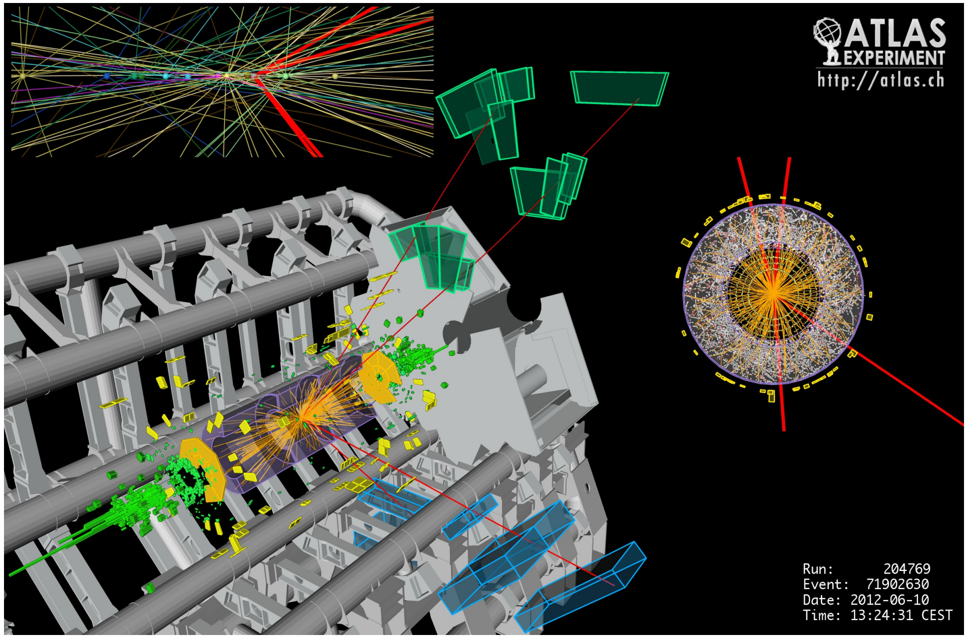
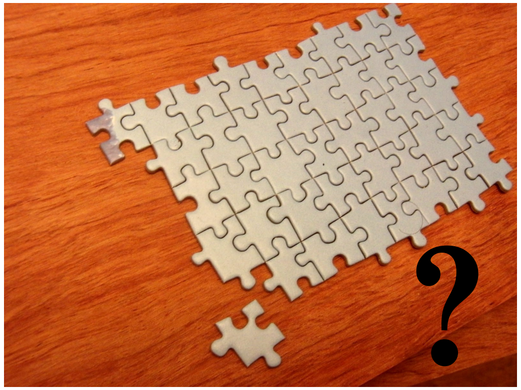




ATLAS Overview

Patricia Conde Muíño
(LIP-Lisboa)

LIP
ATLAS
IF INVESTIGADOR FCT
POPH QUALIFICAR É CRESCER.
QREN QUADRO DE REFERÊNCIA ESTRATÉGICO NACIONAL
COMPETE PROGRAMA OPERACIONAL FACTORES DE COMPETITIVIDADE

Portuguese ATLAS team

National group:
LIP (Lisbon, Coimbra, Minho)
FCUL, FCTUC, U. Minho, CFNUL
CEFITEC/UNL, INESC, CFMC
AdI engineers training program

Group structure

- Physics Analysis and Performance
  - Top quark (A. Onofre, F. Veloso)
  - Exotic searches (N. Castro)
  - Higgs (R. Gonçalo, P. Conde)
  - Heavy Ions (H. Santos)
  - Jets/Etmiss performance & calibration (J. Maneira)

- M&O and Performance
  - TileCal (A. Gomes)
  - Jet Trigger (R. Gonçalo, P. Conde)
  - ALFA detector (A. Maio)

- Detector Upgrades
  - TileCal (A. Gomes)
  - High Level Trigger (P. Conde)
  - AFP (P. Conde)

- GRID computing (H. Wolters)

Current Detector Responsibilities

- TileCal hadronic calorimeter
  - Laser calibration & monitoring system
  - DCS
  - Software
  - Performance
  - Operations

- Jet trigger
  - Algorithm development & maintenance
  - Performance studies in pp & HI
  - Heavy Ions trigger menu
  - Hadronic calibration trigger (for E/p studies)

- ALFA luminosity detector
  - DCS

- GRID distributed computing
  - Sites/services monitoring
  - Operations/shifts

Current Physics & Performance Studies

- Top quark precision measurements
    - W polarization in tt events
    - tt spin correlations
    - Top polarization in tt events
    - Search for FCNC

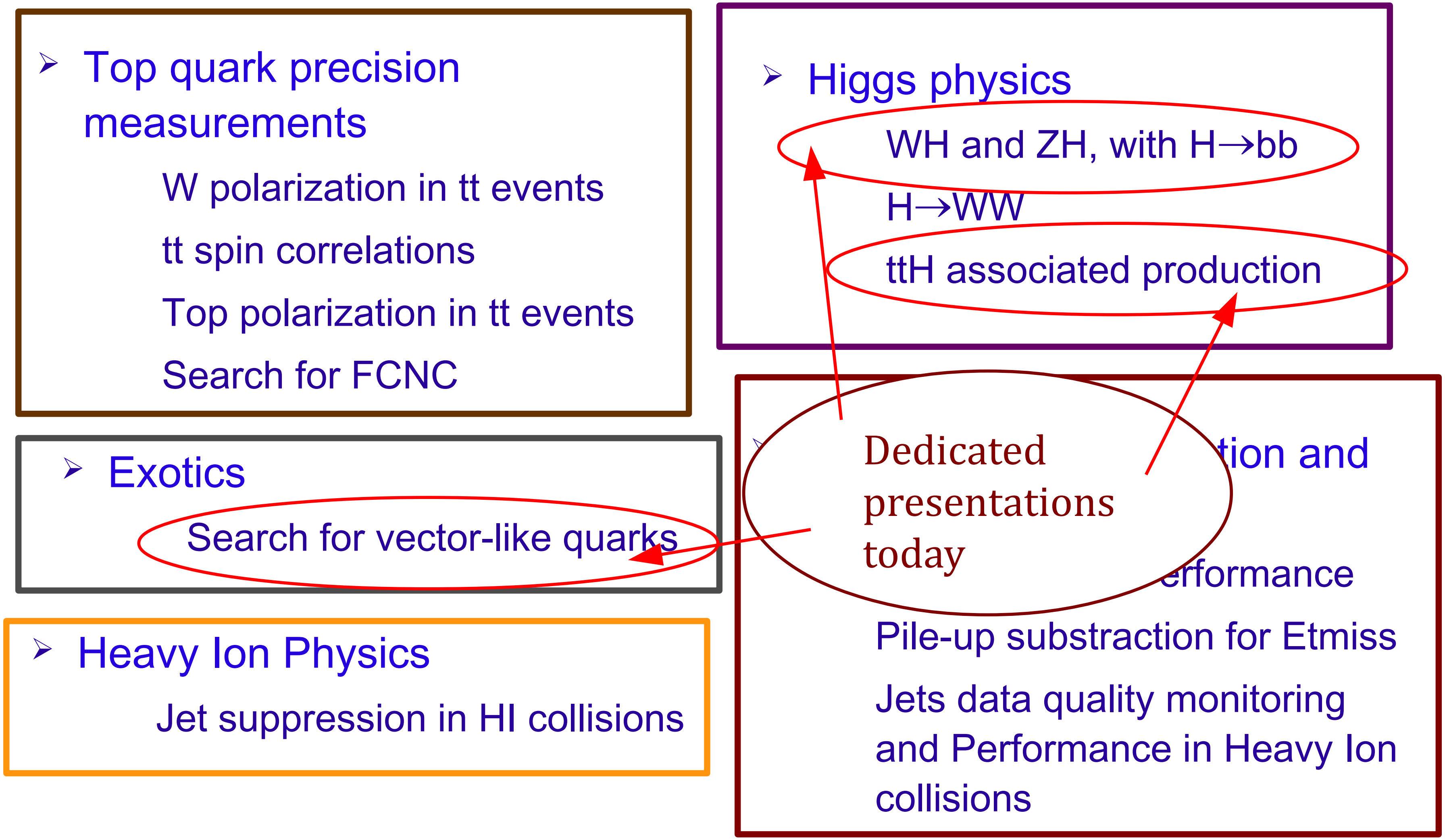
- Higgs physics
    - WH and ZH, with H→bb
    - H→WW
    - ttH associated production

- Exotics
    - Search for vector-like quarks

- Jet and Etmiss calibration and Performance
    - Jet Calibration Performance
    - Pile-up subtraction for Etmiss
    - Jets data quality monitoring and Performance in Heavy Ion collisions

- Heavy Ion Physics
    - Jet suppression in HI collisions

Physics and Performance Studies



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  - Search for vector-like quarks

- Heavy Ion Physics
  - Jet suppression in HI collisions

Dedicated presentations today

- tion and

  erformance
  - Pile-up substraction for Etmiss
  - Jets data quality monitoring and Performance in Heavy Ion collisions

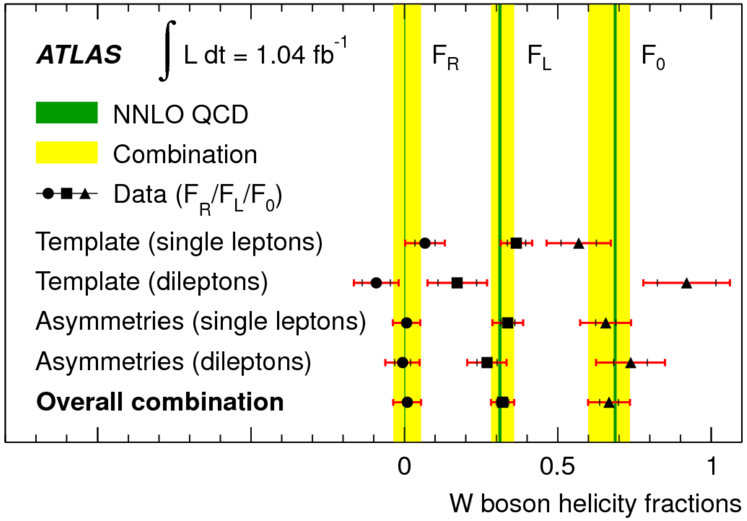
Top quark physics

- W polarization in tt events

  Reflects the V-A Wtb vertex

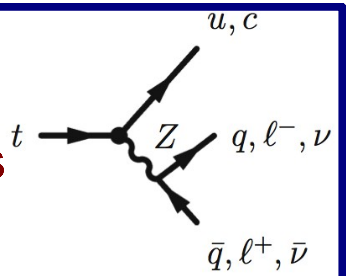
  Sensitive to BSM physics

- Measure angular distribution of ℓ^+ in the W rest frame

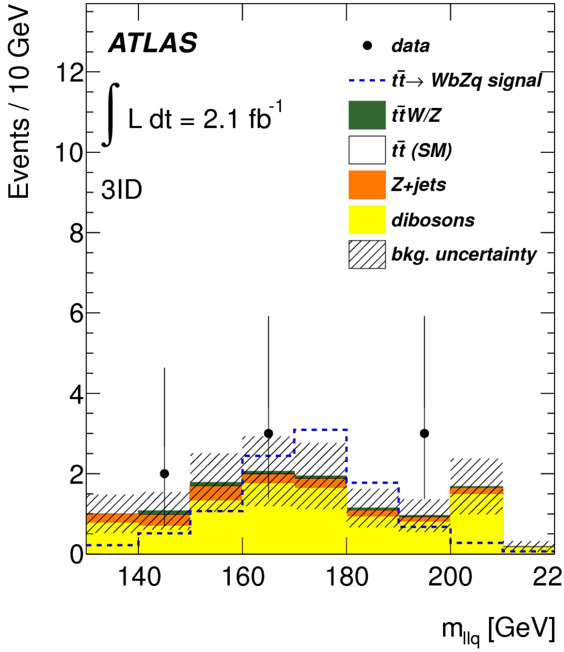


- Search for FCNC in top quark decays

  95% C.L. Limit:



$$\mathrm{BR}(t \to qZ) < 0.73\%$$

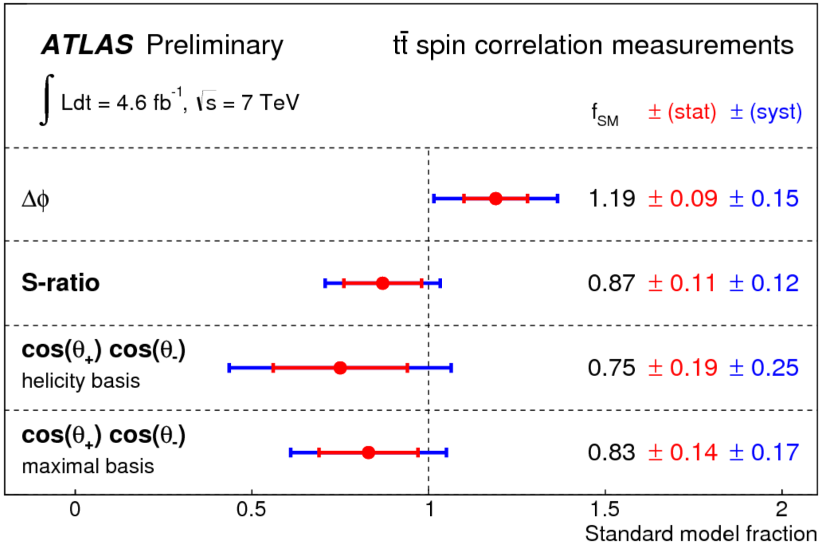


Top quark physics

- tt spin correlations

  Test precise predictions of tt production & decays

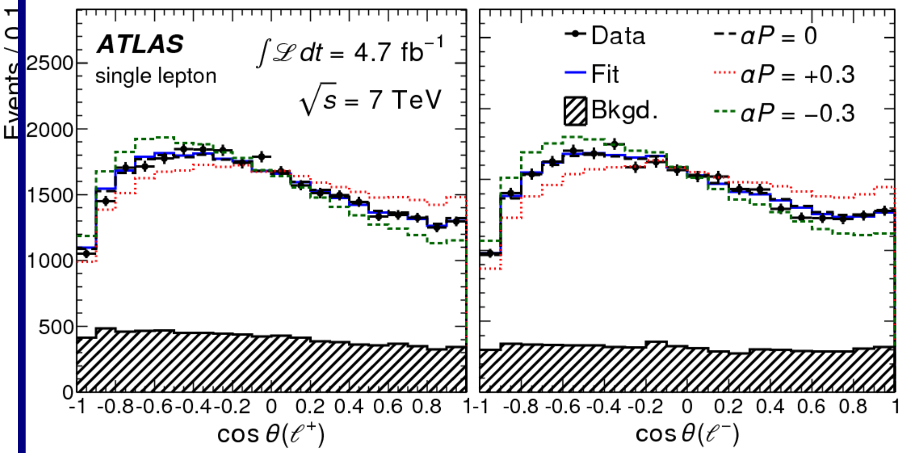
$$A = \frac{N(\uparrow\uparrow)+N(\downarrow\downarrow)-N(\uparrow\downarrow)-N(\downarrow\uparrow)}{N(\uparrow\uparrow)+N(\downarrow\downarrow)+N(\uparrow\downarrow)+N(\downarrow\uparrow)}$$



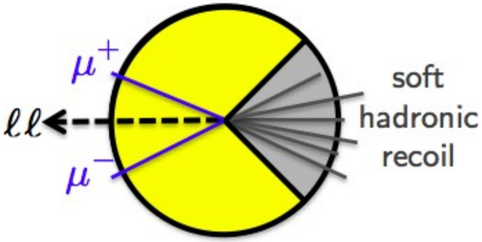
- Top quark polarization in tt events

  QCD parity conservation + unpolarized initial state ⇒top quark unpolarized

  Study polar angle of leptons in top quark's rest frame



H→WW→ℓνℓν analysis



$$f_{\mathrm{recoil}} = \frac{\left|\sum |\mathrm{JVF}| \times \vec{p_T}\right|}{p_T^{\ell\ell}}$$

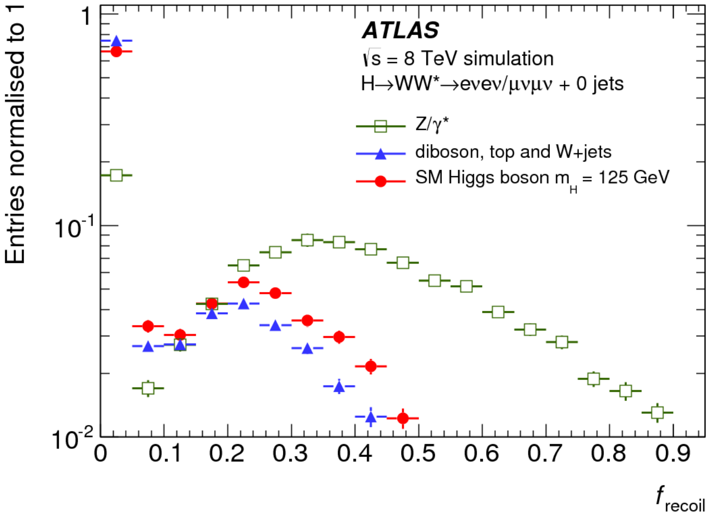
- Same flavour channel

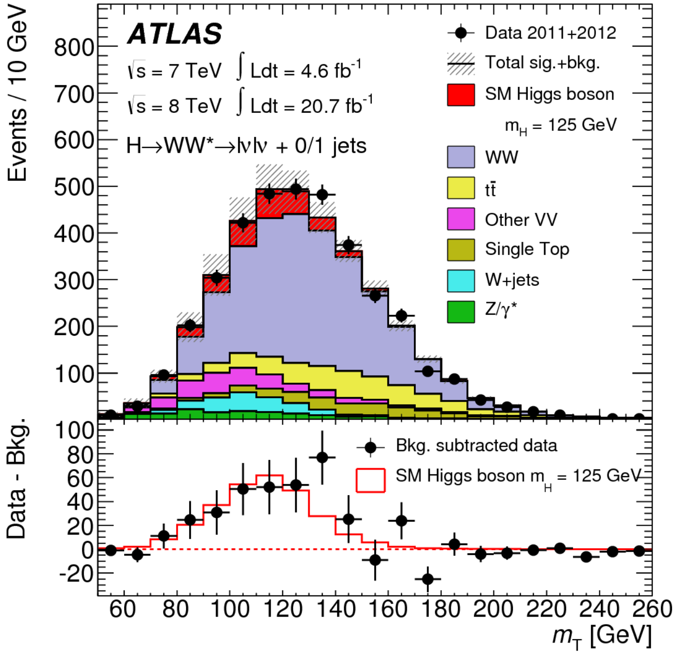
  Improved Z/Drell-Yan background rejection!

  This channel contributes with additional 5-10% significance

- Signal strength: μ = 0.99 $^{+0.31}_{-0.28}$

  compatible with SM expectations

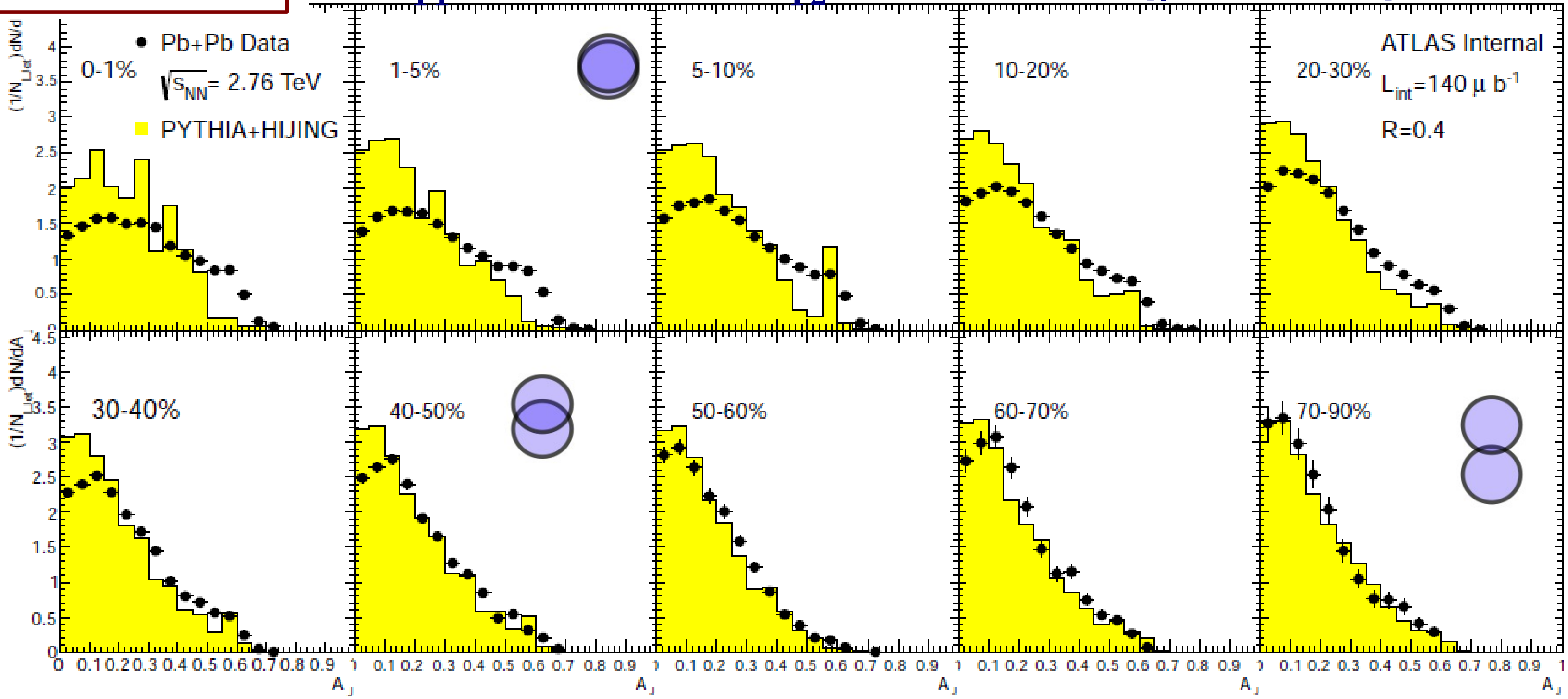




Jet suppression in Heavy Ion Collisions

$$A_J = \frac{E_{T_1} - E_{T_2}}{E_{T_1} + E_{T_2}}$$

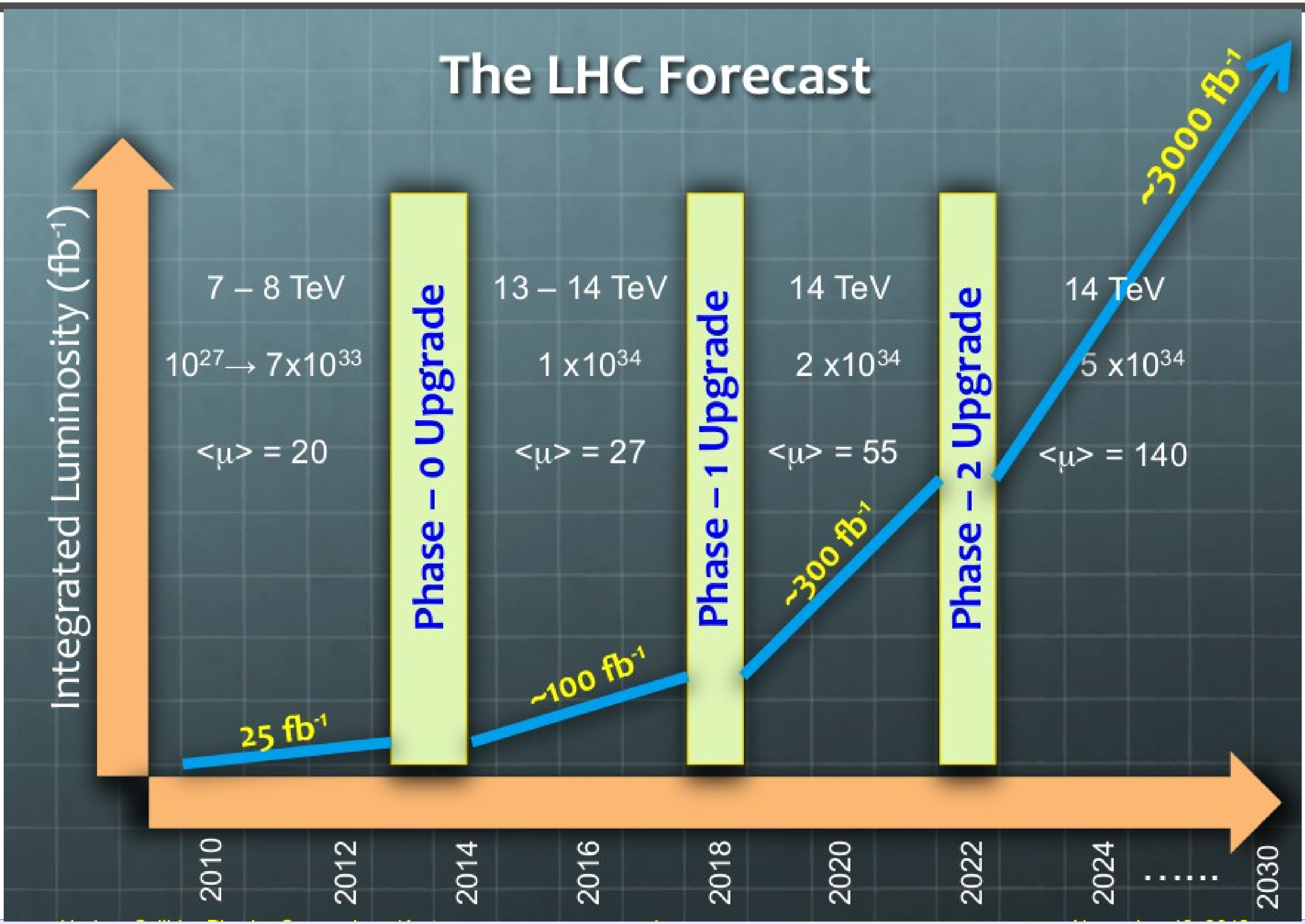
- $E_{T1} > 100$ GeV; $E_{T2} > 25$ GeV; $|\eta| \leq 2.1$; $\Delta\varphi > 2.2$ rad



Other activities:

- Preparation of jet trigger menu of the p+Pb run and jet trigger performance
- Development of the jet data quality monitoring in the Pb+Pb and p+Pb runs;
- Offline jet reconstruction in Pb+Pb, p+Pb and p+p (@2.76 TeV) collisions;
- b-tagging in Pb+Pb collisions.

LHC Upgrade Schedule



ATLAS Detector Upgrades

LS1 ↠ PHASE 0
$\mathscr{L} = 10^{34} \mathrm{cm}^{-2}\mathrm{s}^{-1}$ $<\mu>=24$
100 fb^{-1} (2014-2017)

- 4th Pixel Detector Layer (IBL)
- Pixel Detector improvements
- Topological L1 triggers
- Silicon tracker cooling system replacement
- Muon Endcap Extension chambers completion

🇵🇹

- Tile laser system
- Tile D in L1 muon trigger
- Tile DCS

LS2 ↠ PHASE 1
$\mathscr{L} = 2\mathrm{x}10^{34} \mathrm{cm}^{-2}\mathrm{s}^{-1}$ $<\mu>=50$
350 fb^{-1} (2019-2021)

- New Muon Small Wheel detector
- Upgrade of the central L1 trigger processor
- L1 Calo granularity increase

🇵🇹

- AFP detector
- HLT jet trigger
- Tile gap/crack scintillators
- Tile DCS

LS3 ↠ PHASE 2
$\mathscr{L} = 5\mathrm{x}10^{34} \mathrm{cm}^{-2}\mathrm{s}^{-1}$ $<\mu>=140$
3000 fb^{-1} (2023-2030)

- New “All Silicon” tracker
- L0-L1 trigger separation
- Track info at L1
- Upgrade of the calorimeter readout
- Upgrade of the muon spectrometer

🇵🇹

- Tile HV distributor system
- Tile DCS

The SM is incomplete

96% of the universe dominated by dark matter/energy ?

- What are they?

SUSY?

- Why is the universe dominated by matter? ?

Compositeness?

- Why is the Higgs mass so low? ?

Tecnicolor?

Hidden sector?

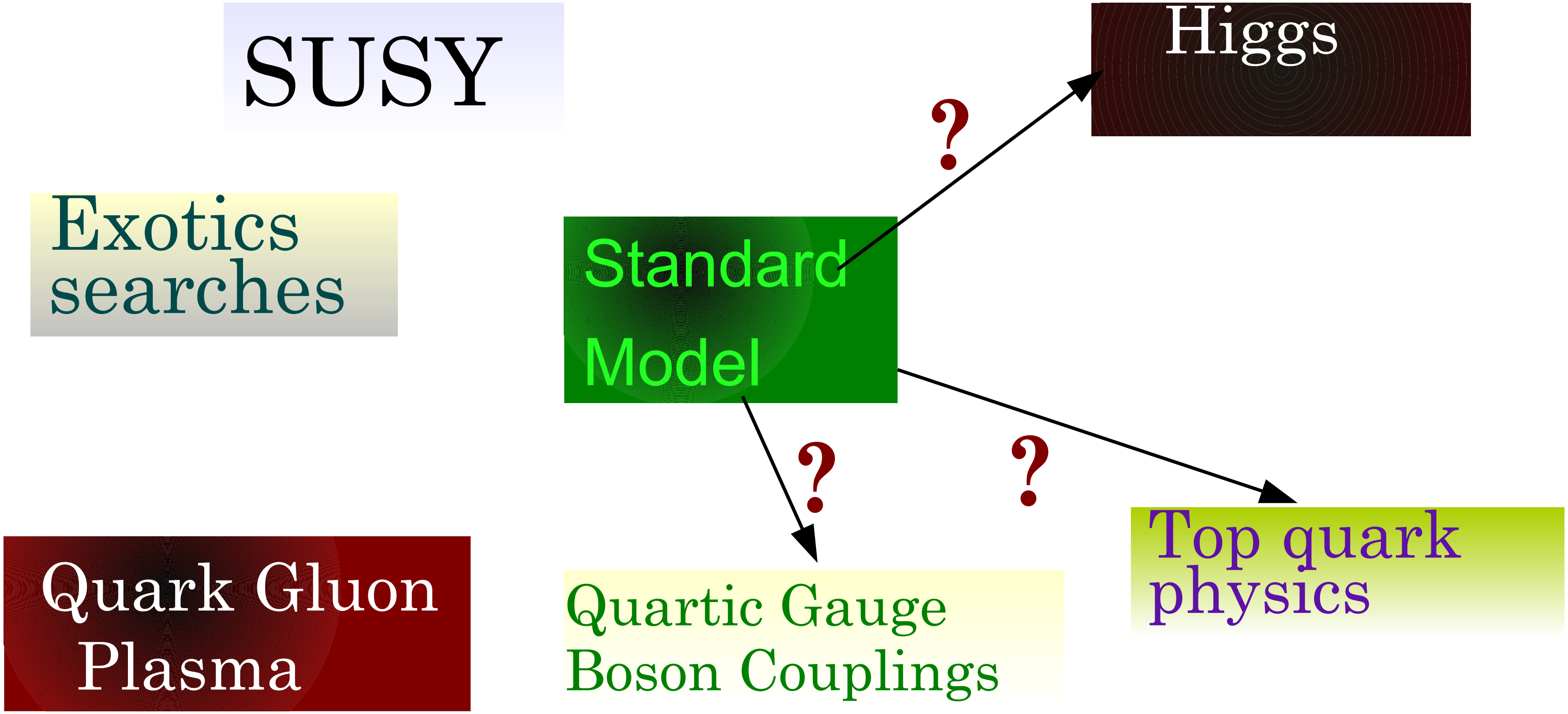
Extra-dimensions?

- Neutrino masses? ?

Extended Higgs sector?

- Why is gravity so weak? ?

Some of the Upgrade Physics Topics



SUSY

Exotics searches

Standard Model

Higgs

?

?

?

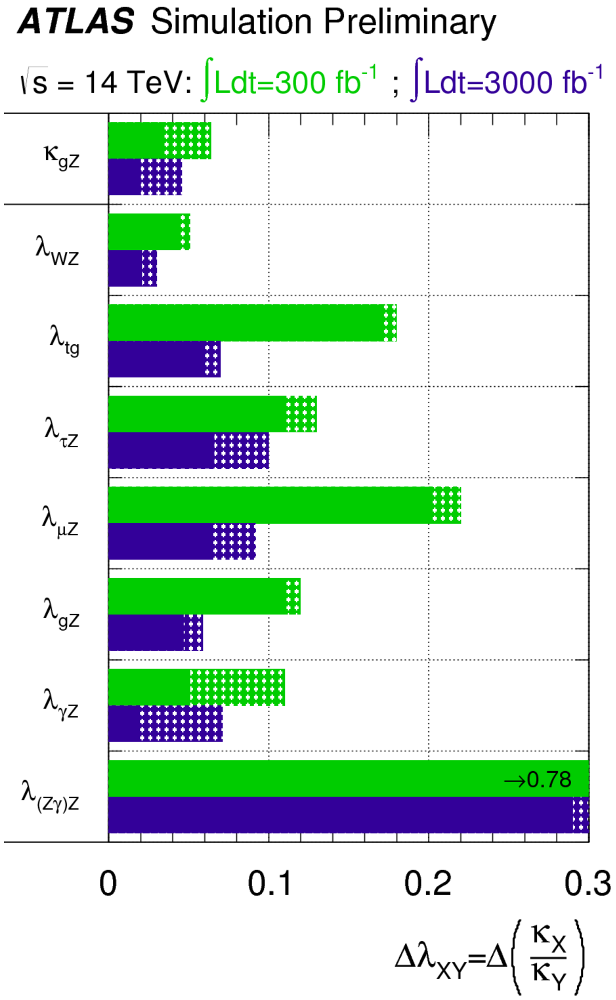
Top quark physics

Quartic Gauge Boson Couplings

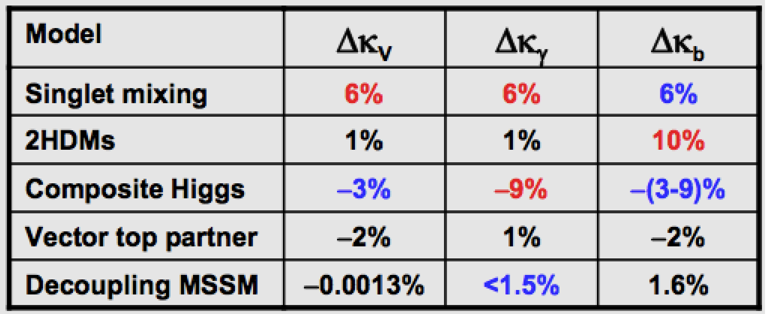
Quark Gluon Plasma

Examples of HL-LHC expectations

- Higgs couplings

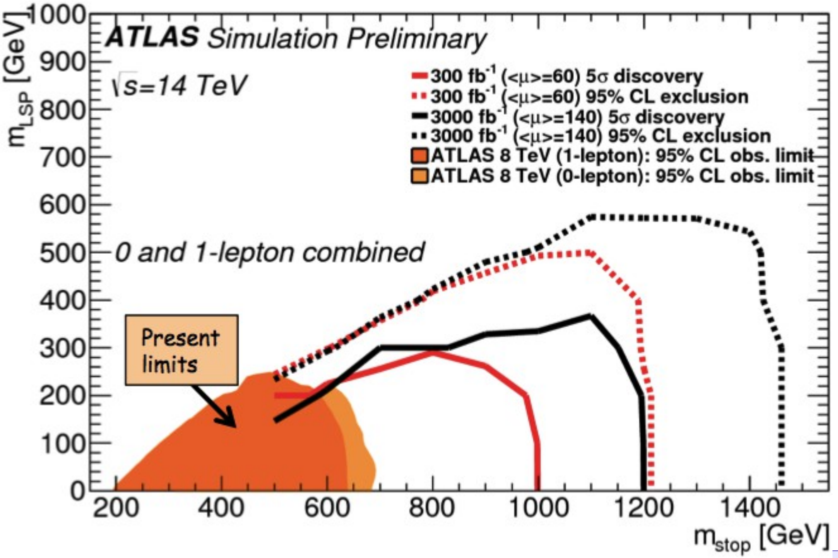


Snowmass 2013

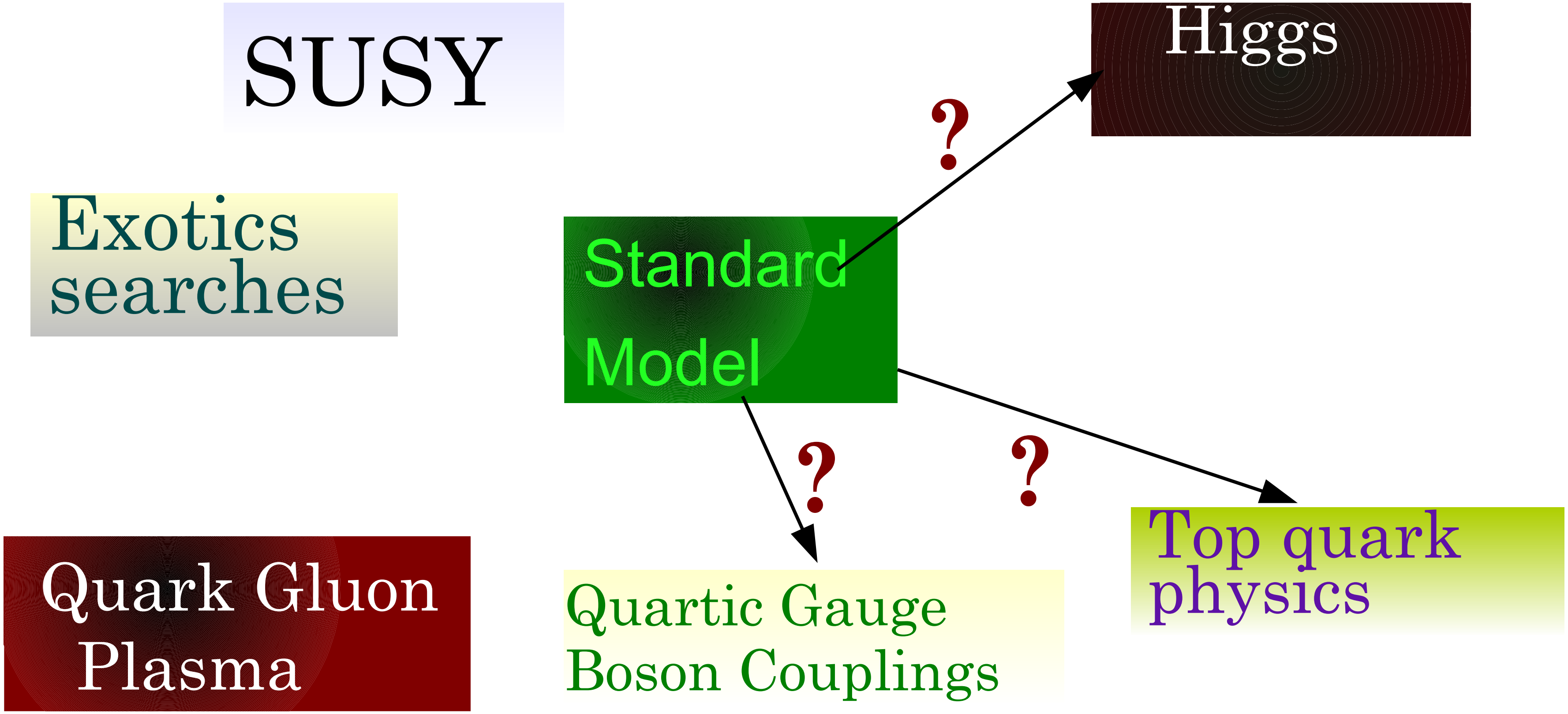


Model	$\Delta\kappa_V$	$\Delta\kappa_\gamma$	$\Delta\kappa_b$
Singlet mixing	6%	6%	6%
2HDMs	1%	1%	10%
Composite Higgs	–3%	–9%	–(3-9)%
Vector top partner	–2%	1%	–2%
Decoupling MSSM	–0.0013%	<1.5%	1.6%

- SUSY searches



Some of the Upgrade Physics Topics



SUSY

Higgs

Exotics searches

Standard Model

?

?

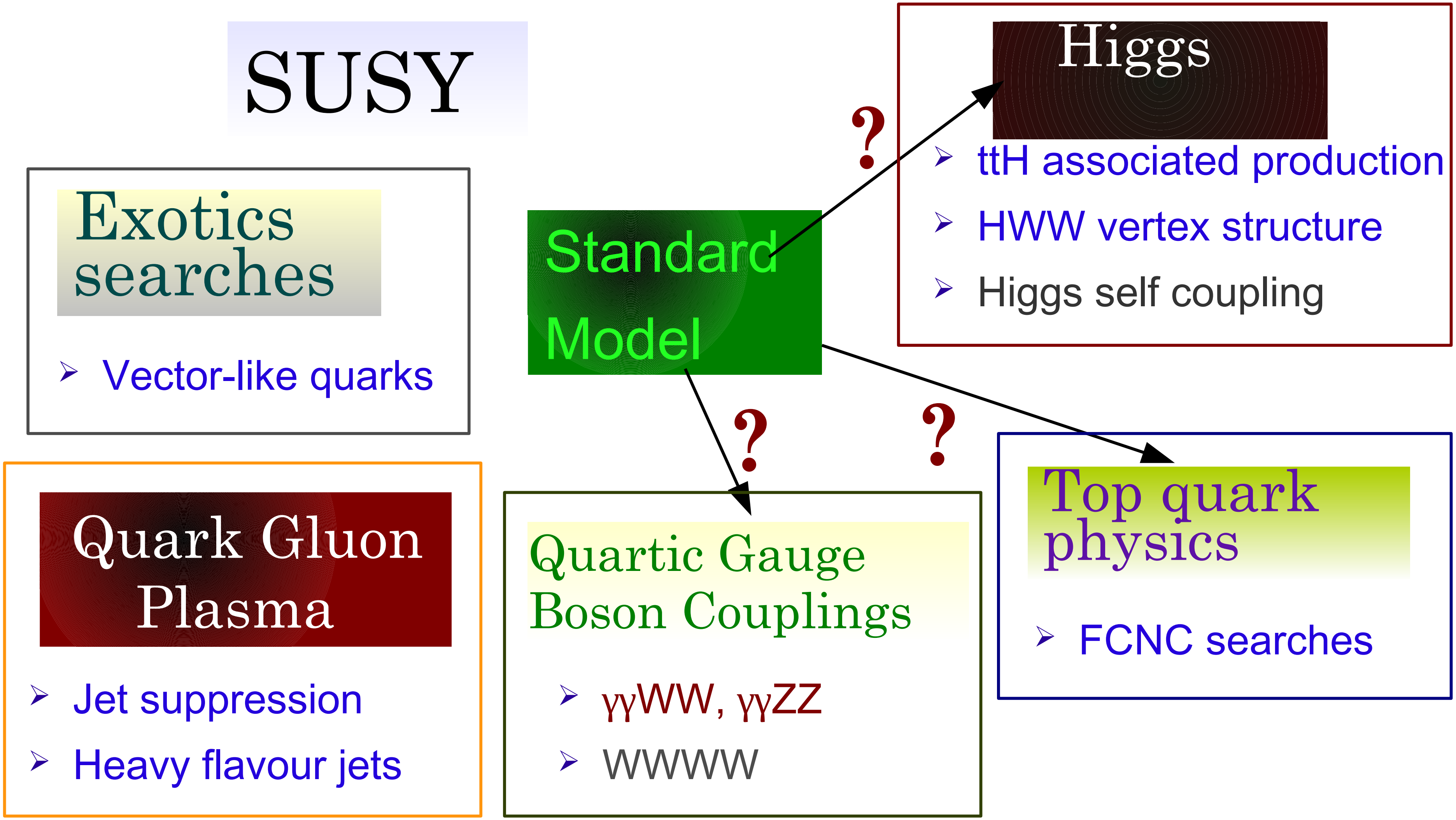
?

Top quark physics

Quark Gluon Plasma

Quartic Gauge Boson Couplings

Some of the Upgrade Physics Topics



SUSY

Exotics searches

- Vector-like quarks

Standard Model

Higgs

- ttH associated production
- HWW vertex structure
- Higgs self coupling

Quark Gluon Plasma

- Jet suppression
- Heavy flavour jets

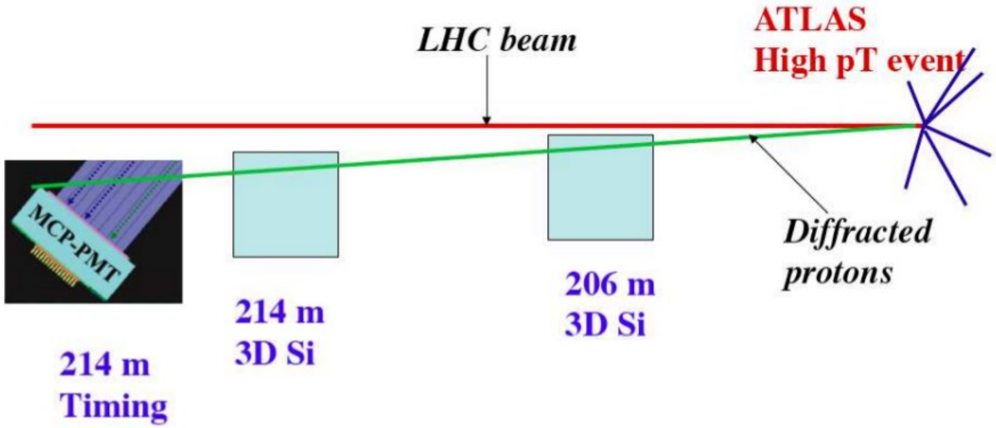
Quartic Gauge Boson Couplings

- γγWW, γγZZ
- WWWW

Top quark physics

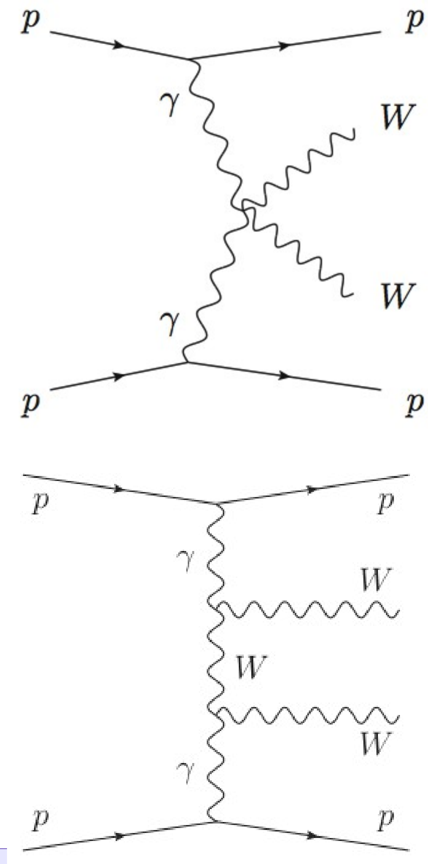
- FCNC searches

Quartic Gauge Boson Couplings & AFP



- QGBC introduced in the SM due to the non abelian nature of the EW symmetry
- Very precise predictions:
  - WWWW, γγWW, WWZZ exist
  - ZZZZ, γγZZ: only at loop level
- Might be modified by BSM physics!

- Forward proton tagging converts the LHC in a γγ collider!



Summary and Conclusions

- ATLAS experiment
  - Finalizing the Run I Physics Studies
  - Preparing for the new run and the detector Upgrades to exploit the HL-LHC era
- Portuguese ATLAS team contributes to
  - Detector M&O
  - Physics studies
    - Top quark precision measurements
    - Higgs Physics
    - Exotic searches
    - Heavy Ions
  - Detector Upgrade
- And we are prepared to exploit the physics capabilities of the HL-LHC

Ongoing PhD Thesis

- $H \rightarrow WW \rightarrow \ell\nu\ell\nu$ searches (J. Miguéns)
- Search for $H \rightarrow bb$ in WH associated production channel (A. Palma)
- ttH searches (S. Santos)
- Search for FCNC in top quark decays (Bruno Galhardo)
- Search for vector-like quarks (Juan Pedro Araque)
- Search for Hbb in the ZH associated production channel (M. Sousa)
- Search for Hbb with MVA techniques (R. Pedro)
- Development of boosted jet triggers for Higgs searches (A. Delgado)

Backup

Heavy Ion Physics for the Upgrade

- Run II: 5-10 times higher stats!

  Pb-Pb ~1nb^{-1} @ $\sqrt{s_{NN}}$ ~ 5.1 TeV, p-Pb, pp reference at 5.1 TeV

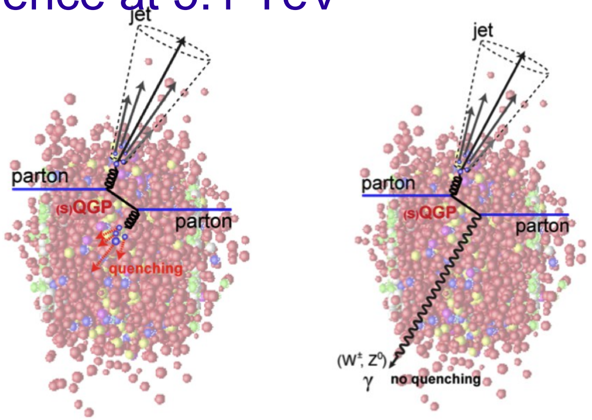
- Run III, IV: requested >10 nb^{-1} Pb-Pb

  p-Pb, pp, possibly light ions (e.g. Ar-Ar)

- Focus on rare probes:

  Coupling with QGP medium

  medium-modified hadronization process



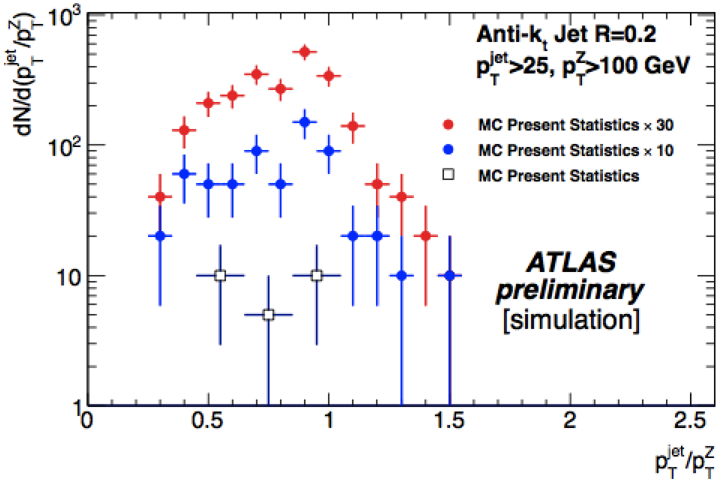
- Jets: characterization of energy loss

  testing ground for the multi-particle aspects of QCD

  probe of the medium density

- Heavy flavour:

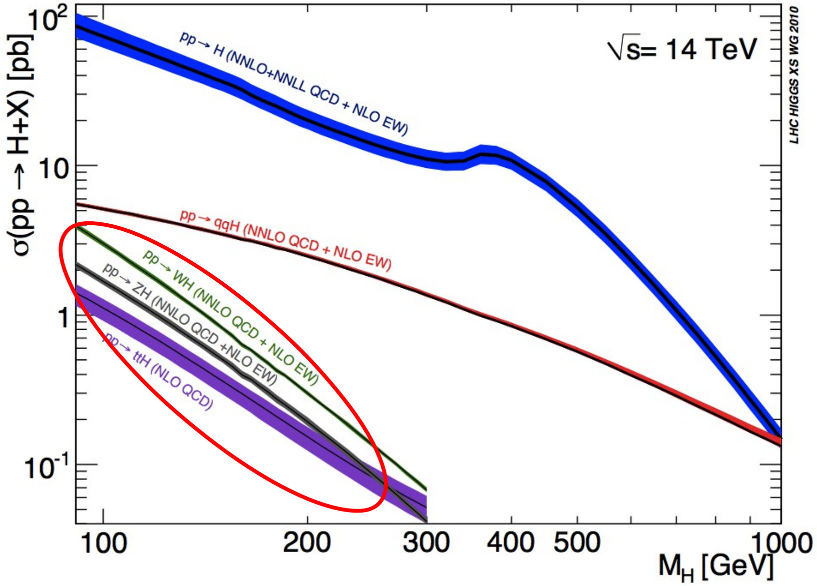
  mass dependence of energy loss



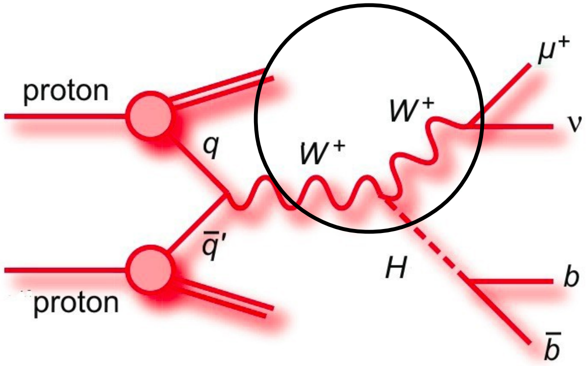
Higgs physics for the upgrade

In the absence of direct evidence for new physics, the Higgs will be

- Fundamental to test the validity of the SM!
- Probe of new physics
- Rare decay & production modes
  - Probe Yukawa couplings to quarks

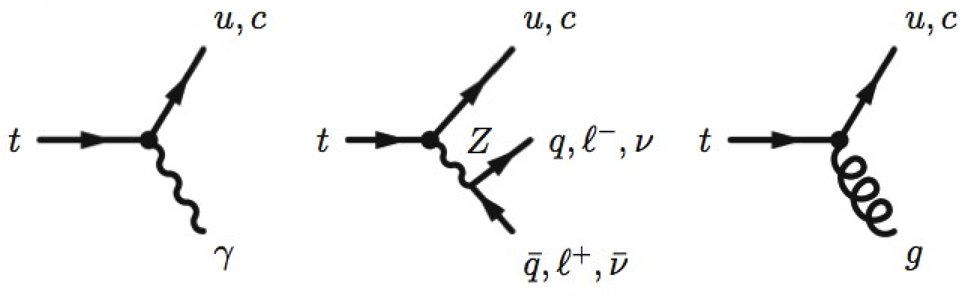


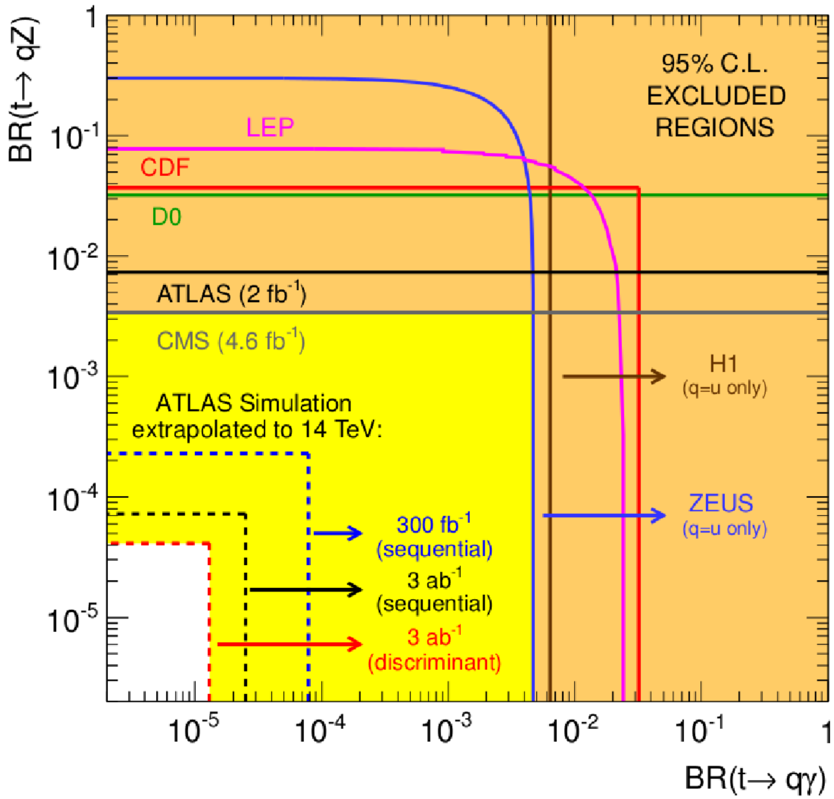
- Study tensor structure of the HWW vertex in the associated production channel



- Sensitive to
  - Beyond SM contributions
  - CP violation

FCNC in top quark decays



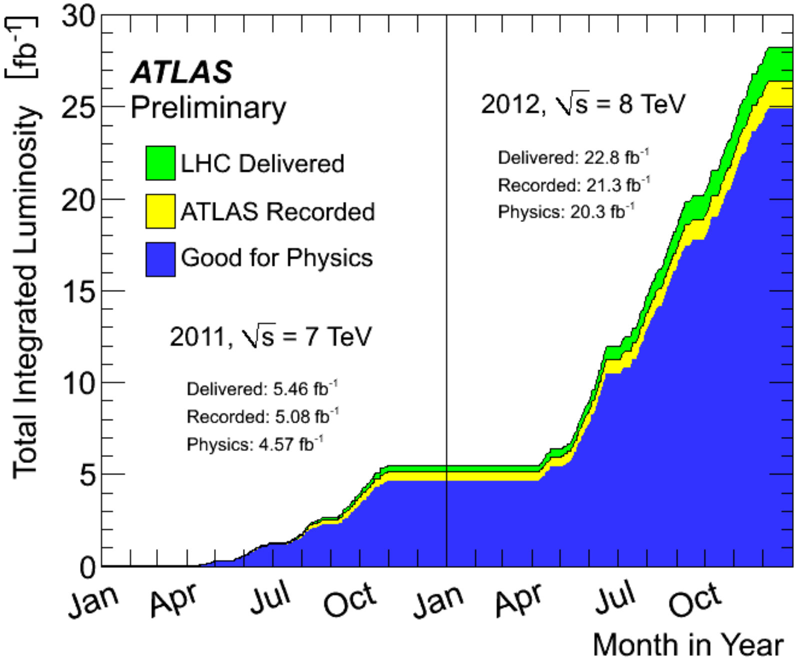


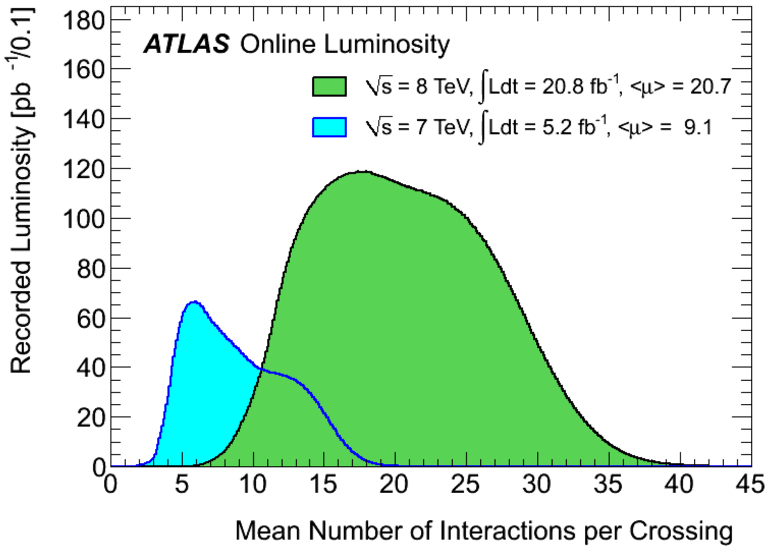
- FCNC branching ratios ~10^{-12}, 10^{-14} in the SM
- But much larger in BSM models:

  10^{-4}-10^{-9}

- With 300 fb^{-1} ATLAS will improve the sensitivity to FCNC in top quark decays by ~ two orders of magnitude
- With 3000 fb^{-1} limits in the BR can reach ~10^{-5}-5×10^{-5}

Data taking during LHC Run I





- pp collisions recorded at ATLAS

  21.3 fb^{-1} @ 8 TeV

  5.08 fb^{-1} @ 7 TeV

- ~95% physics quality data!

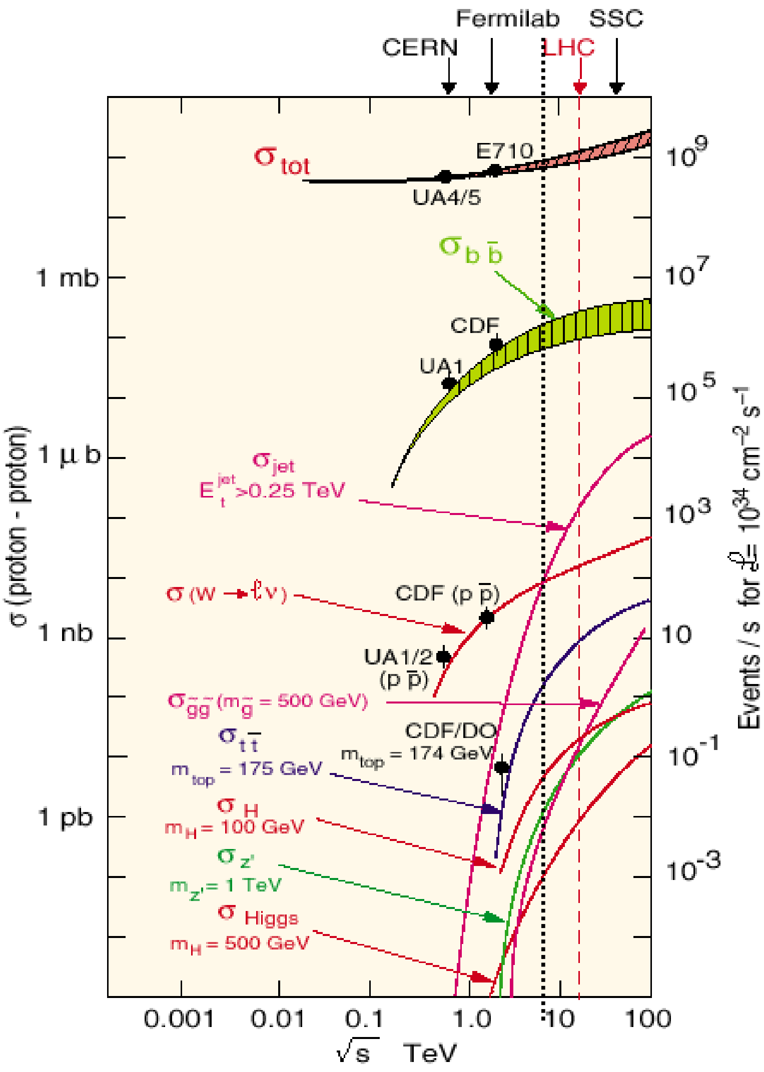
- In addition:

  150 μb^{-1} of Pb-Pb collisions

  @ 2.76 TeV

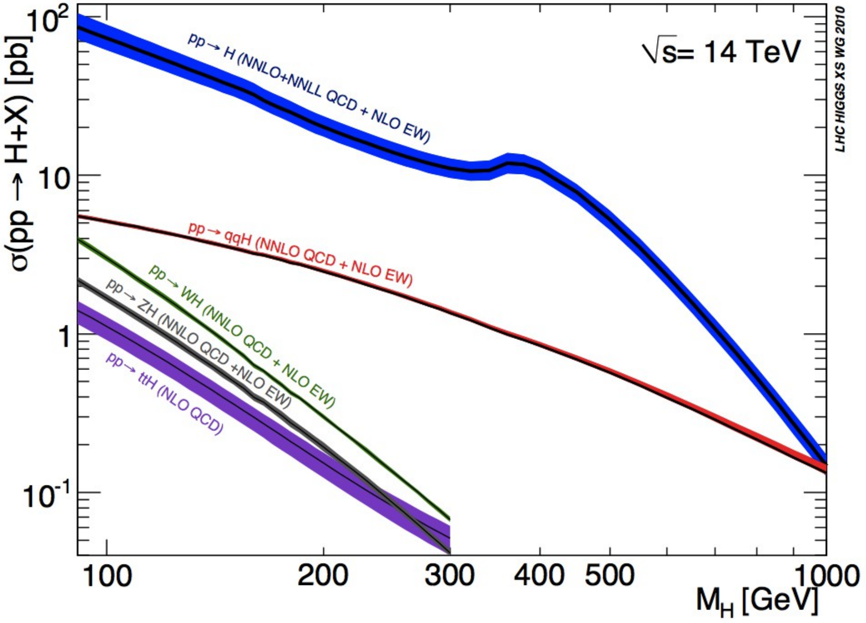
  30 nb^{-1} of p-Pb collisions

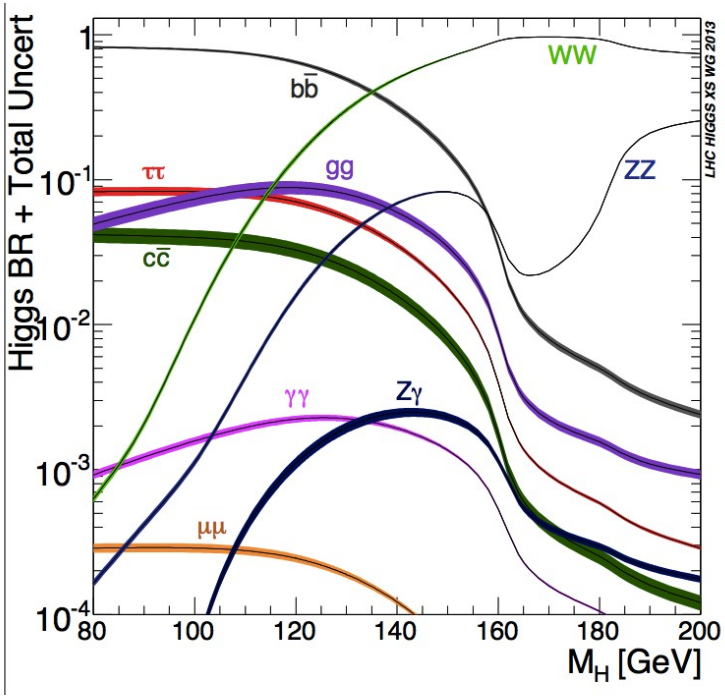
Physics at $\sqrt{s}$=14 TeV



- Moving from 8 TeV to 14 TeV the cross sections of the following processes increase by
    - Top quark production ~ a factor 4
    - Low mass Higgs boson ~ factor 3
    - Exotic heavy particles, like Z', up to a factor 10
- Background processes, like W/Z boson production or jet cross sections increase more slowly
- The sensitivity improves considerably!

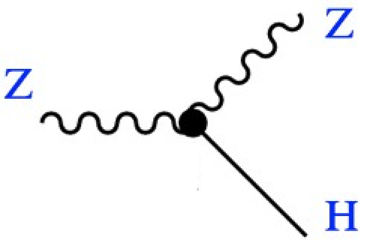
Higgs @ 14 TeV





- With more data
  - Rare decays
  - Rare production mechanisms

} Become accessible



H→ZZ vertex tensor structure

- Generic Higgs coupling vertex to a vector boson

$$A(X \to VV) = v^{-1} \Big(g_1^{(0)} m_V^2 \epsilon_1^* \epsilon_2^* + g_2^{(0)} f^{*(1)}_{\mu\nu} f^{*(2),\mu\nu} + g_3^{(0)} f^{*(1),\mu\nu} f^{*(2)}_{\mu\alpha} \frac{q_\nu q^\alpha}{\Lambda^2} + g_4^{(0)} f^{*(1)}_{\mu\nu} \tilde{f}^{*(2),\mu\nu} \Big)$$

CP-Even tree level component

CP-Even loop induced

CP-Odd contributions

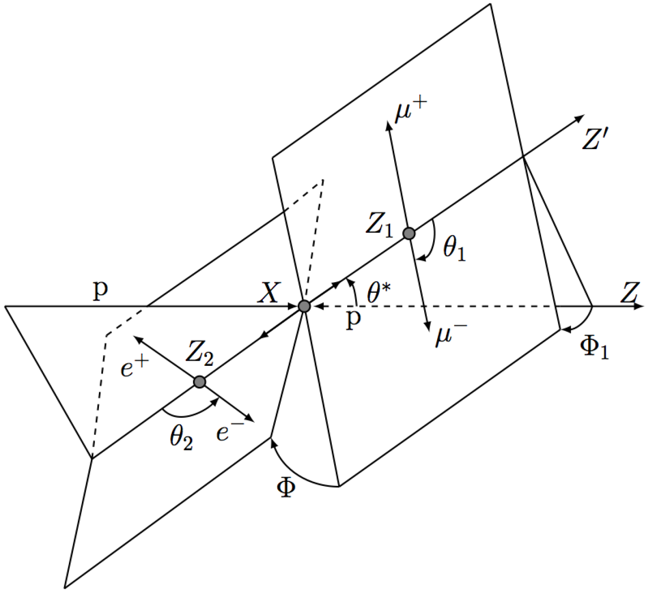
- CP-conserving tree level SM:

  g1=1, g2=g3 = g4 = 0

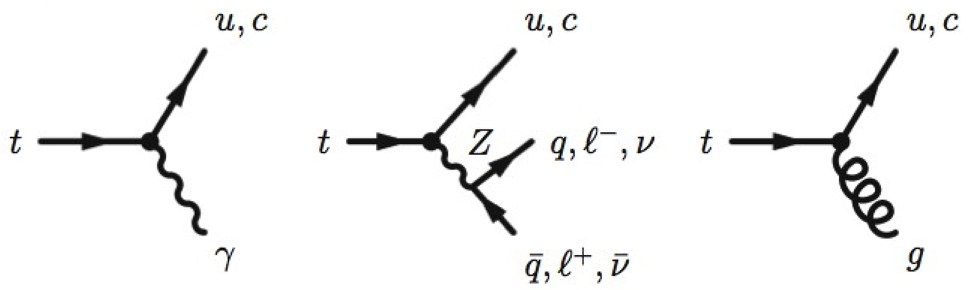
- CP violation in the Higgs sector:

  g4≠ 0, either g1 or g2, g3 ≠0

- Sensitivity to new vertex contributions through angular distributions of the Higgs decay products



FCNC in top quark decays



BR($t \rightarrow$ FCNC) in several models:

	SM	QS	2HDM	FC 2HDM	MSSM	$\not{R}$ SUSY	TC2	RS
$t \rightarrow q\gamma$	$\sim 10^{-14}$	$\sim 10^{-9}$	$\sim 10^{-6}$	$\sim 10^{-9}$	$\sim 10^{-6}$	$\sim 10^{-6}$	$\sim 10^{-6}$	$\sim 10^{-9}$
$t \rightarrow qZ$	$\sim 10^{-14}$	$\sim 10^{-4}$	$\sim 10^{-7}$	$\sim 10^{-10}$	$\sim 10^{-6}$	$\sim 10^{-5}$	$\sim 10^{-4}$	$\sim 10^{-5}$
$t \rightarrow qg$	$\sim 10^{-12}$	$\sim 10^{-7}$	$\sim 10^{-4}$	$\sim 10^{-8}$	$\sim 10^{-5}$	$\sim 10^{-4}$	$\sim 10^{-4}$	$\sim 10^{-9}$

Acta Phys. Polon. B35 (2004) 2695–2710; Phys. Rev. D68 (2003) 015002; Phys. Rev. D 75 (2007) 015002

present experimental limits:

	LEP	HERA	Tevatron	LHC
BR($t \rightarrow q\gamma$)	2.4%	0.47 %	3.2 %	—
BR($t \rightarrow qZ$)	7.8%	30%	3.2 %	0.05%
			2.0×10^{-4} (tug)	5.7×10^{-5} (tug)
BR($t \rightarrow qg$)	17%	13%	3.9×10^{-3} (tcg)	2.7×10^{-4} (tcg)

Quartic Gauge Boson Couplings

- $L_{WEAK} = -1/4F^{(a)}_{\mu\nu}F^{(a)\mu\nu} + i\bar{\Psi}_L(\gamma^\mu(D_\mu) - m)\Psi_L$

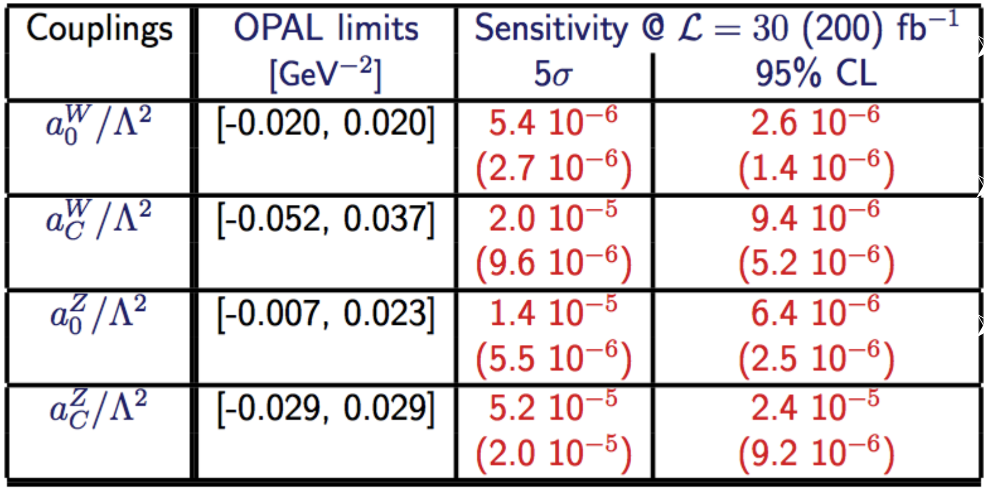
$$F^{(a)}_{\mu\nu} = \partial_\mu W^a_\nu - \partial_\nu W^a_\mu - g_s\varepsilon_{abc}W^b_\mu W^c_\nu$$

Gives rise to triple & quartic gauge boson couplings

- Very precise predictions:
  - WWWW, γγWW, WWZZ exist
  - ZZZZ, γγZZ: only at loop level

Might be modified by BSM physics!

- Best limits in γγWW, γγZZ obtained at ATLAS with the AFP detector



Couplings	OPAL limits $[\text{GeV}^{-2}]$	Sensitivity @ $\mathcal{L} = 30$ (200) fb^{-1} 5σ	95% CL
a_0^W/Λ^2	[-0.020, 0.020]	$5.4\ 10^{-6}$ $(2.7\ 10^{-6})$	$2.6\ 10^{-6}$ $(1.4\ 10^{-6})$
a_C^W/Λ^2	[-0.052, 0.037]	$2.0\ 10^{-5}$ $(9.6\ 10^{-6})$	$9.4\ 10^{-6}$ $(5.2\ 10^{-6})$
a_0^Z/Λ^2	[-0.007, 0.023]	$1.4\ 10^{-5}$ $(5.5\ 10^{-6})$	$6.4\ 10^{-6}$ $(2.5\ 10^{-6})$
a_C^Z/Λ^2	[-0.029, 0.029]	$5.2\ 10^{-5}$ $(2.0\ 10^{-5})$	$2.4\ 10^{-5}$ $(9.2\ 10^{-6})$

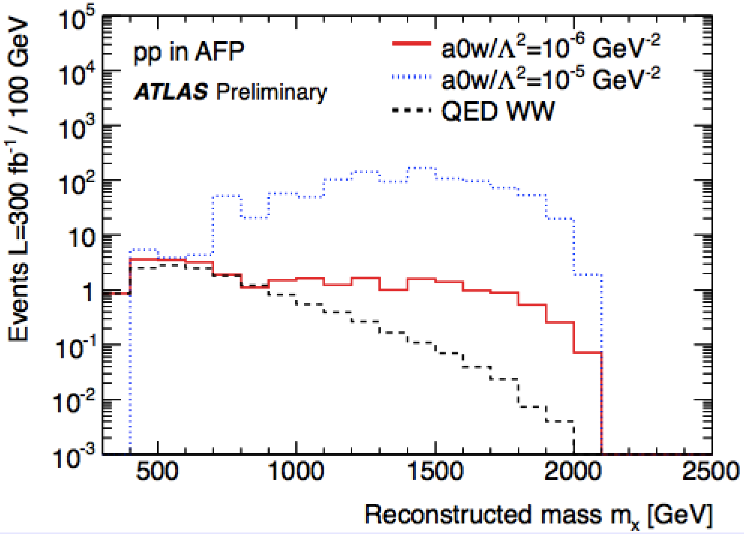
Improve D0/CDF results by ~2 orders of magnitude

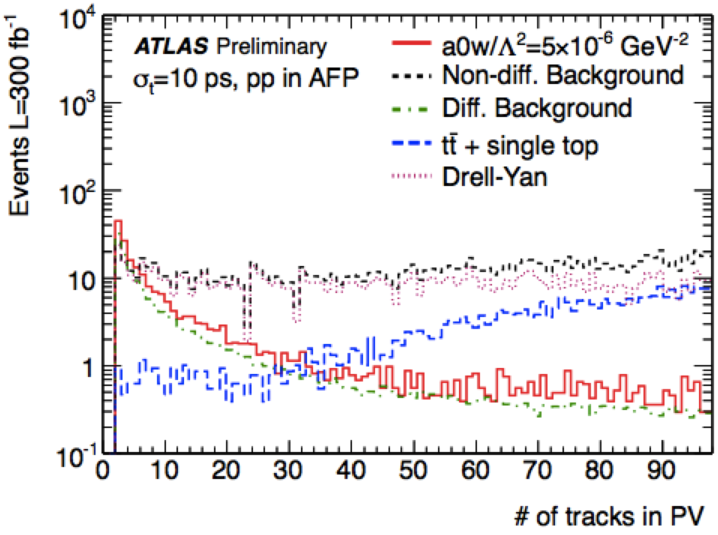
AFP improves ATLAS results by 2 orders of magnitude

Reach sensitivity to extra-dimensional models!

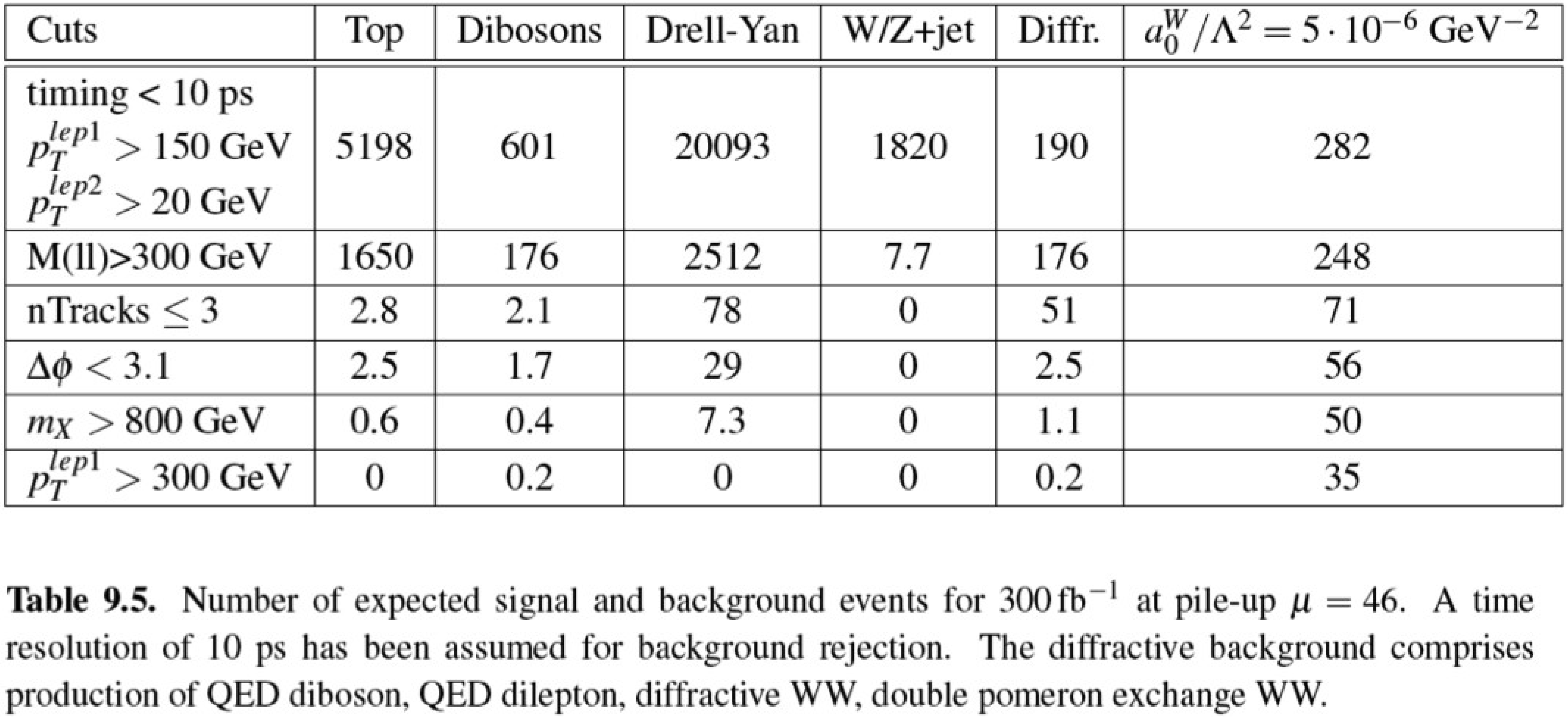
Search for γγWW anomalous couplings

- Reach on anomalous couplings studied using a full simulation of the ATLAS detector, including all pile-up effects; only leptonic decays of Ws are considered
- Signal appears at high lepton p_T and dilepton mass (central ATLAS) and high diffractive mass (reconstructed using forward detectors)
- Cut on the number of tracks fitted to the primary vertex: very efficient to remove remaining pile-up after requesting a high mass object to be produced (for signal, we have two leptons coming from the W decays and nothing else)





Selection conditions

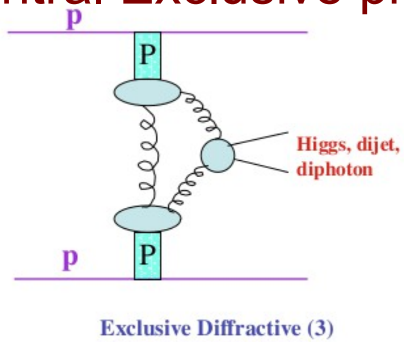


Cuts	Top	Dibosons	Drell-Yan	W/Z+jet	Diffr.	$a_0^W/\Lambda^2 = 5 \cdot 10^{-6}$ GeV^{-2}
timing < 10 ps $p_T^{lep1} > 150$ GeV $p_T^{lep2} > 20$ GeV	5198	601	20093	1820	190	282
M(ll)>300 GeV	1650	176	2512	7.7	176	248
nTracks ≤ 3	2.8	2.1	78	0	51	71
$\Delta\phi < 3.1$	2.5	1.7	29	0	2.5	56
$m_X > 800$ GeV	0.6	0.4	7.3	0	1.1	50
$p_T^{lep1} > 300$ GeV	0	0.2	0	0	0.2	35

Table 9.5. Number of expected signal and background events for 300 fb^{-1} at pile-up $\mu = 46$. A time resolution of 10 ps has been assumed for background rejection. The diffractive background comprises production of QED diboson, QED dilepton, diffractive WW, double pomeron exchange WW.

Diffractive physics with AFP

Central Exclusive production

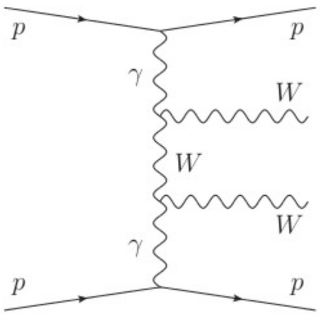


- Higgs

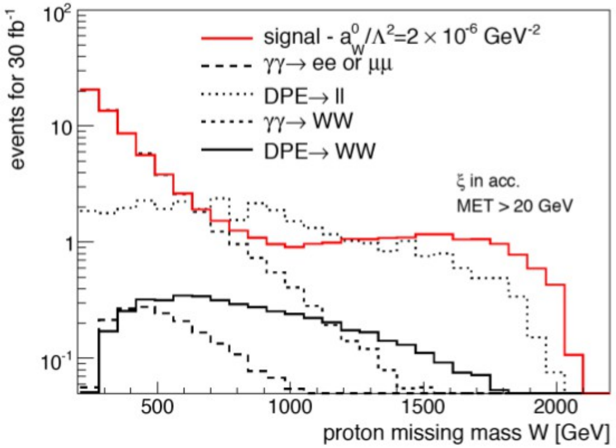
  Good mass resolution from p energy loss (~2-3%)

  Tests J^{CP} & improve b-Higgs coupling measurement
- Di-jets

  Test QCD calculations



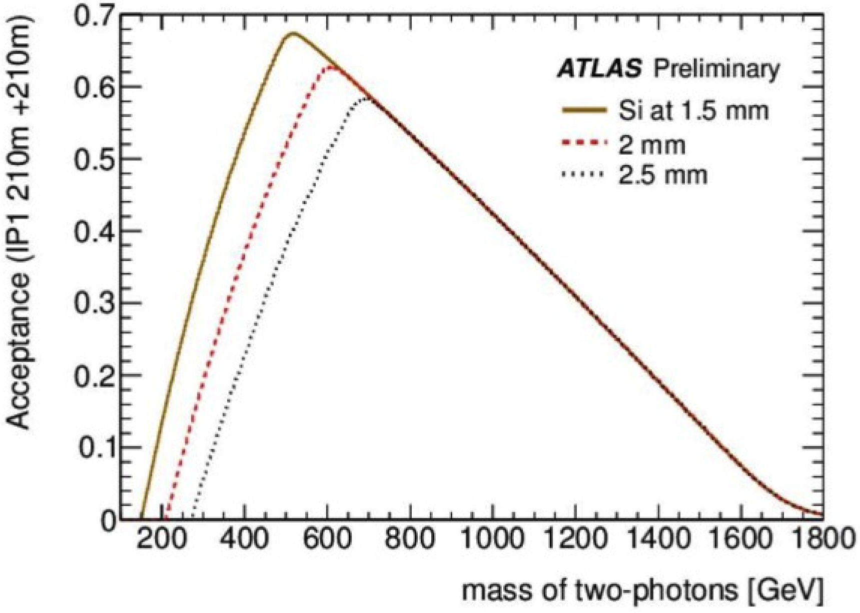
Triple and quartic anomalous gauge boson couplings

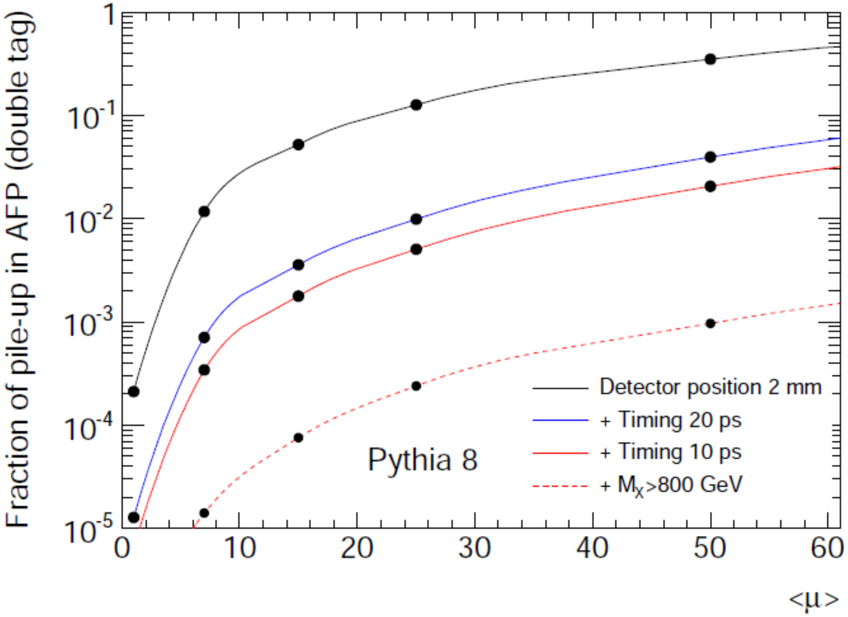


- Exclusive production of WW via photon exchange ($\sigma_{WW\to WW}$ well kno
- Diffractive mass computed from p energy loss

  Large mass tails sensitive to anomalous couplings
- Improvement of LEP sensitivity by more than 4 orders of magnitude with 30-200 fb^{-1}

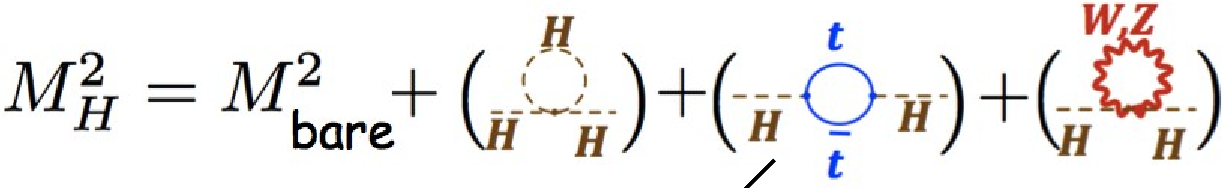
AFP background suppression and acceptance



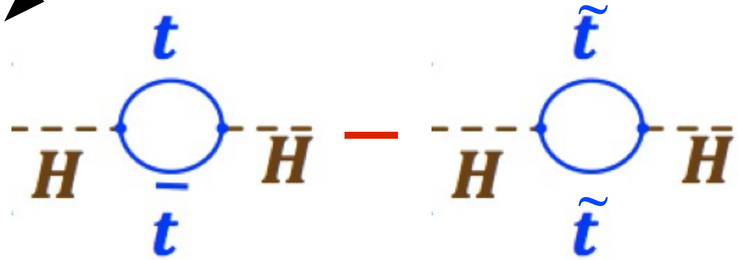


- Very good mass resolution (few %)

The stability of the Higgs mass



$\sim m_t^2\Lambda^2$



- Cancel out large terms:

  Stop → SUSY

  But... stop mass cannot be much larger than the top mass

    Avoid fine tunning!

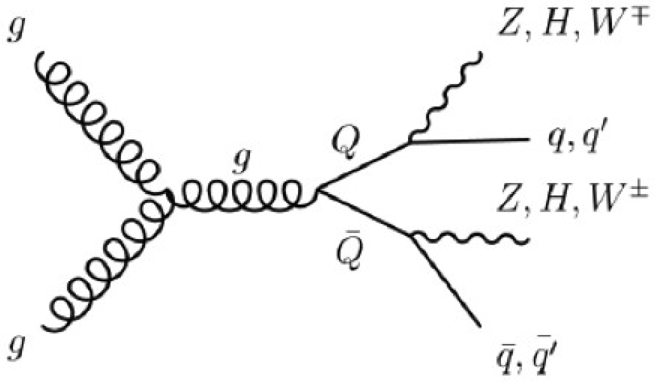
- Given the observed mass of the Higgs boson, the stop mass should not be much larger than 1-1.5 TeV

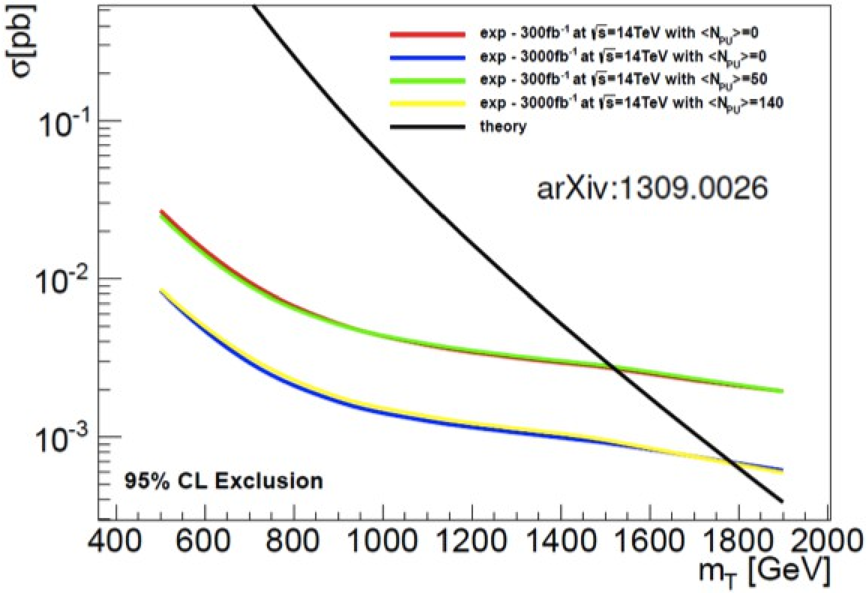
  Accessible at the LHC?

Vector-like quarks

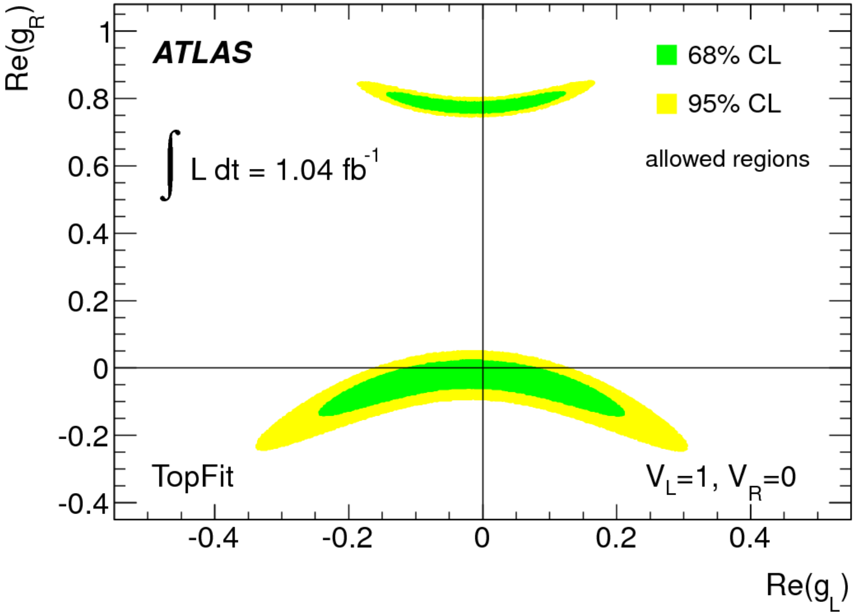
- Vector-like quarks appear in certain models to cancel Higgs mass divergencies
  - Little Higgs, extra-dimensions
- Left-handed and right-handed components transform in the same way under SU(2)

See Juanpe's presentation for current results!

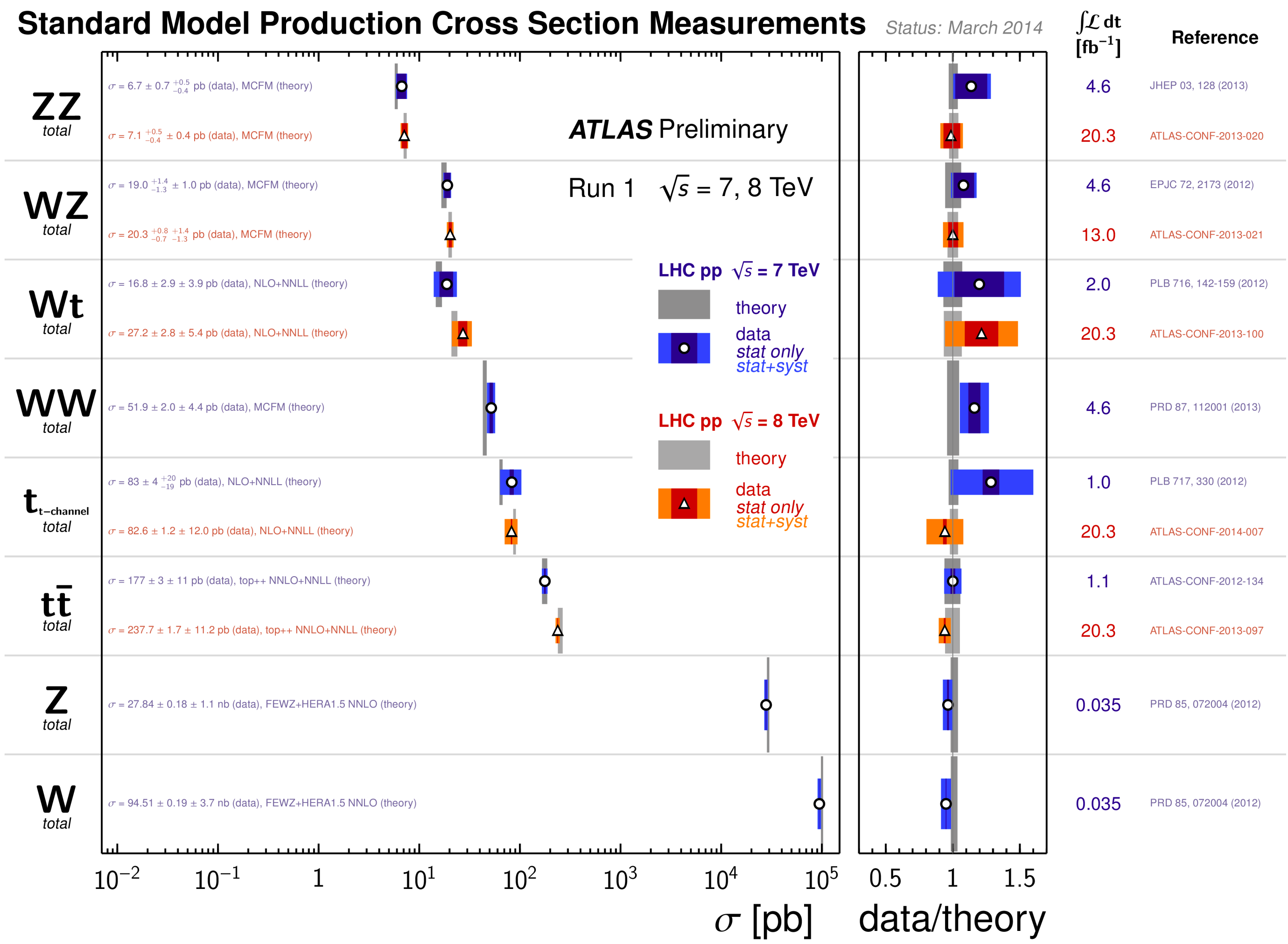




arXiv:1309.0026


ATLAS
🟩 68% CL
🟨 95% CL
allowed regions
$\int L\,dt = 1.04\ fb^{-1}$
TopFit
V_L=1, V_R=0
Re(g_R)
Re(g_L)
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.4
-0.2
0
0.2
0.4

Standard Model Physics Measurements



Standard Model Production Cross Section Measurements