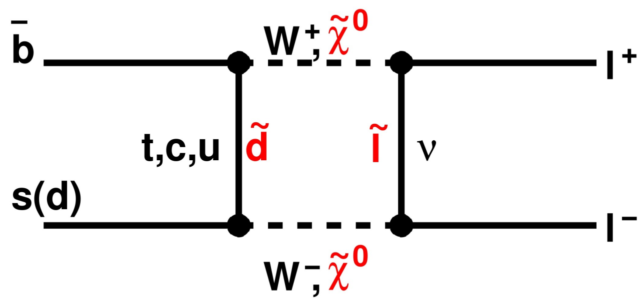


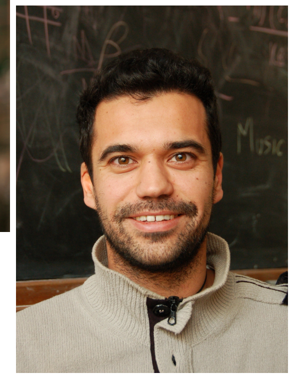
Parton information is required for QCD measurements such as parton fragmentation functions and structure functions: the study of QCD in this new kinematic region is crucial to test the standard model and look for new physics – does the quark have structure?

What: Rare B decays

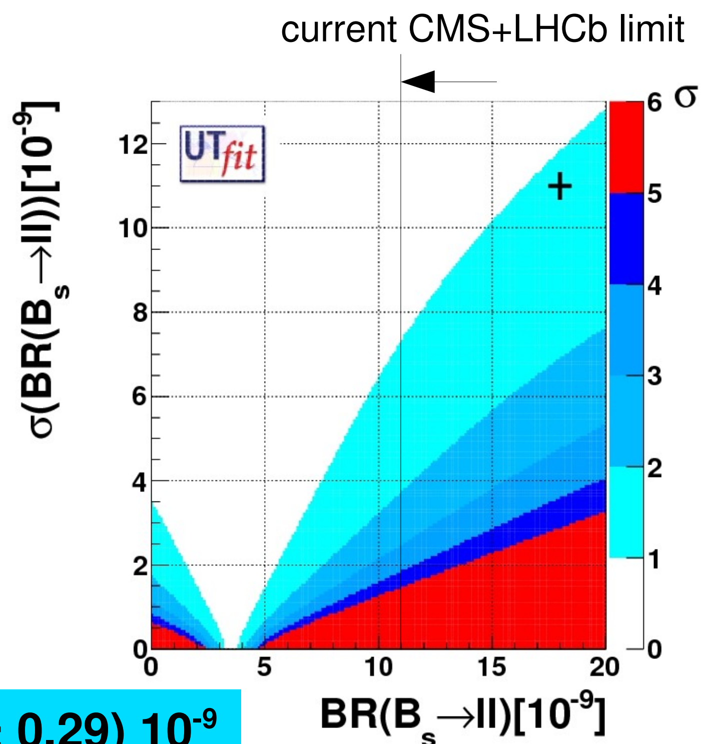
Marcella Bona, Cristiano Alpigiani







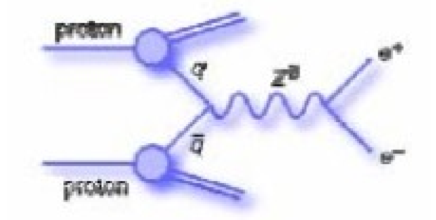
- B mesons decays to μμ is dominated by loop diagrams
- The Standard Model expectation for its branching ratio is ~ 3.5 10^{-9}
- Perfect ground for indirect search for New Physics: probing NP scales even higher that the direct search
- Best current limit: ~ 1.1 10^{-8} @ 95% CL
- 2012 data might reach the sensitivity for a measurement

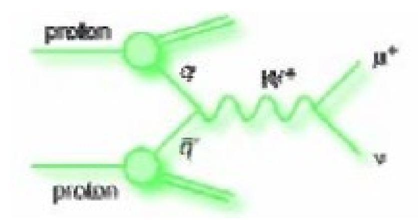


$BR(B_s \to ll) = (3.54 \pm 0.29)\ 10^{-9}$

What: Z/W bosons production with jets

Marcella Bona, Gregory Fletcher





Z(+jets) is a calibration channel for:

simulation, reconstruction, detector performances

W+jets is a relevant background

$t\bar{t}$ and single top; higgs searches; SUSY searches

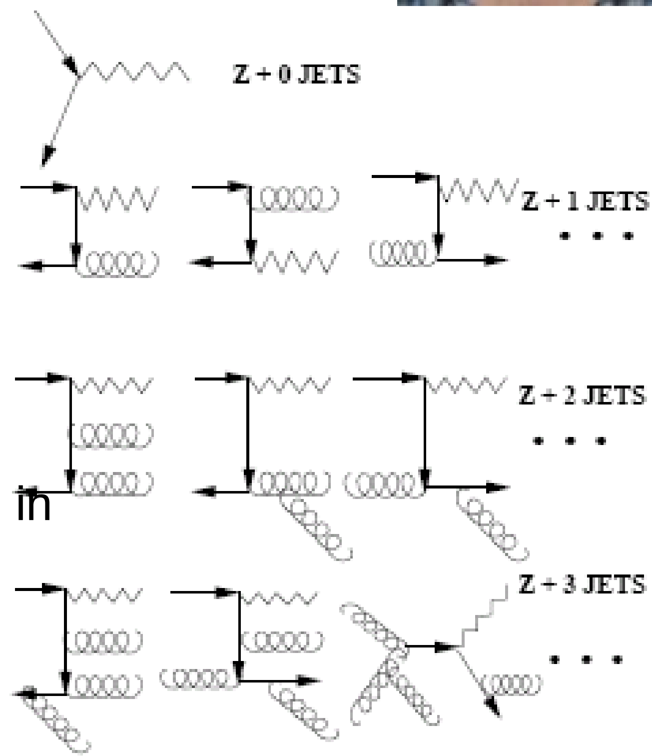
Testing perturbative QCD at order N:

for LO, NLO and NNLO predictions are in good agreement

higher order perturbative QCD in the case of more jets.

They are both interesting for searches:

allow for a consistency check of the SM with robust observables, against additional vector-boson production mechanism expected in (some) NP models

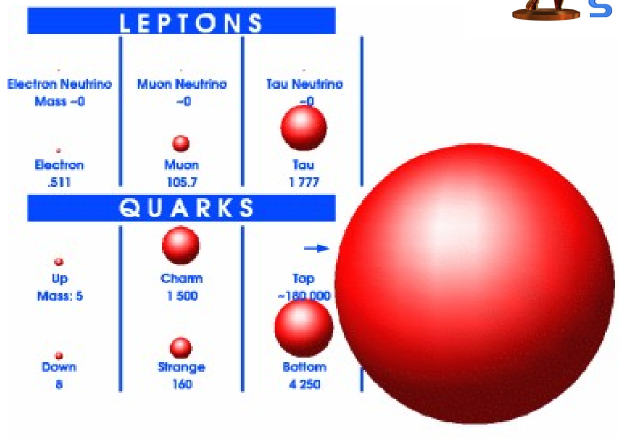


"Berends-Giele" scaling

σ(Z+ (n+1) jets)/σ(Z+ n jets) ~ α_s

What: top quark production

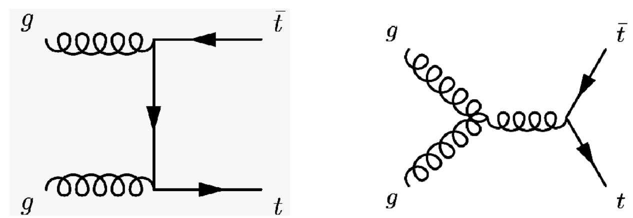
Top quark is very different from the other 5 quarks
- ✔ short lifetime: it decays before hadronizing
  - ➢ possibility to study the properties of a bare quark
- ✔ high mass, thus large coupling to Higgs boson, if it exists



Main goals of top physics:
- ✔ test of Standard Model predictions:
  - ➔ precision measurements on cross section, mass, couplings
  - ➔ searches for deviations as hint of new physics
- ✔ search for new physics:
  - ➔ new non-Standard Model particles, decaying into top quark pairs (resonances)
- ✔ detector calibration:
  - ➔ top quark decay involves all possible products: electrons, muons, jets, b-jets and neutrinos

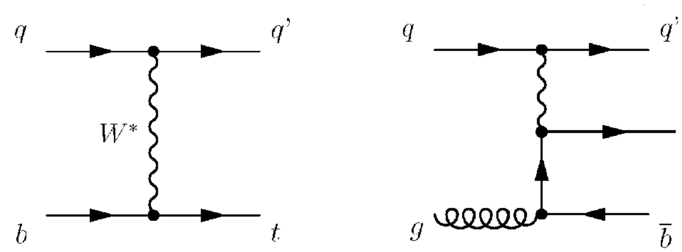
Pair Production:
dominated at LHC by the gluon-gluon fusion:

σ ~ 165 pb



Single top production:
dominated at LHC by the t-channel production

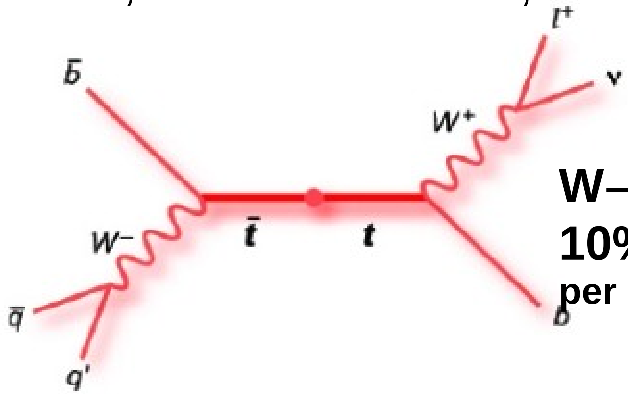
σ ~ 65 pb



What: top pair production

Lucio Cerrito, Giuseppe Salamanna, John Morris, Giacomo Snidero, Ruth Sandbach

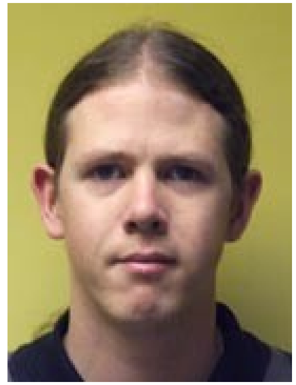
tt → bW bW → blν bjj



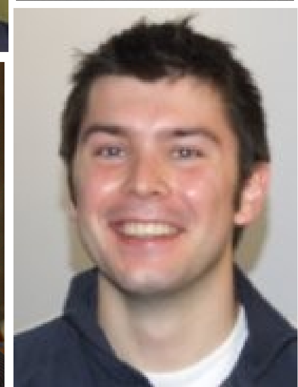
W→lν
10%
per lepton

Top Cross-Section:

- ✔ **Semi-leptonic decay:**
  lepton + 4-jets where at least one is tagged as coming from a b quark.
- ✔ Tagging strategy: **Soft Muon Tagger (SMT):**
  - ➔ reconstructing low pt muons in the b jet
  - ➔ likelihood to separate jets originated from b and c quarks (signal) vs jets from light quarks (large background).
  - ➔ Charge information from muon (b/c or $\bar{b}/\bar{c}$).
  - ➔ Overall efficiency due to BR(b→μ) ≈ 10%

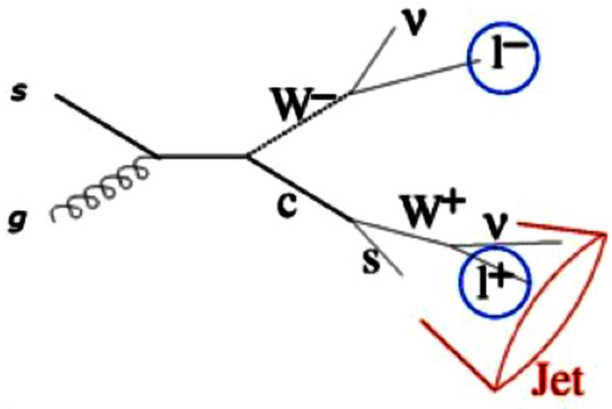



- Analysis complementary to other ATLAS measurements as sensitive to different systematic uncertainties
- Same analysis can also be used to measure W+c

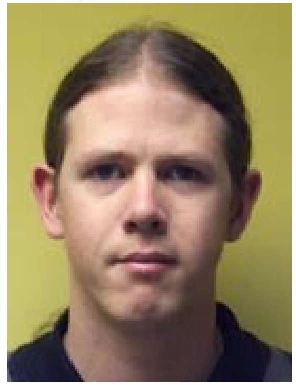



What: W boson with a c quark

Lucio Cerrito, Giuseppe Salamanna, John Morris, Giacomo Snidero, Ruth Sandbach

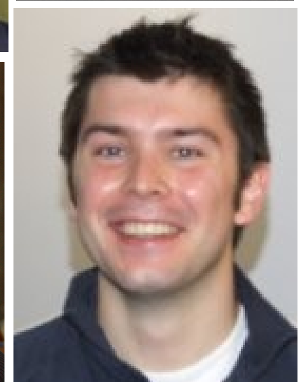


Process pp → W + c + X
Directly related to:
- ✔ s-quark proton content at $Q^2 \sim M^2_W$
- ✔ CKM matrix element $|V_{cs}|$



Analysis based on the charge correlation:
➔ opposite sign (OS) lepton from W and SMT-tagged muon in the c jet

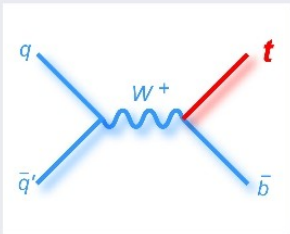
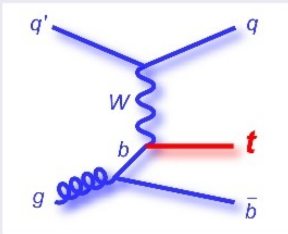
- ✓Main backgrounds are symmetric: same probability for the two leptons to have the same sign or to have opposite sign
- ✓few per cent accuracy
- ✓high purity W+c sample will provide information on how well the charm production is simulated



What: single top production

Steve Lloyd, Matilde Castanheira

Electroweak single top production:

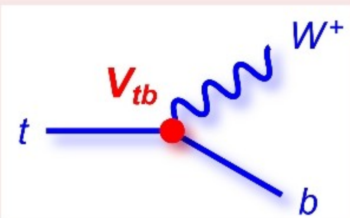
	s-channel (tb)	*t*-channel (tqb)
		
σ_{NLO}[†]	0.88 ± 0.11 pb	1.98 ± 0.25 pb (m_t=175 GeV)
$\sigma_{(N)NLO}$[‡]	1.12 ± 0.05 pb	2.34 ± 0.13 pb (m_t=170 GeV)

Focus on the t-channel:
events with W boson decaying into leptons

Signature: 1 energetic lepton, missing transverse energy, ≥2 jets, 1 b-jet
Main backgrounds: W+jets, QCD, top pair

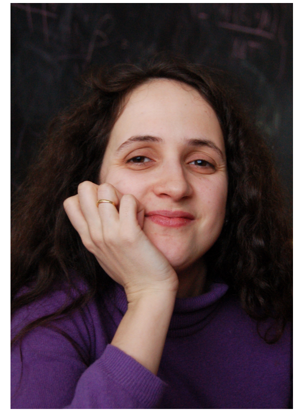
The Wtb coupling

$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & \mathbf{V_{tb}} \end{pmatrix}$$



- Direct $|V_{tb}|$ measurement
- Unitarity test of CKM matrix

✔ Does not hadronize - in fact $\tau_{decay} / \tau_{hadronize} \sim 10^{-1}$
⇒ provides a "clean" laboratory for studies of a quark
✔ Studying single top processes allows for direct measurement of V_{tb}
✔ Test the charged current coupling of the top quark
✔ Interestingly one of the EW processes with cross sections comparable to QCD
✔ Determine b-quark density in hadrons
✔ Background for other processes
✔ m_t close to the EW symmetry breaking scale
⇒ expect sensitivity to new physics

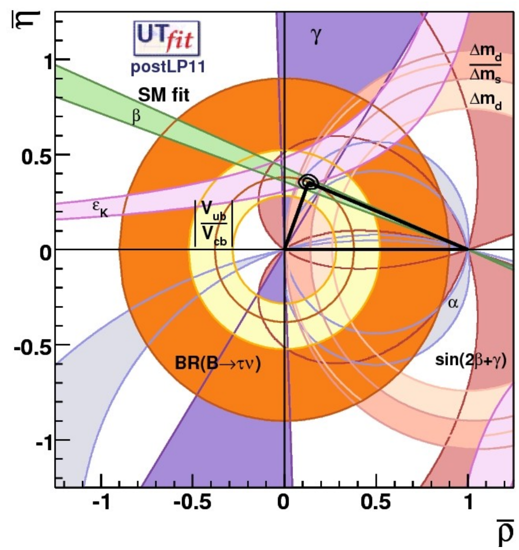


What: a little phenomenology..

Eram Rizvi, Marc Cano Bret

BlackMax: a state-of-the-art monte carlo simulator for TeV scale gravity effects including models for semi-classical micro-blackhole production, stringball production, and Planckian blackholes. All known grey-body emission factors are included as well as several phenomenological models for energy loss prior to the formation of a quantum gravitating object.

The **UTfit Collaboration** is a phenomenological analysis group that extracts the fundamental parameters of the Standard Model from results obtained from all the present and past experiments and from the most updated theoretical calculations. Through a global bayesian fit, the UTfit collaboration is giving the most accurate estimate of the fundamental CKM matrix parameters ρ and η.



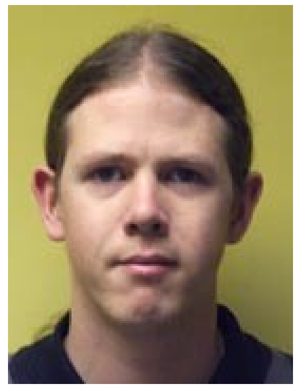
Adrian Bevan, Marcella Bona

***When*: the future**

Adrian Bevan, Marcella Bona, Lucio Cerrito, Murrough Landon, John D. Morris, Graham Beck, Fred Gannaway, Jagdish Mstry, John Morris, Geoff Simpson, Craig Wiglesworth



ATLAS **Upgrade project**

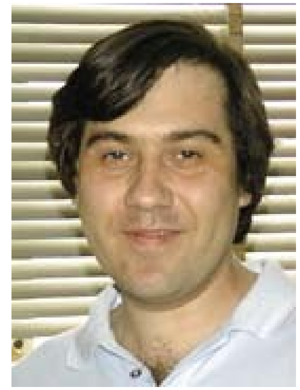
ATLAS tracker upgrade:
- ✔ Material modelling and tests (mechanical and thermal)
- ✔ SCT tracker support structures
- ✔ Stave testing and transport boxes
- ✔ CERN test beam work
- ✔ radiation tests




Level 1 Calo upgrade:
- ✔ trigger optimisation
- ✔ online software and databases
- ✔ offline calibration and monitoring
- ✔ online operations

When: the future

Adrian Bevan, Alex Martin, Gianluca Inguglia, Graham Beck
Fred Gannaway, Jagdish Mistry, John Morris, Geoff Simpson





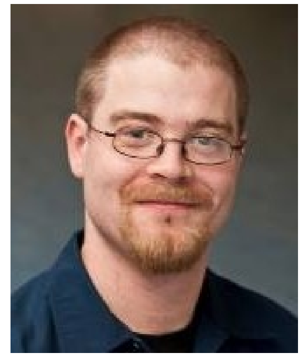
The SuperB experiment is a high luminosity flavour physics experiment to study the decays of B, D, Y mesons and τ leptons with billions of events. It will allow us to start reconstructing the Lagrangian for any physics beyond the Standard Model that may be encountered, and do precise tests of the Standard Model of particle physics.

Adrian Bevan is Physics Coordinator of SuperB

What: GridPP

GridPP
UK Computing for Particle Physics

Steve Lloyd, Alex Martin, Neasan O'Neill, Zara Qadir



Queen Mary is involved in GridPP, an STFC funded project to building a distributed computing Grid across the UK

- ✔ QMUL hosts one of GridPP's largest computer clusters as part of the London Tier-2 Centre
- ✔ 3 members of staff manage and maintain the cluster (Alex Martin, Chris Walker and Dan Traynor)
- ✔ Steve Lloyd is Chair of the GridPP Collaboration Board and Chair of the London Tier-2 Board

PPRC and communications:

- ✔ QMUL is also involved in outreach and publicity for GridPP hosting the project's dissemination officer (Neasan O'Neill)
- ✔ The group are also a member of the e-ScienceTalk project (Zara Qadir) which brings the success stories of Europe's e-infrastructure to a wider audience.

e science TALK

Who: behind every great ~~man~~ person..

the great IT crew

Alex Owen, Cozmin Timis

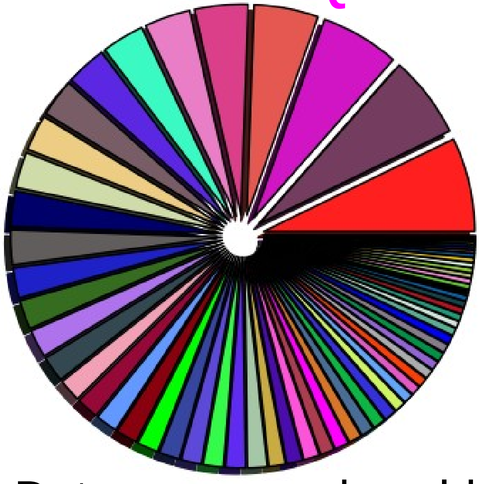
- ✔ Physicist programmers
- ✔ Lead the development of a database for the ATLAS upgrade
- ✔ System Managers for the Group's computing facilities
- ✔ installation and maintenance of the centralised management system and backup procedures, group home file servers, mail server, printer server, web server, subversion repository
- ✔ local 136 core, 60 TB local batch system (Tier-3)
- ✔ maintenance of the ATLAS software and distributed analysis tools
- ✔ release building for ATLAS as part of the Software Infrastructure Team




Chris Walker, Dan Traynor

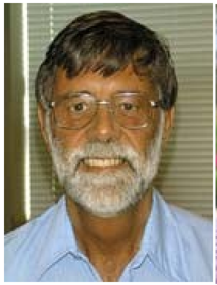
- ✔ Amministration and running of the Tier-2 cluster for GridPP
  - ➔ 3500 CPU cores and 1400 TB of disk
  - ➔ 390 000 ATLAS jobs in a month (Jan '12)
  - ➔ 2100 TB processed data in a month (Jan '12)
  - ➔ averaged 760 Mbit/s: twice the rest of the College

QM is third



Data processed worldwide
Total: 36 000 TB (Jan '12)

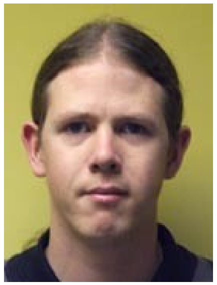
Who: PPRC ATLAS group *and friends*


SuperB



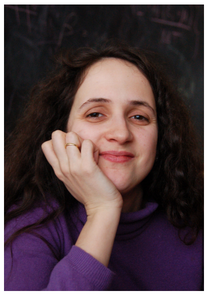




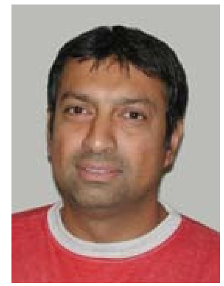






GridPP
UK Computing for Particle Physics



ATLAS



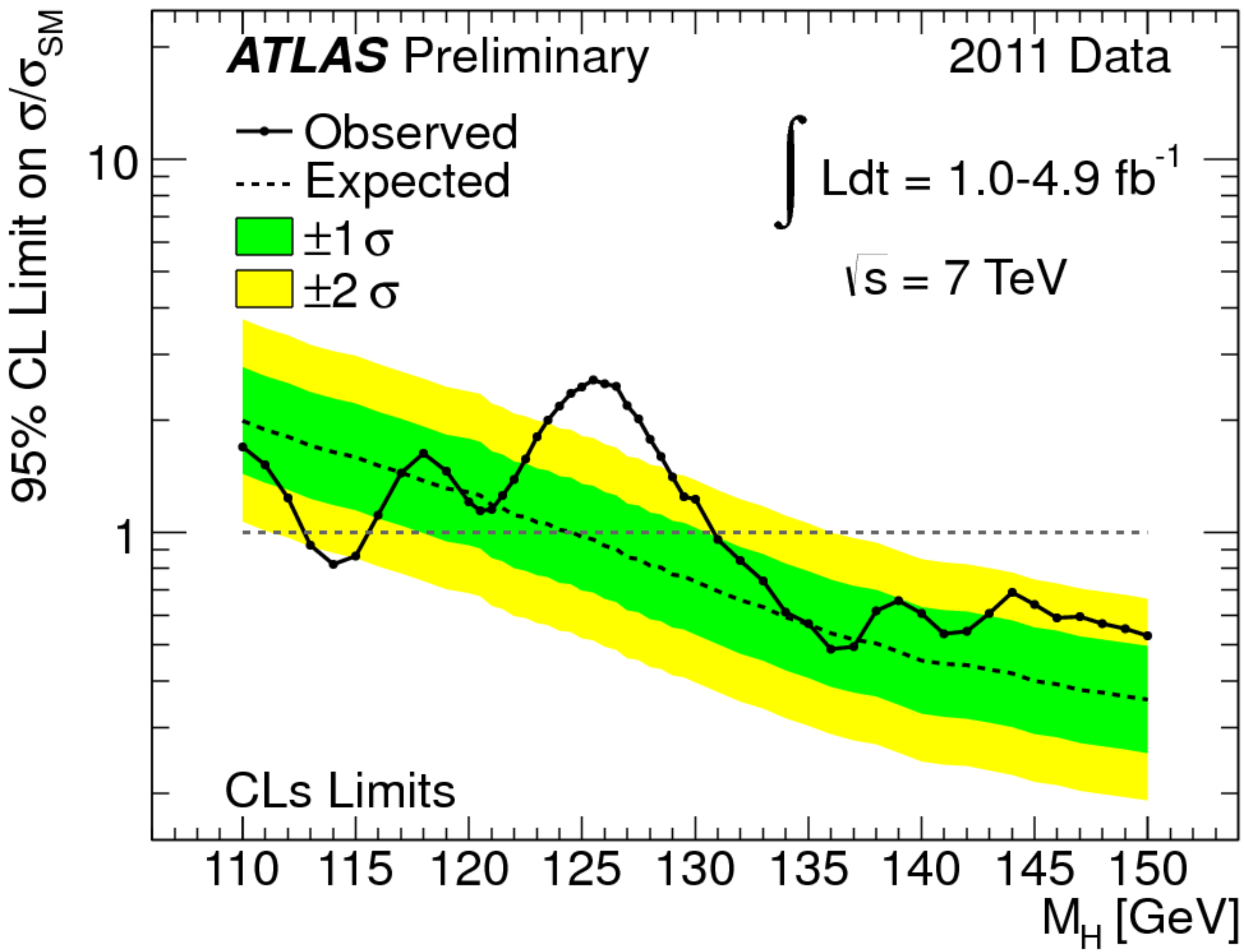
e science TALK




extra slides

Higgs search: state of the art

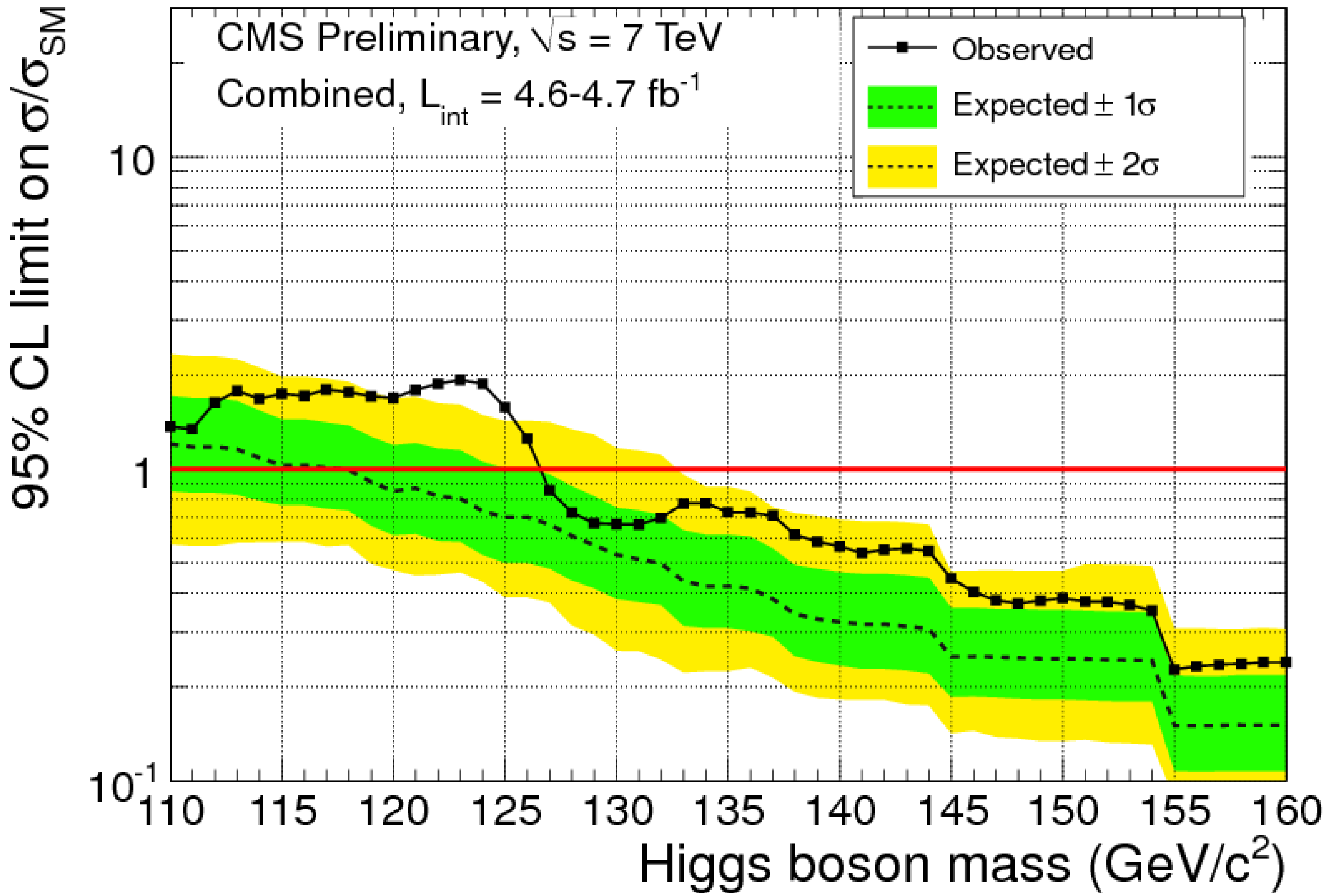
Experimental limits from ATLAS on Standard Model Higgs production in the mass range 110-150 GeV. The solid curve reflects the observed experimental limits for the production of Higgs of each possible mass value (horizontal axis). The region for which the solid curve dips below the horizontal line at the value of 1 is excluded with a 95% confidence level (CL). The dashed curve shows the expected limit in the absence of the Higgs boson, based on simulations. The green and yellow bands correspond (respectively) to 68%, and 95% confidence level regions from the expected limits.



the most likely mass region for the Higgs boson is restricted to 115-130 GeV/c^2

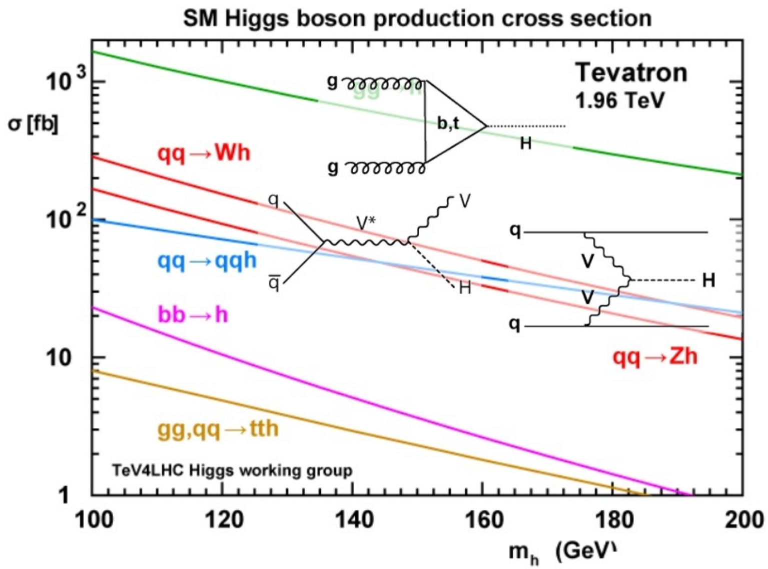
Higgs search: state of the art

SM Higgs exclusion limit at 95% confidence level for 4.7 fb^{-1} proton-proton data collected by CMS in 2010 and 2011, showing the lower mass region.

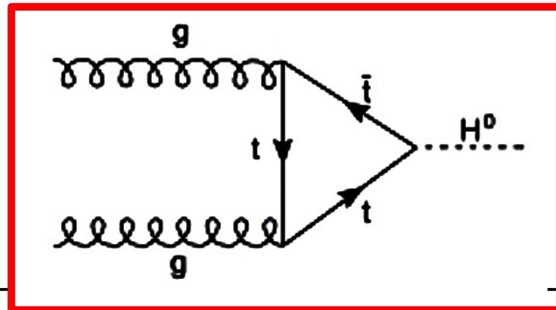


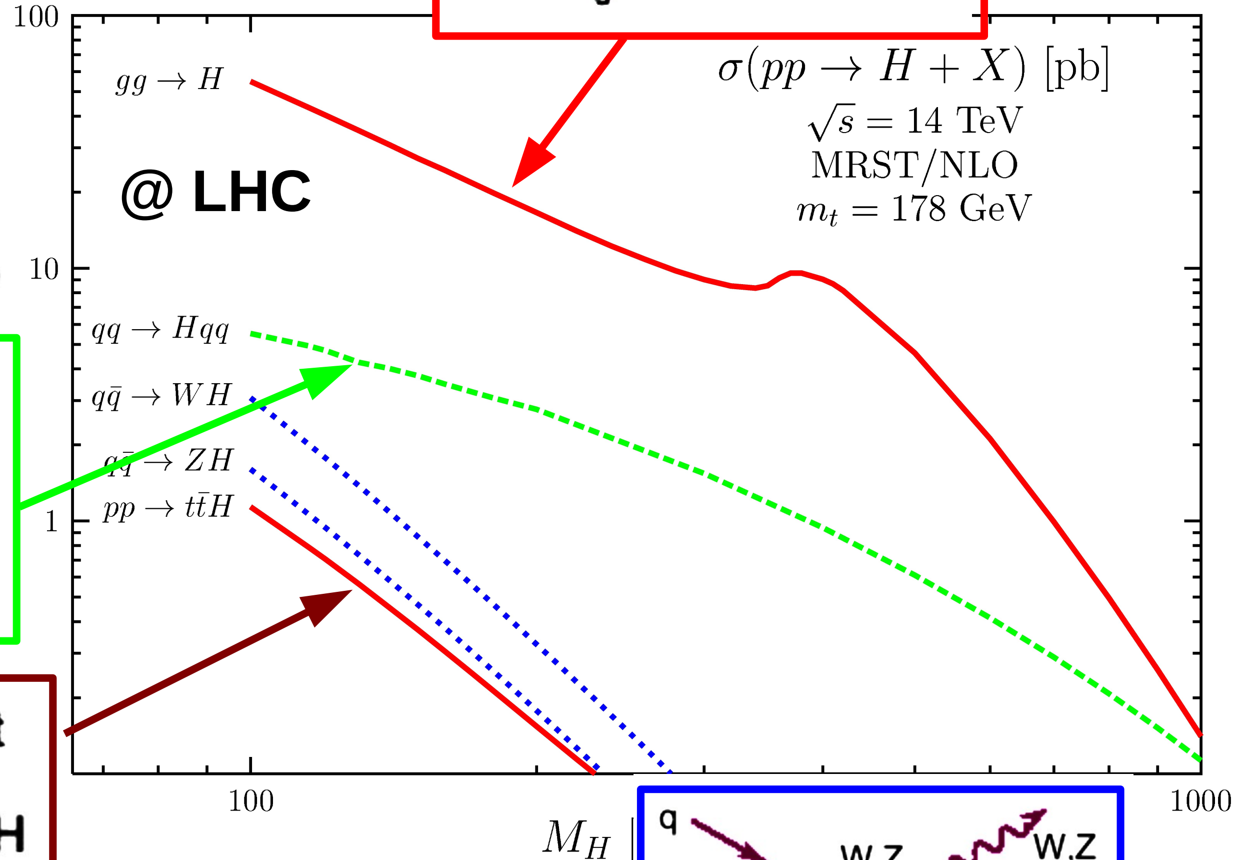
the most likely mass region for the Higgs boson is restricted to 115-127 GeV/c^2

Higgs production

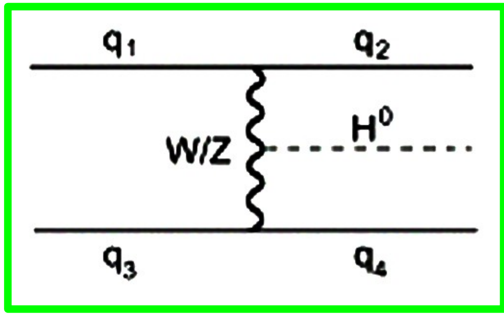


gluon-gluon fusion

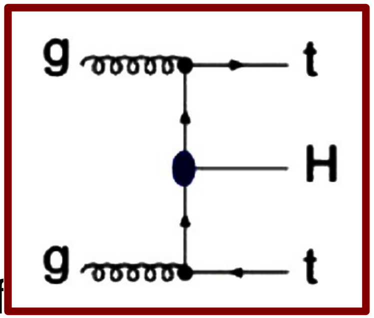




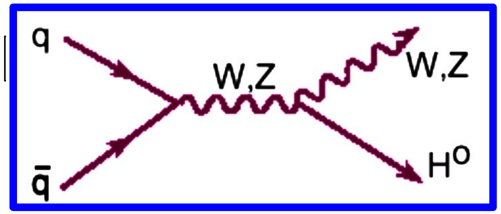
vector boson fusion



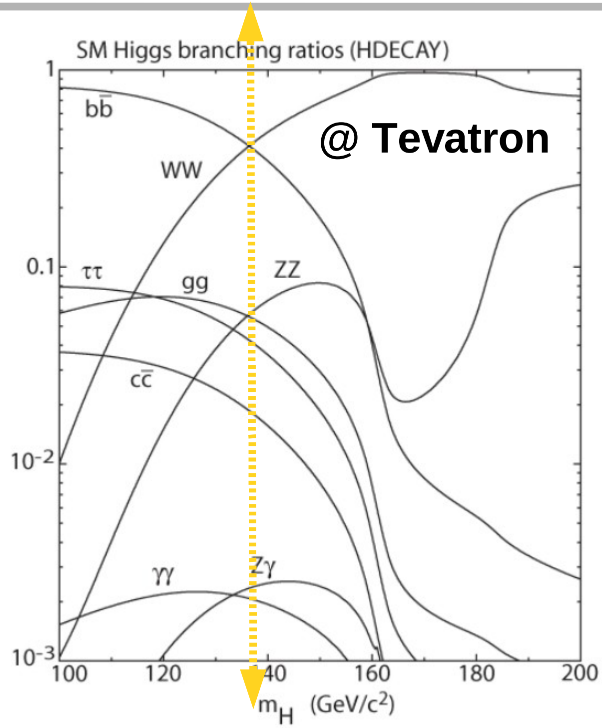
tt-fusion

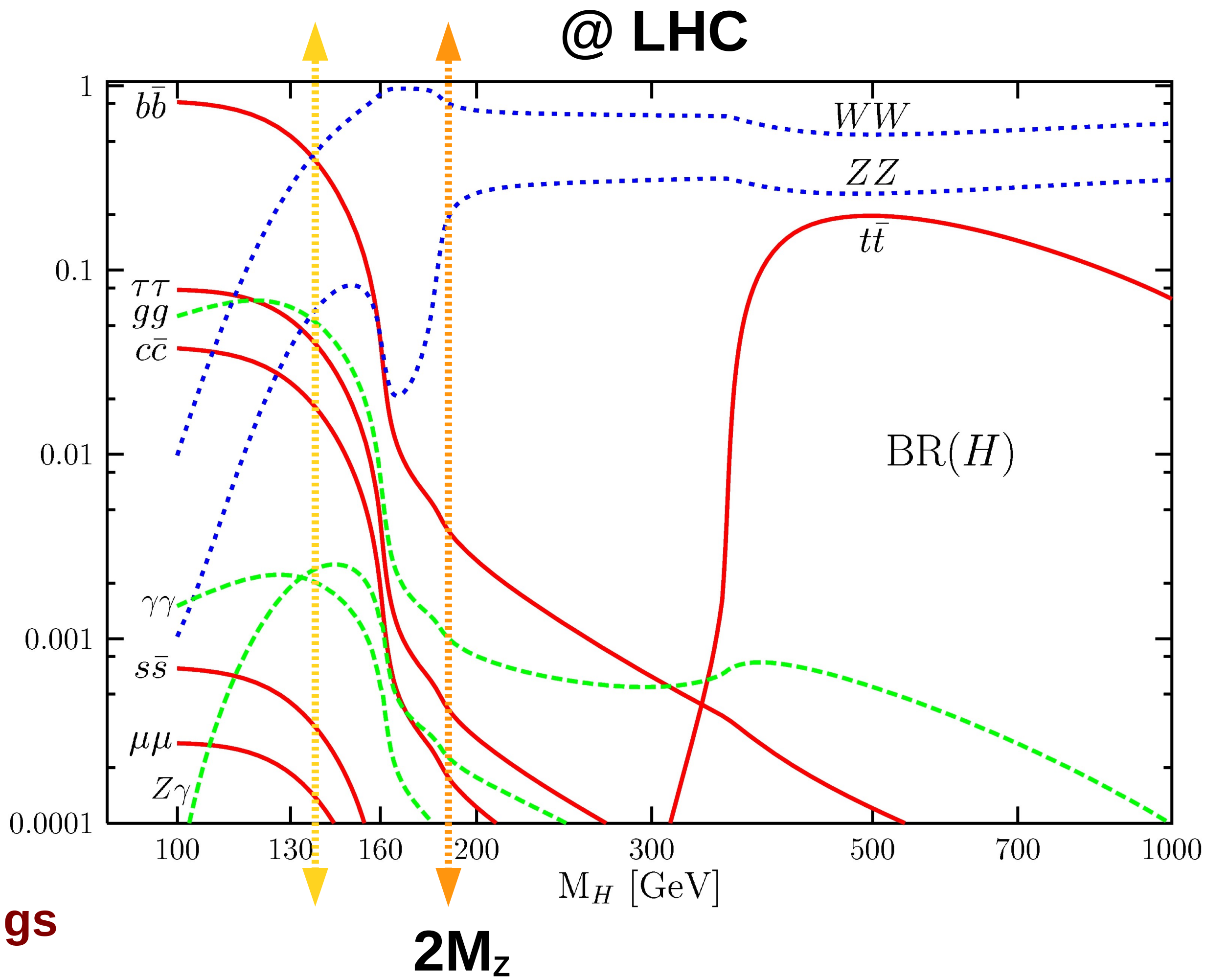


associated production



and Higgs branching ratios





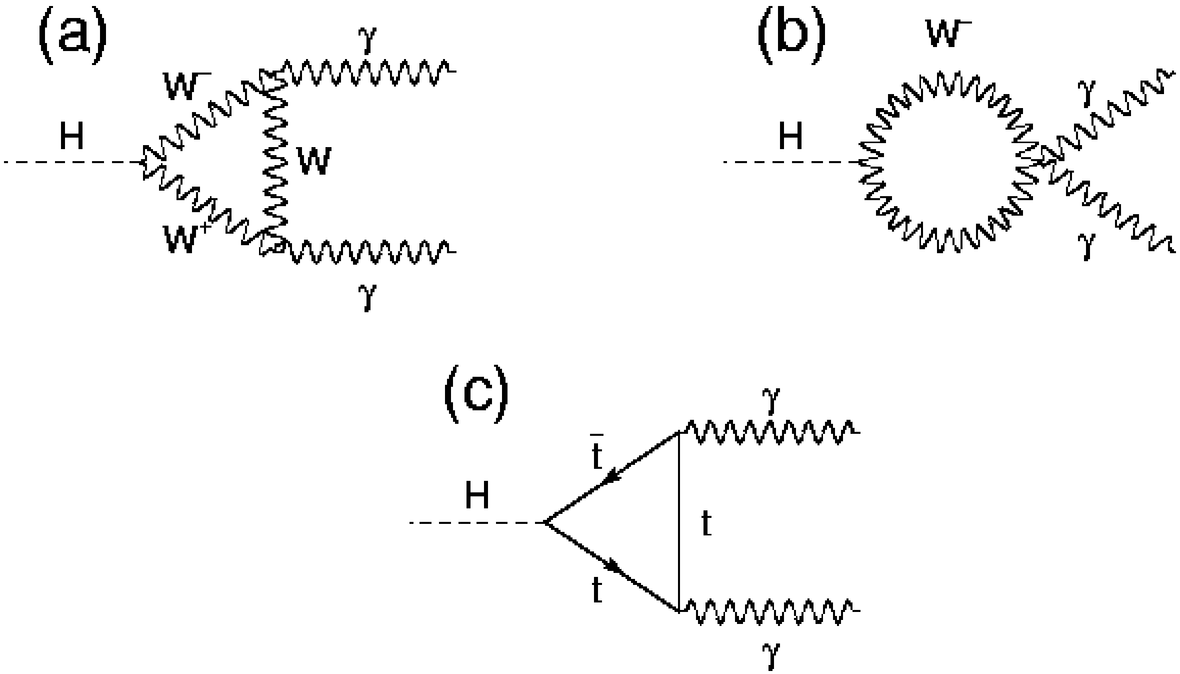
100-135 GeV/c^2: light SM Higgs
⇨ **bb decays dominate**
⇨ **tt is also playing a role**

above 135 GeV/c^2: heavy SM Higgs
⇨ **WW dominates**
⇨ **ZZ also but Z→ll only 3% per lepton**

"golden modes" @ low mass

- ⇨ bb decays dominate but very high background
- ⇨ ττ accessible through vector boson fusion. cleaner but still difficult
- ⇨ γγ final state is the real "golden mode" even if significantly smaller σ:
  direct production or in association with hadronic jets

γγ decay



“golden modes” @ low mass

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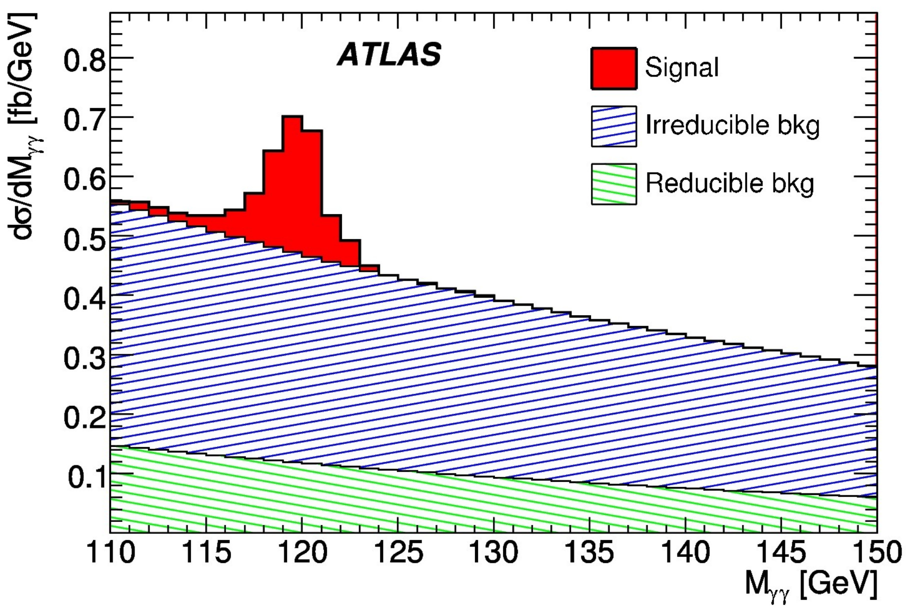
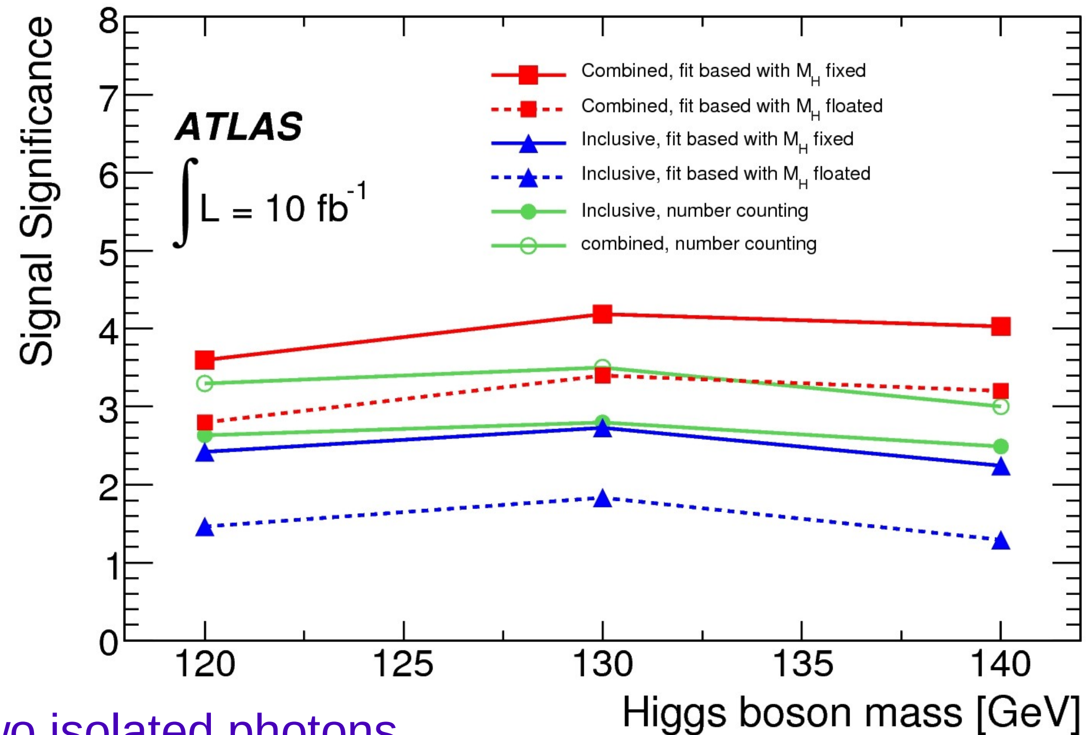
γγ+2jets





irreducible background: production of two isolated photons
reducible background: events with at least one fake photon

“golden modes” @ low mass

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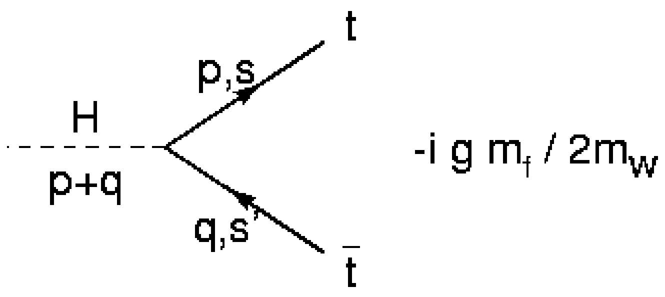
fermionic decays



the Higgs couples to all fermions proportional to their mass so the coupling to a pair of top quarks is by far the strongest. If the Higgs mass is below the double top mass the dominant fermionic decay will be to bottom quarks.

“golden modes” @ low mass

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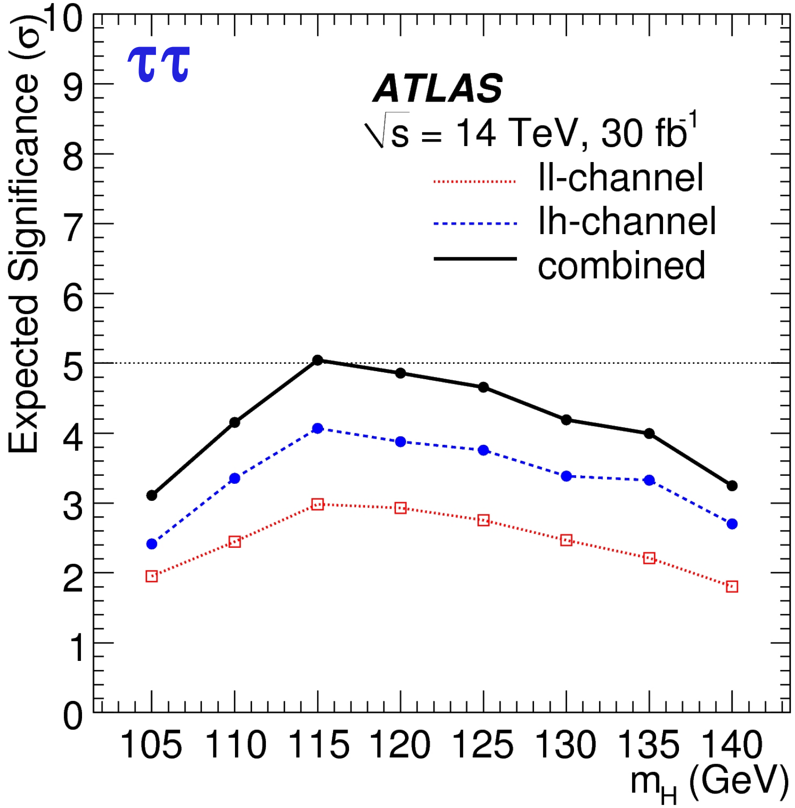
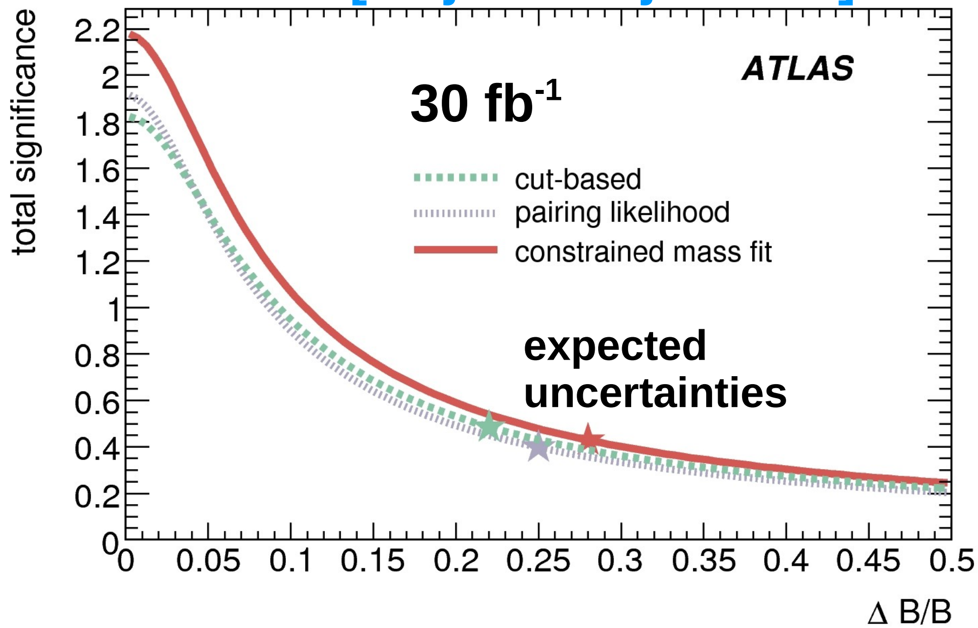
- ⇨ **ττ accessible through vector boson fusion. cleaner but still difficult**

vector- boson fusion



ttH→Wb Wb bb

[4b jets + 2 jets + lν]



ττ pair in the collinear approximation
Z+jets and tt as main background

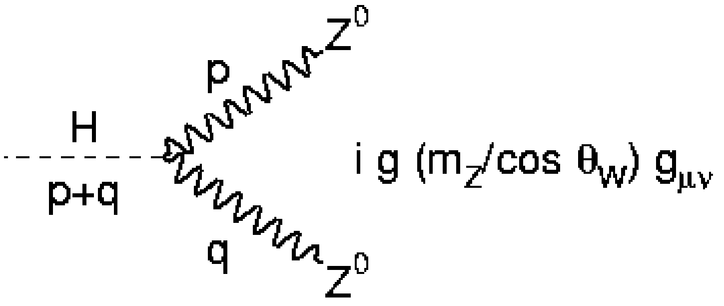
up

very efficient light jets rejection
and b-tagging efficiency:
main backgrounds are ttbb and ttjj

"golden modes" @ high mass

⇨ WW decay dominates: "golden mode" for the high mass with gluon fusion and vector-boson fusion production
⇨ ZZ decay: very clean final state with 4 leptons

vector-boson decay



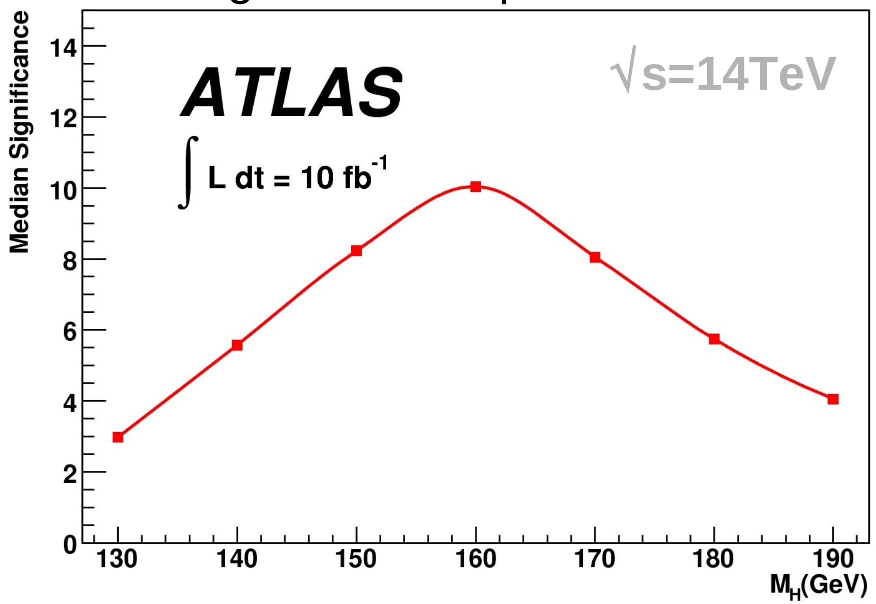
The width of the Higgs decaying to W^+W^- is the same as the width of the Z^0Z^0 decay, except that the two decay particles are not equal leading to a factor two larger result.

"golden modes" @ high mass

- ⇨ **WW decay dominates: "golden mode" for the high mass with gluon fusion and vector-boson fusion production**
- ⇨ **ZZ decay: very clean final state with 4 leptons**

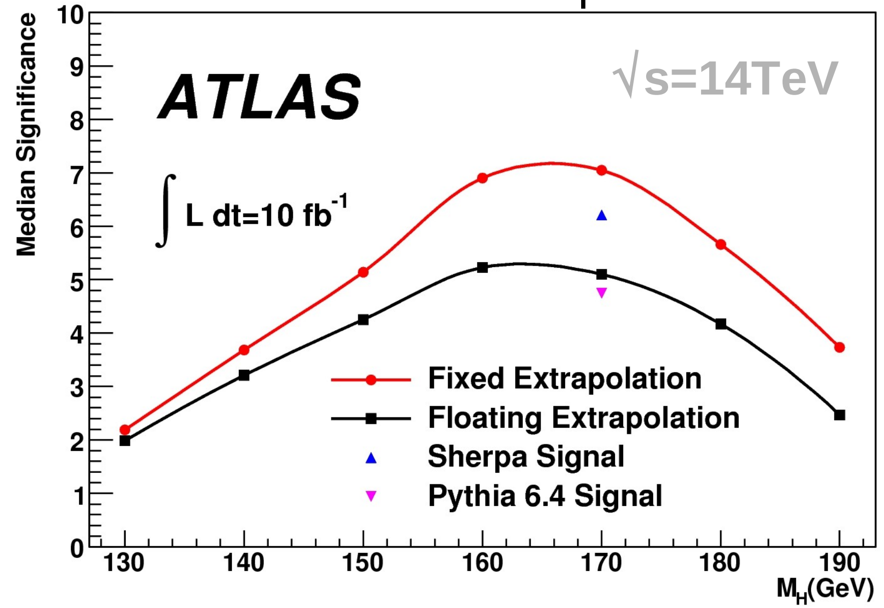
H→WW

gluon fusion production



main background: WW

vector-boson fusion production



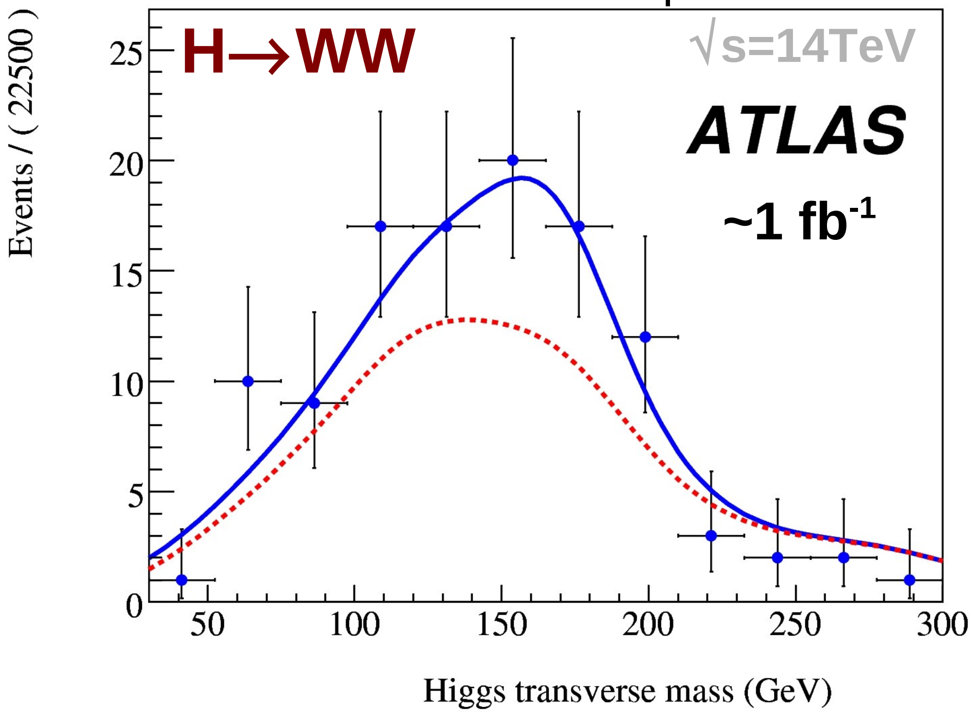
main background: tt

“golden modes” @ high mass

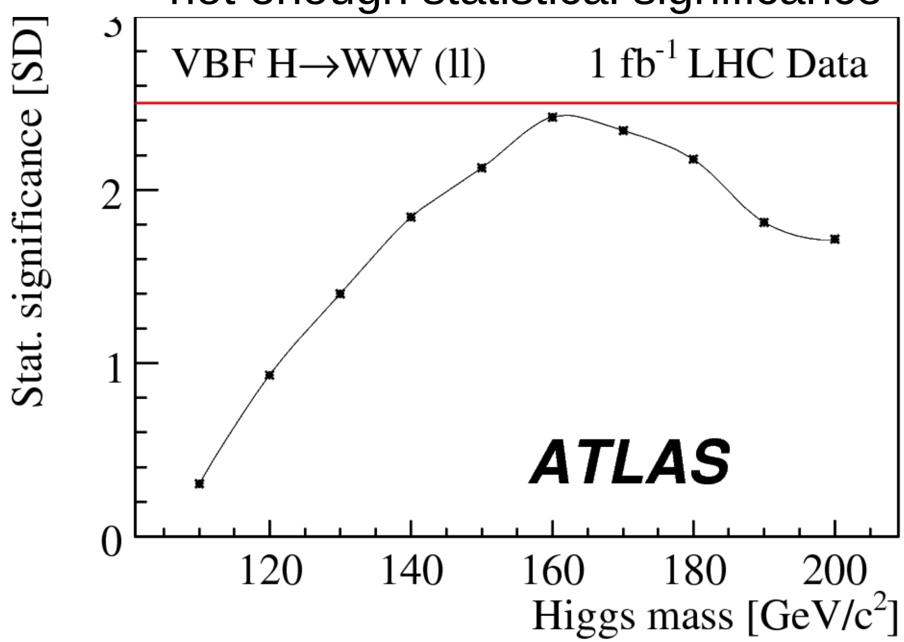
⇨ **WW decay dominates: “golden mode” for the high mass with gluon fusion and vector-boson fusion production**

⇨ **ZZ decay: very clean final state with 4 leptons**

vector-boson fusion production



not enough statistical significance



"golden modes" @ high mass

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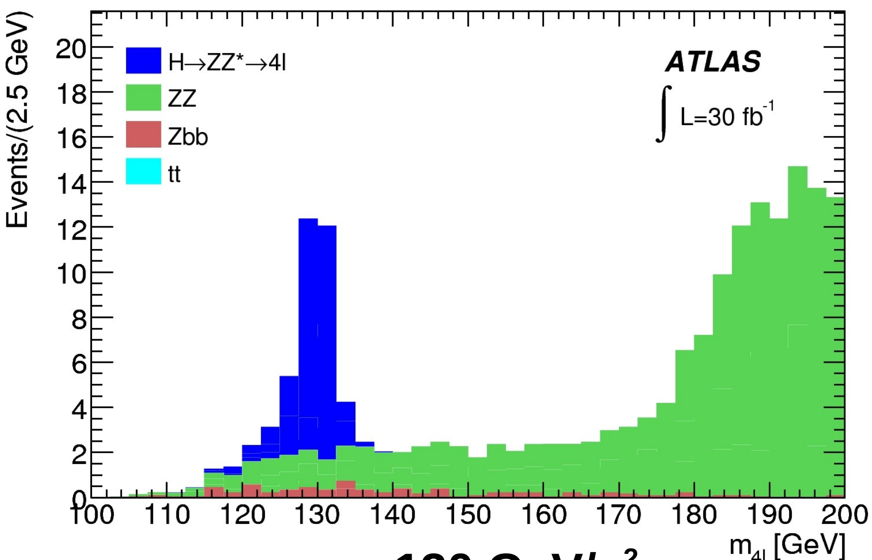
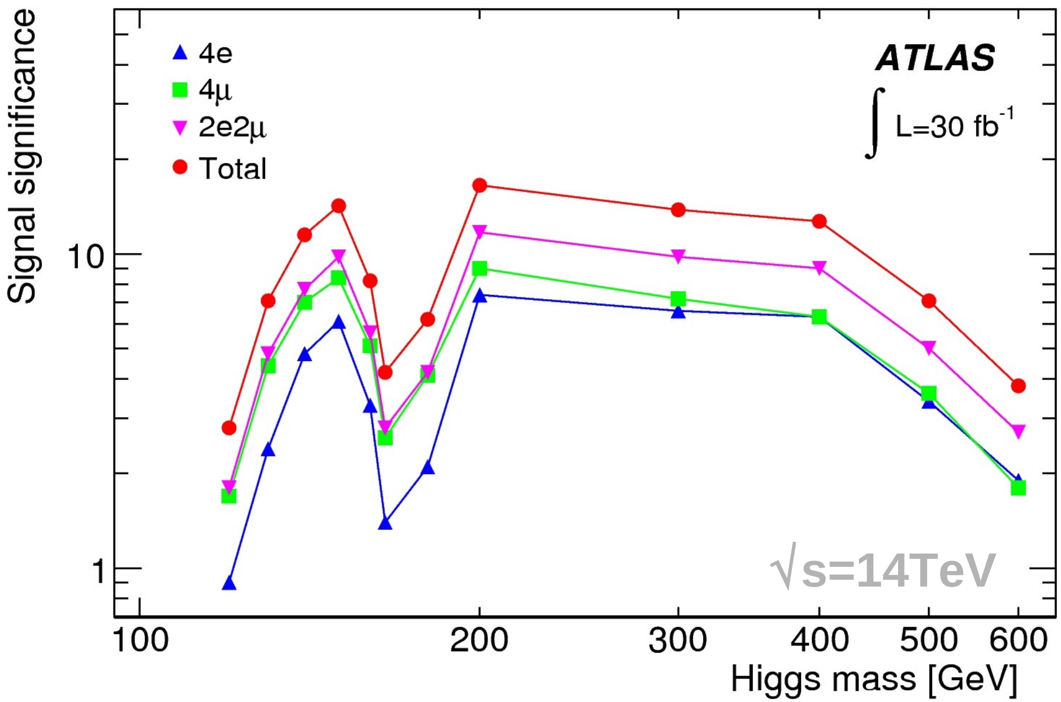
$H \to ZZ$

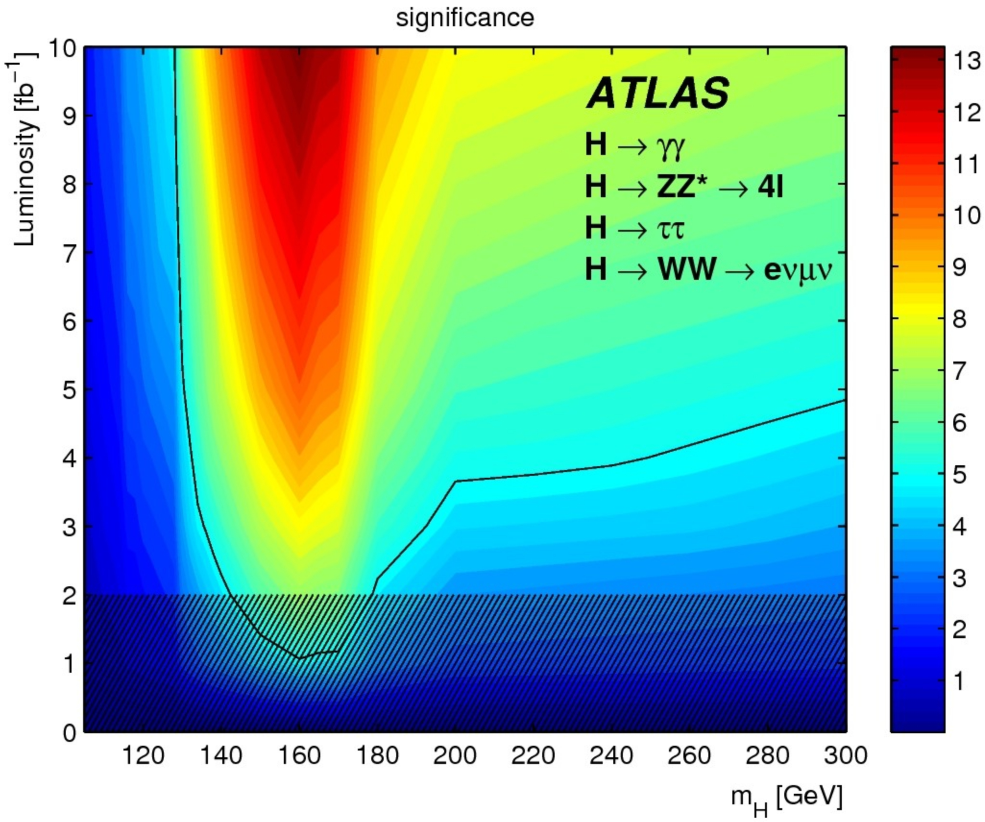


m_H=130 GeV/c^2

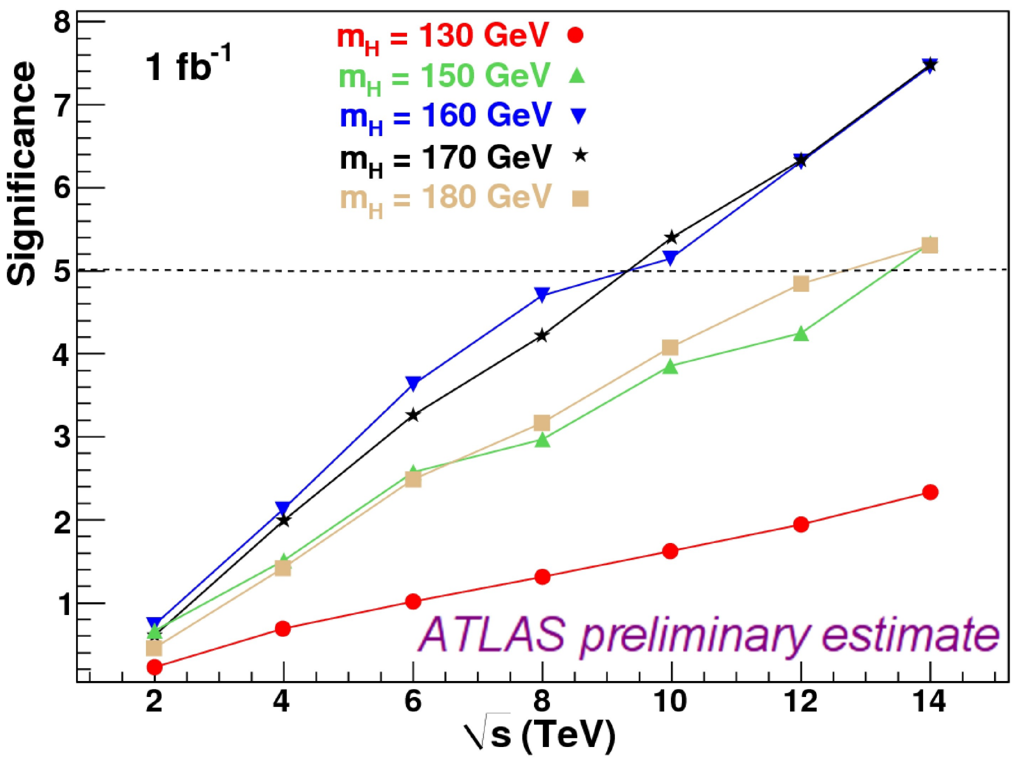


scaling to the near future

combined significance from the listed channels vs integrated luminosity



estimate scaling with respect to the centre-of-mass energy



The LHC Data Challenge

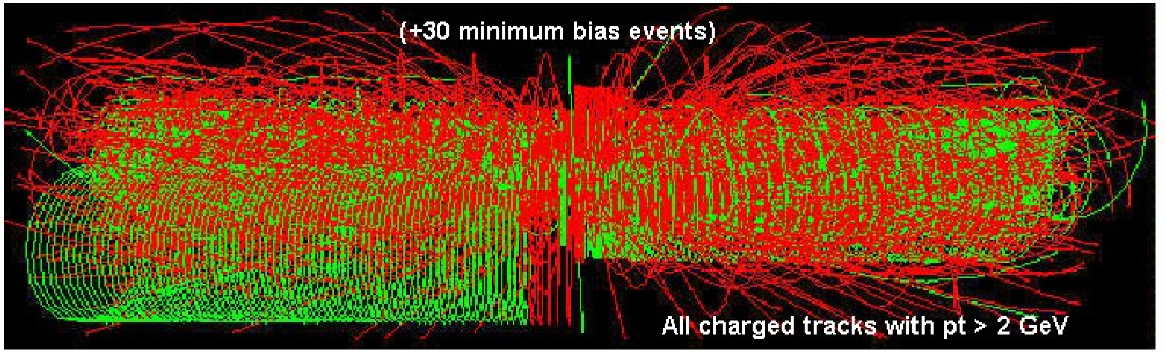
- ~100,000,000 electronic channels
- 800,000,000 proton-proton interactions per second
- 0.0002 Higgs per second
- 10 PBytes of data a year
- (10 Million GBytes = 14 Million CDs)

Selectivity: 1 in 10^{13}

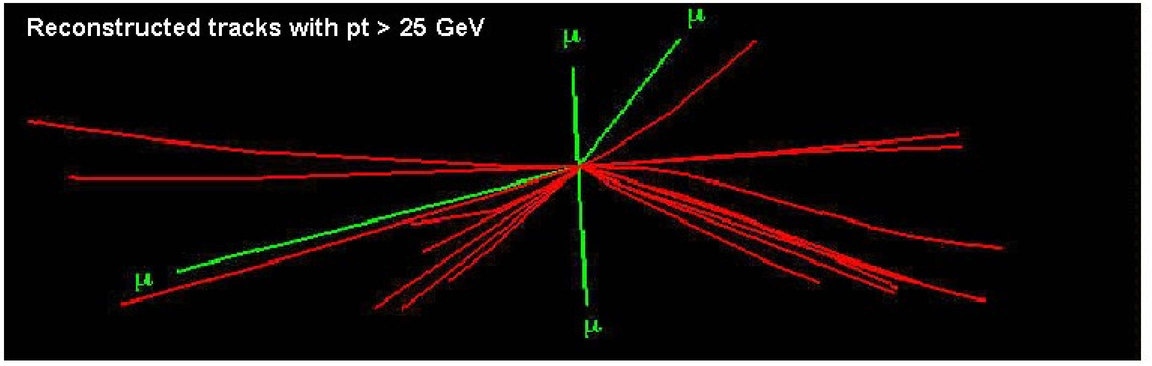
Like looking for 1 person in a thousand world populations

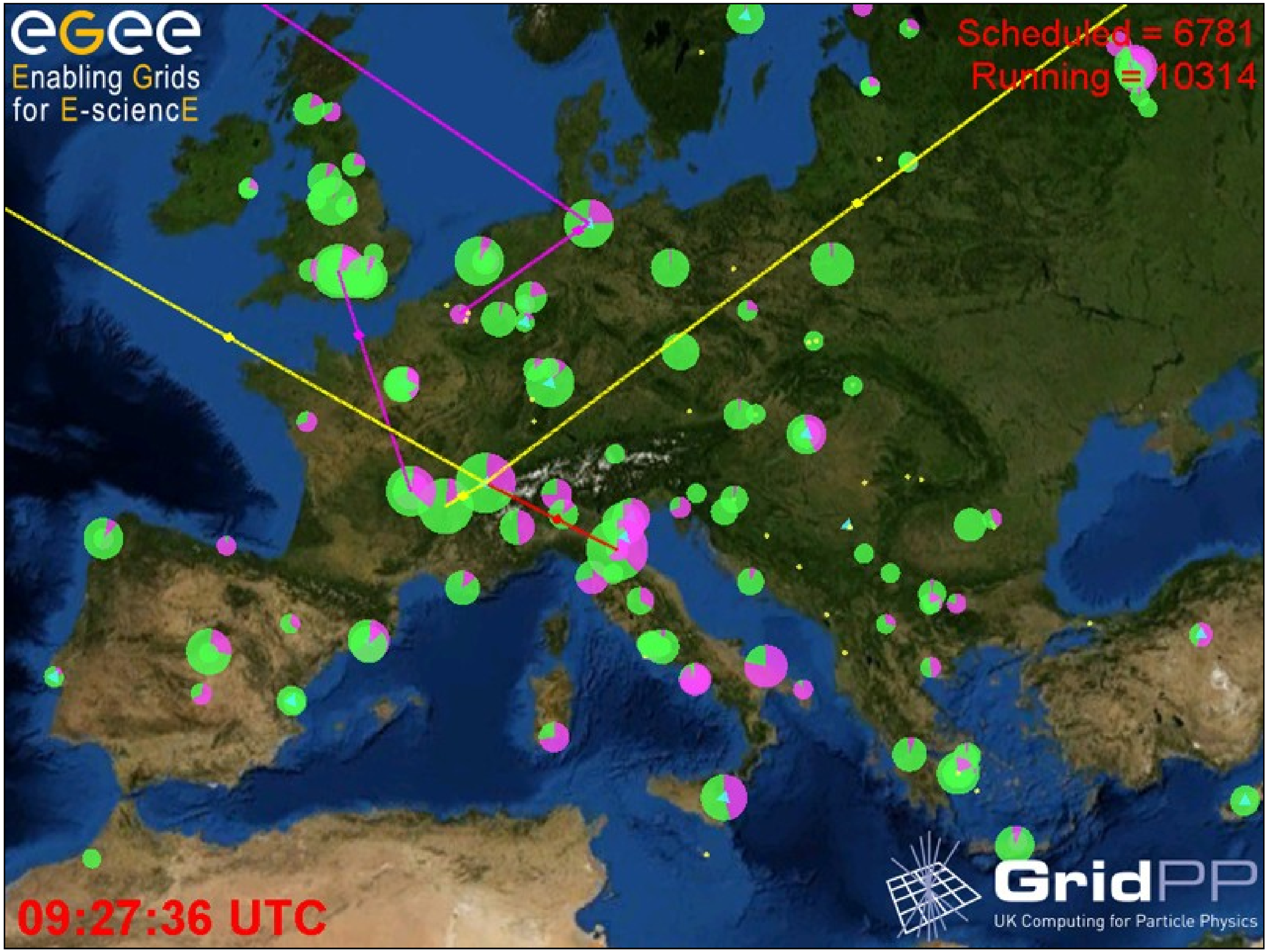
Or for a needle in 20 million haystacks!

Starting from this event…



We are looking for this "signature"





Worldwide

267 Sites

55 Countries

101,080 CPUs

129 PB Disk

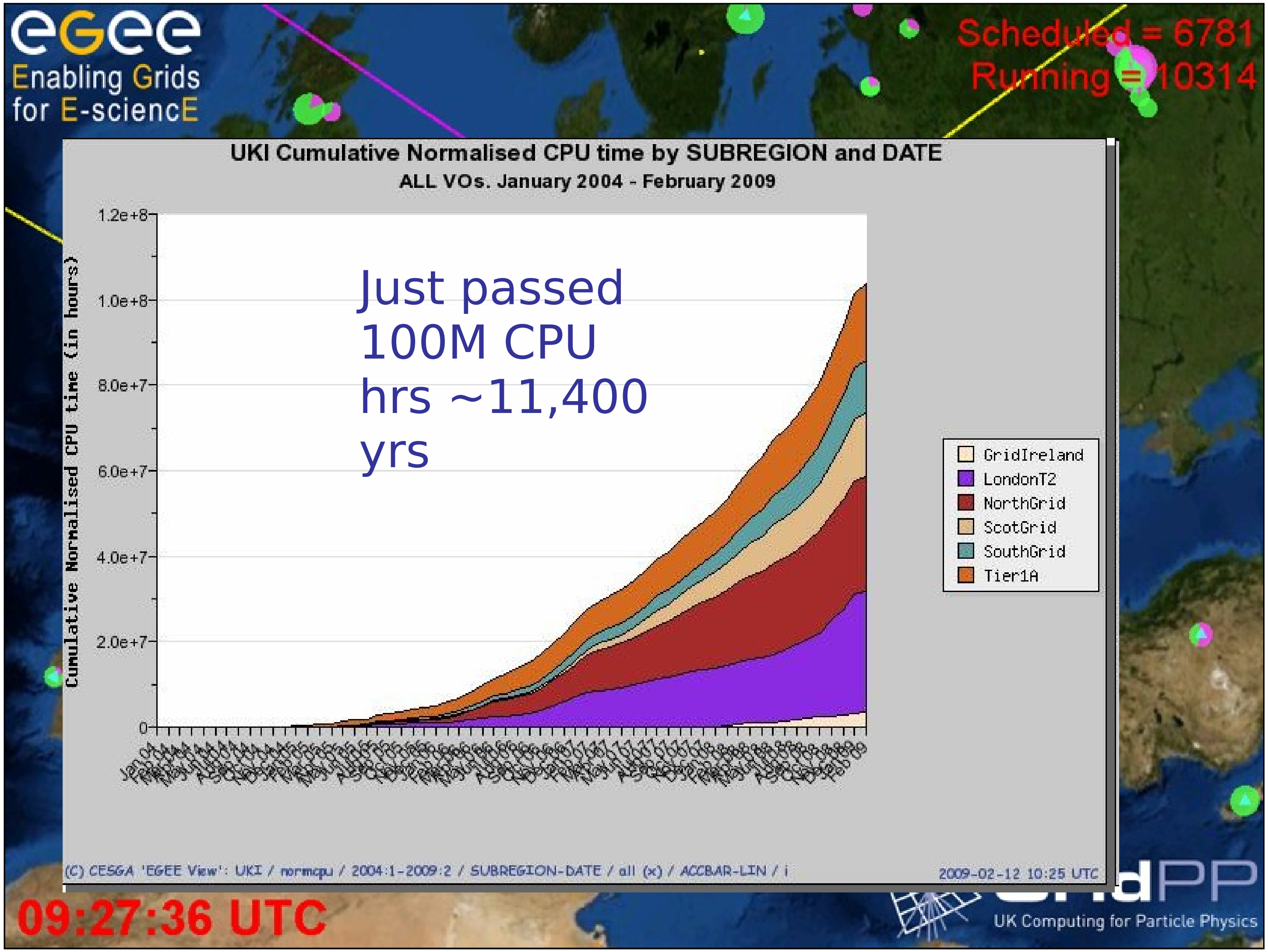
UK

21 Sites

15,158 CPUs

2.9 PB Disk

The European Grid



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