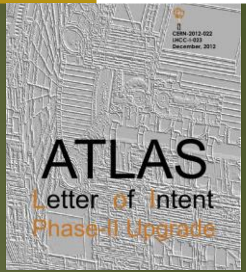
Physics prospects at HL-LHC with the ATLAS detector

Lydia ICONOMIDOU-FAYARD
LAL-Univ. Paris Sud-CNRS/IN2P3-Paris Saclay

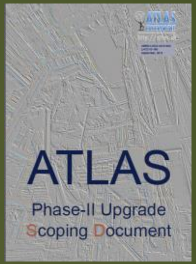
CORFU September 2017
04/09/2017

The ATLAS path to HL-LHC

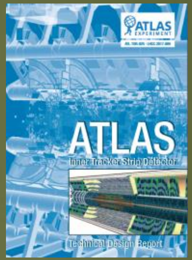
- Submission of Letter of Intent, December 2012



- Publication of Scoping Document , September 2015



- Publication of Strip-ITK TDR, April 2017



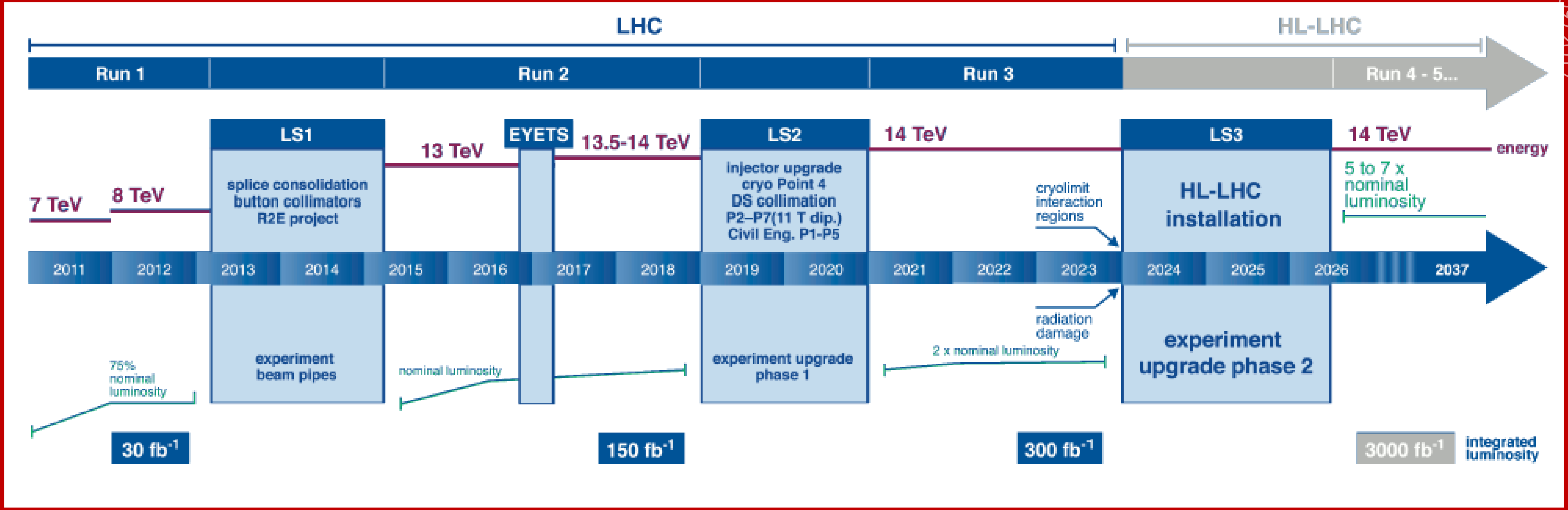
- Muon, Larg & Tile Calorimeter, TDAQ and Pixel TDRs in preparation

.. assembling detector upgrades and relevant physics prospects

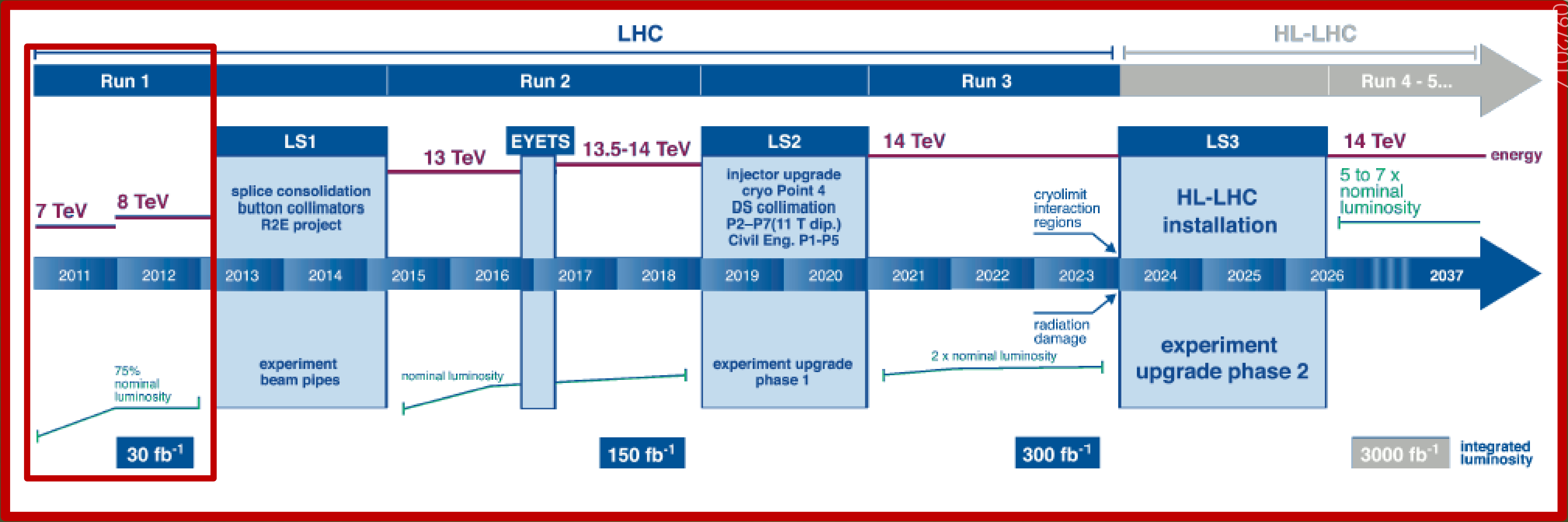
On top of many public documents on performances and physics channels

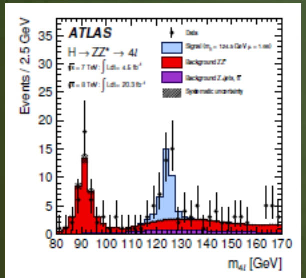
The LHC timeline

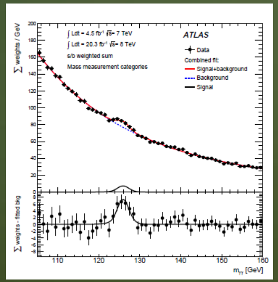
Time, Energy, Luminosity



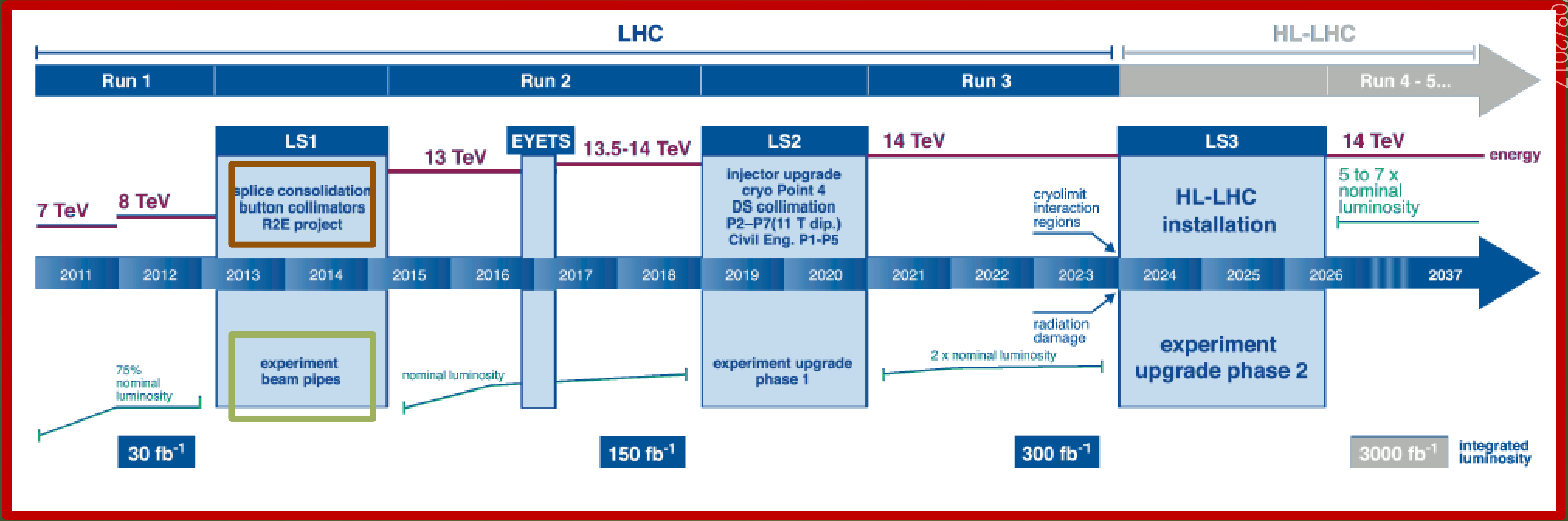
The LHC timeline

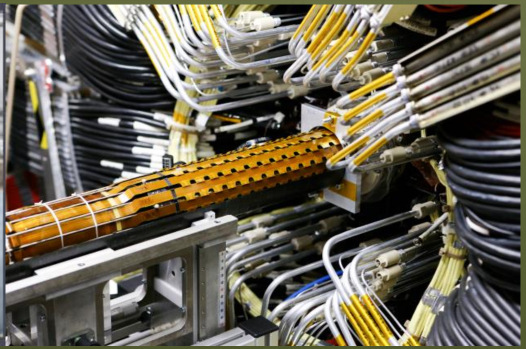




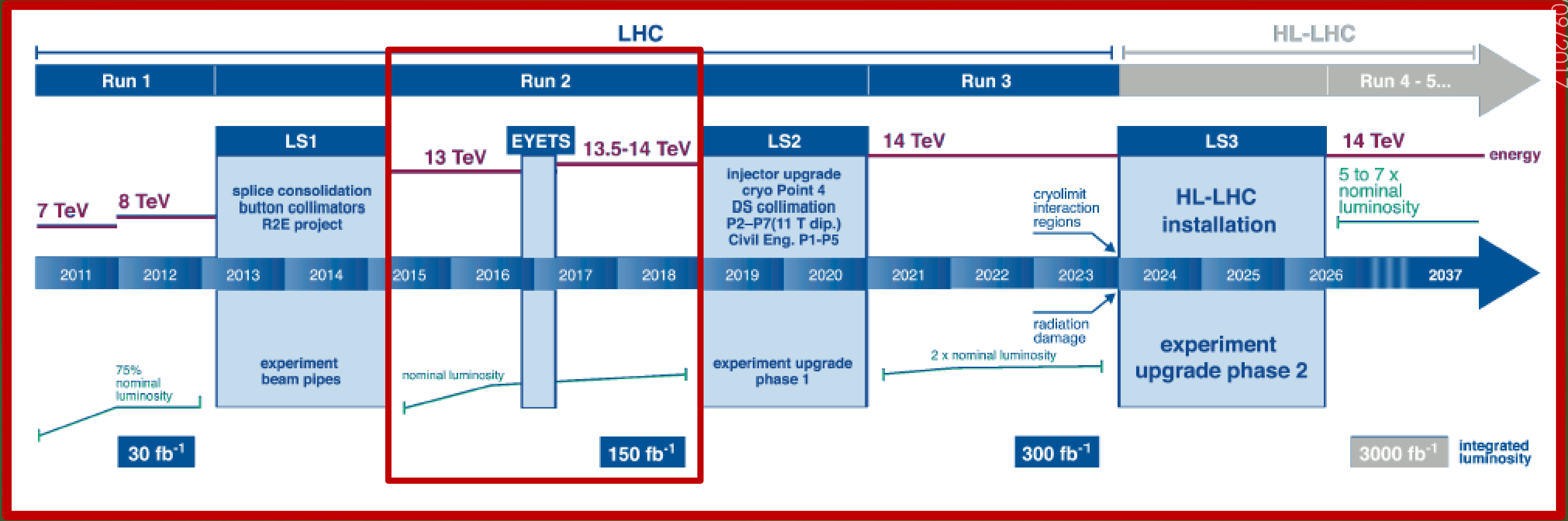


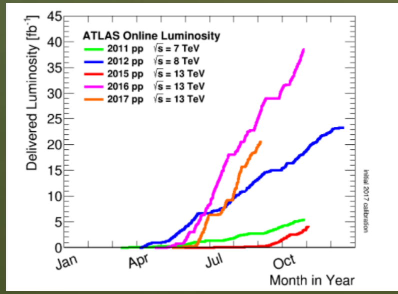
The LHC timeline



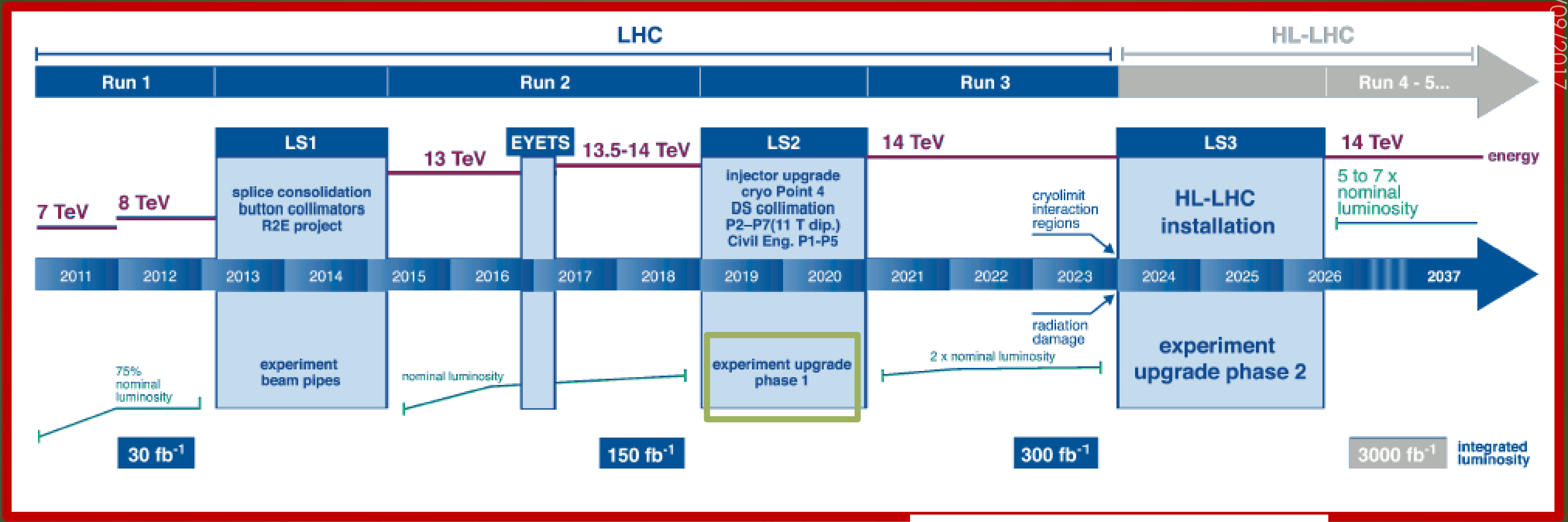


The LHC timeline

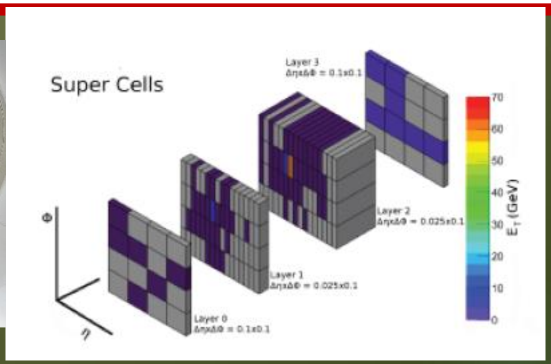




The LHC timeline

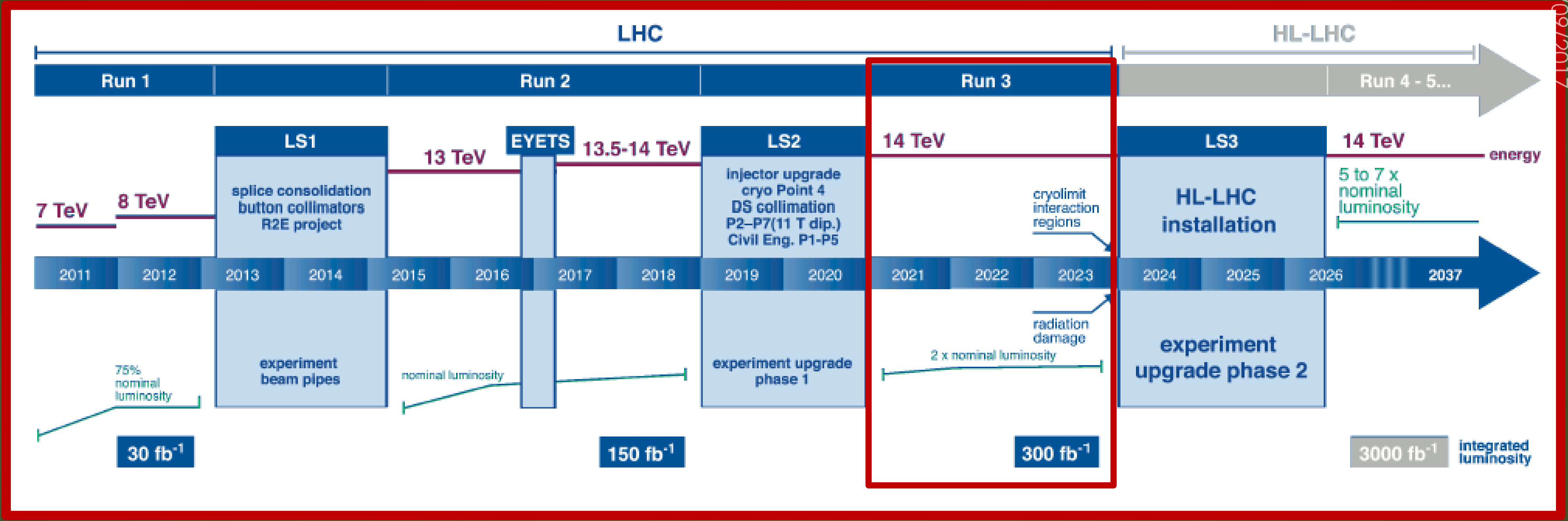


NSW: Precision tracking
Track information at
trigger level

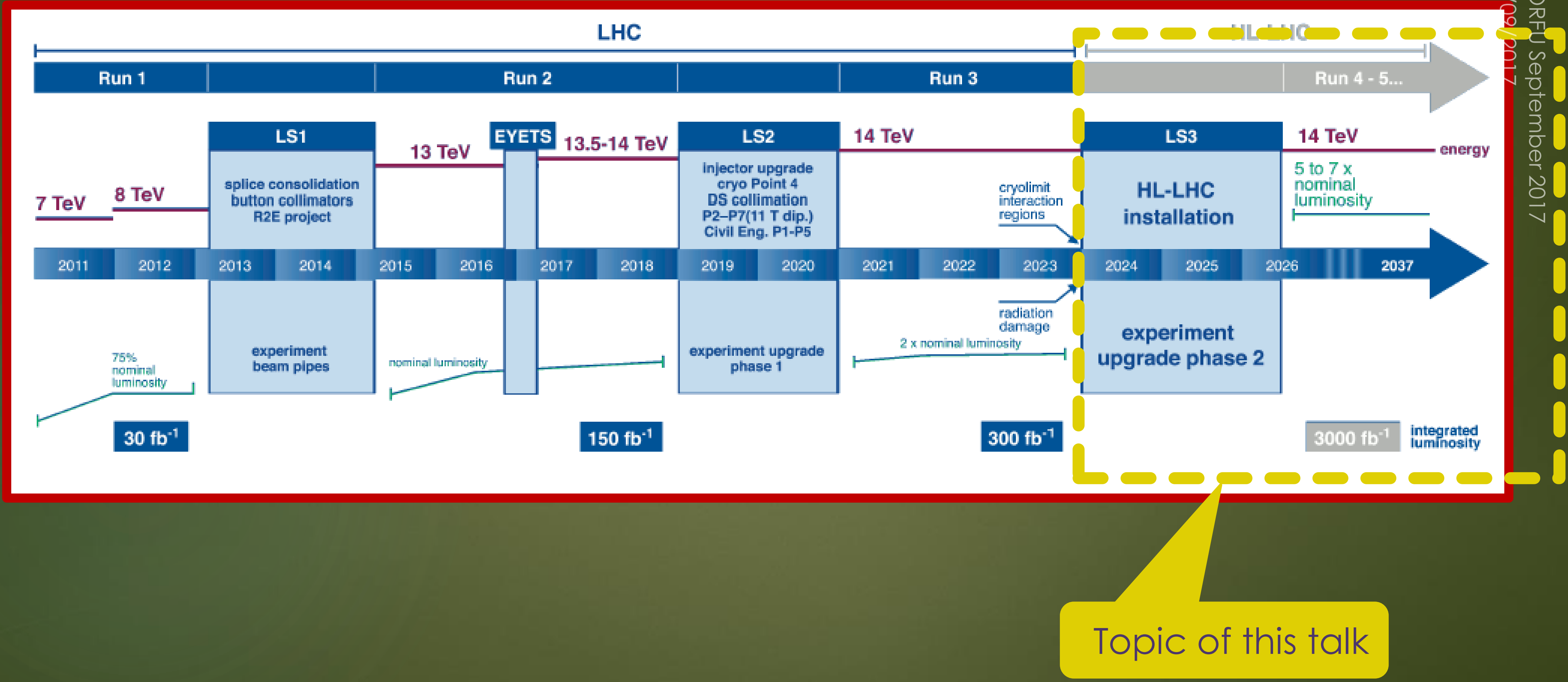


Higher granularity for
the LAr trigger towers

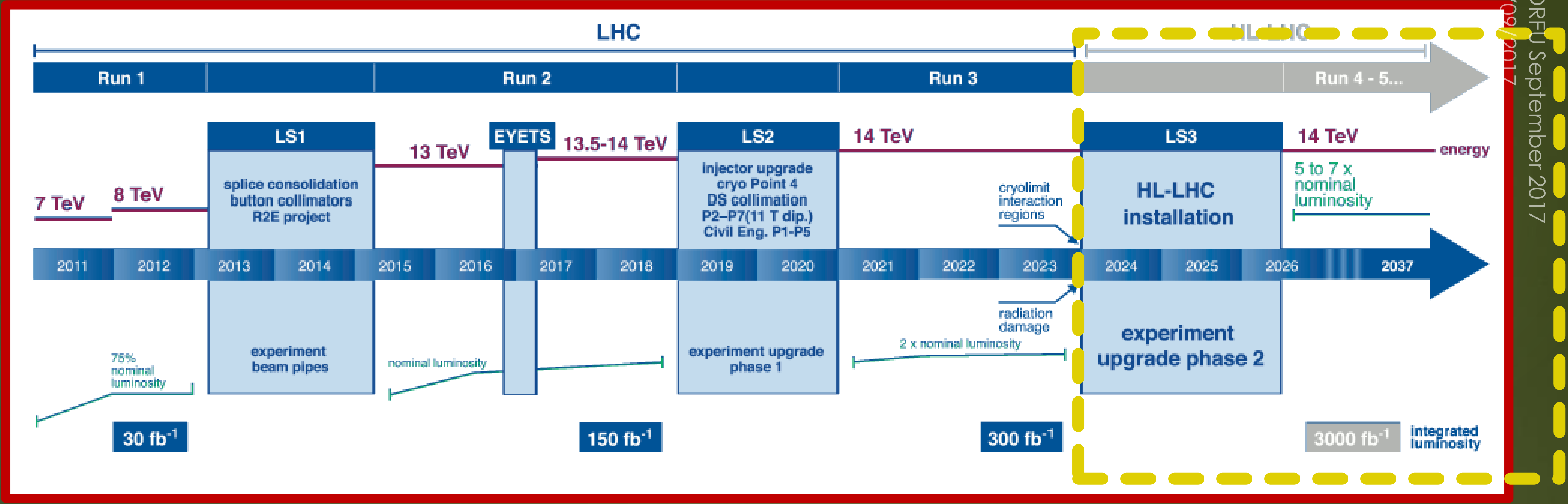
The LHC timeline



The LHC timeline



The LHC timeline



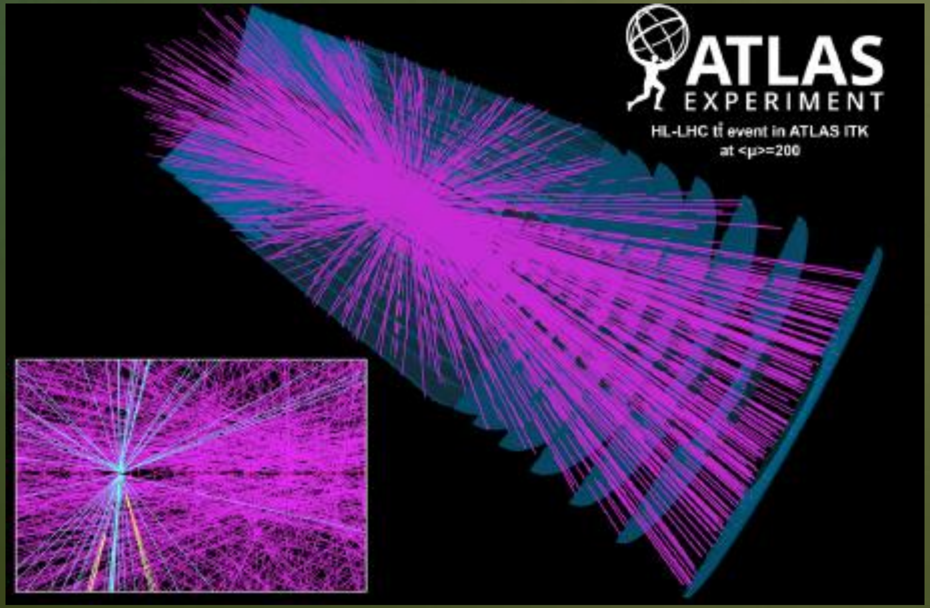
March 2016 : HL-LHC classified as landmark-project by the European Strategy Forum on Research Infrastructures (ESFRI)
June 2016: HL-LHC approved by the CERN council

The tools for HL-LHC: ATLAS upgrade

- Stand the 5-7 10^{34} /cm^2/s instantaneous luminosity is beyond the capabilities of the current detectors
- Replace several parts to achieve a robuster, faster, radiation harder and lighter detector.
- Goal : have the same-or better- performances in HL-LHC harsh conditions than in Run2
- Upgrade: fruit of permanent feedback between physics requirements and detectors' component design

The tools for HL-LHC: ATLAS upgrade

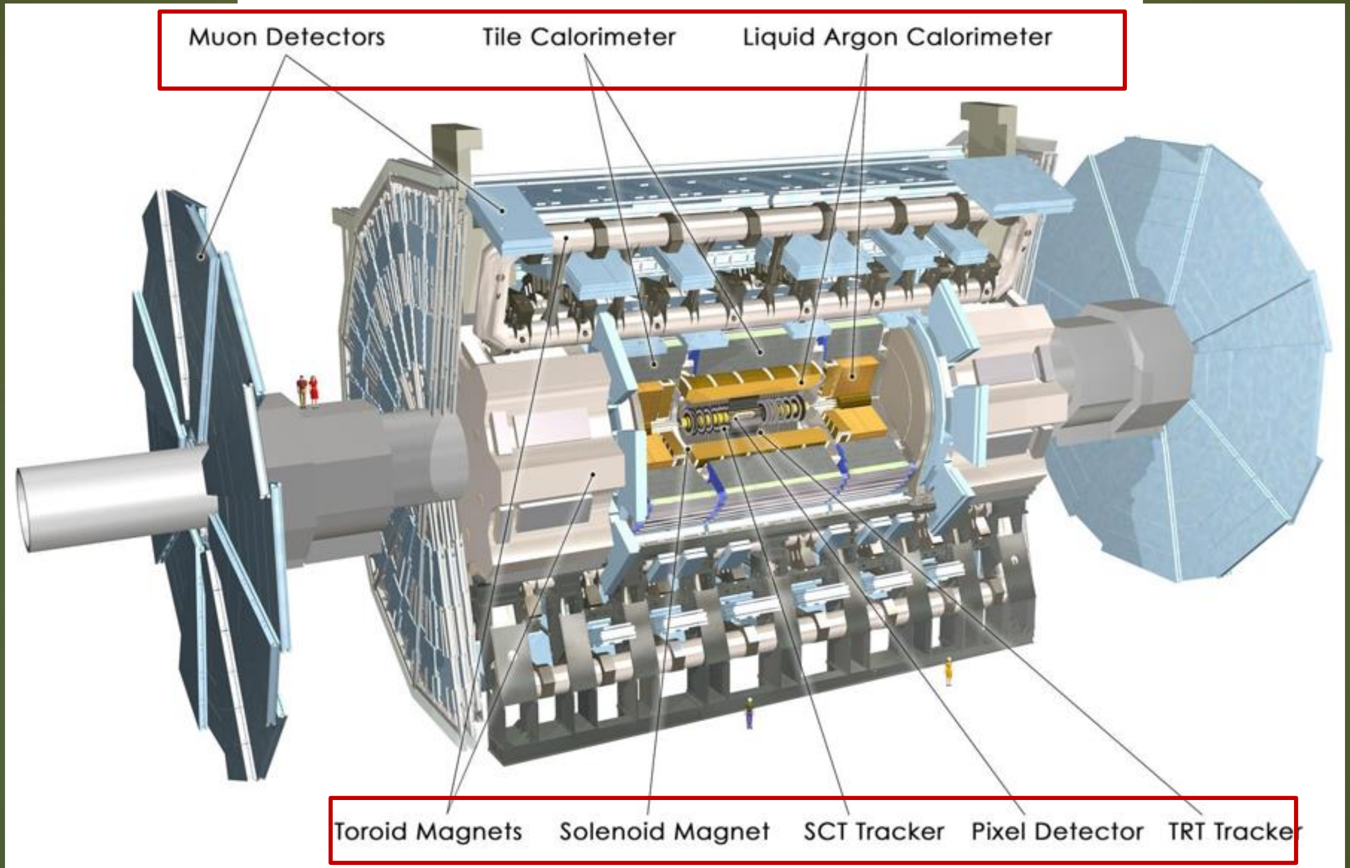
- Stand the 5-7 10^{34} /cm^2/s instantaneous luminosity is beyond the capabilities of the current detectors
- Replace several parts to achieve a robuster, faster, radiation harder and lighter detector.
- Goal : have the same-or better- performances in HL-LHC harsh conditions than in Run2
- Upgrade: fruit of permanent feedback between physics requirements and detectors' component design



➔Protect against high fluencies
➔Mitigate pileup rates and occupancy
➔Keep low P_T requirements for main triggers
➔Guarantee precise measurements up to large rapidity
➔Lighten the detector , dropping material

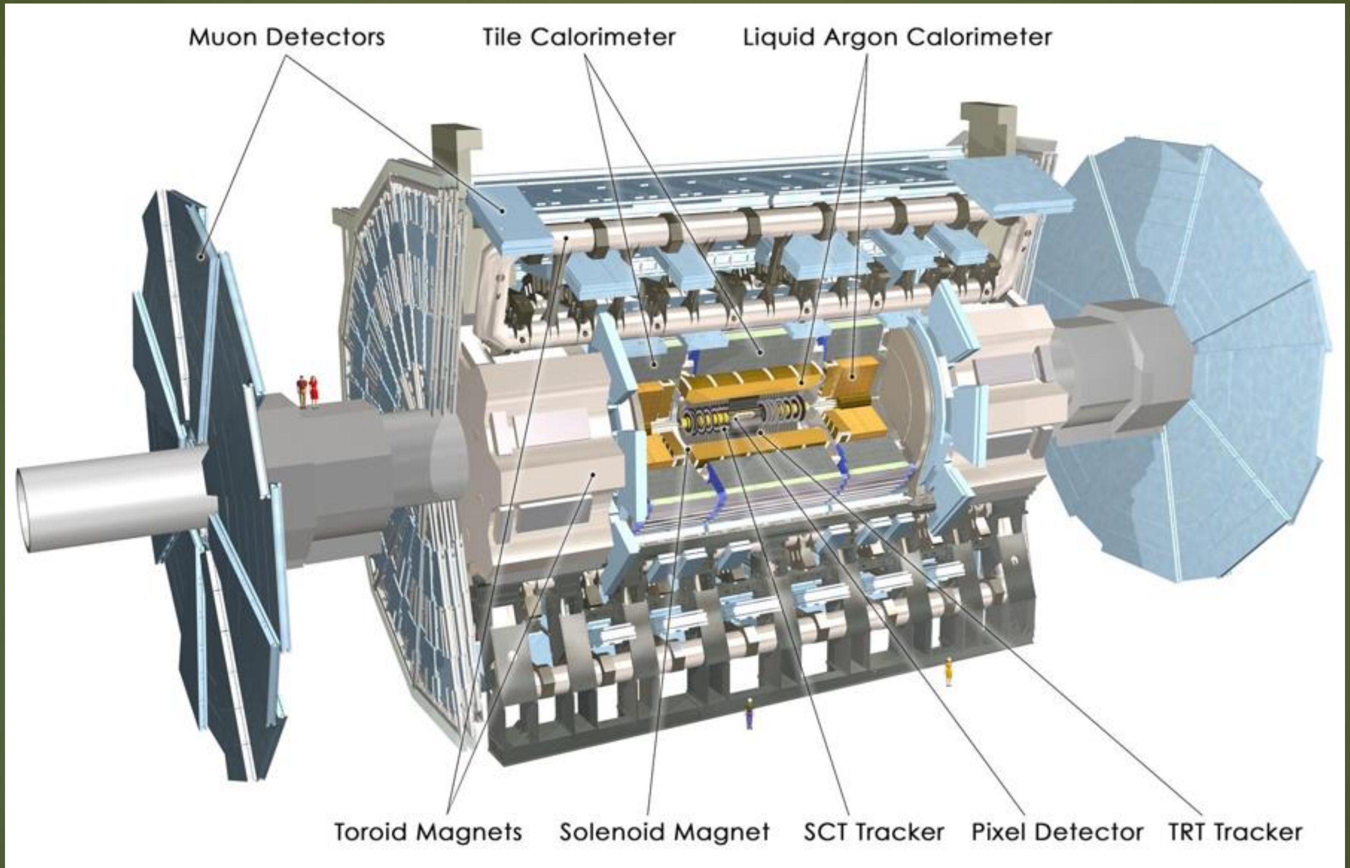
The tools for HL-LHC: ATLAS upgrade

Current detector



The tools for HL-LHC: ATLAS upgrade

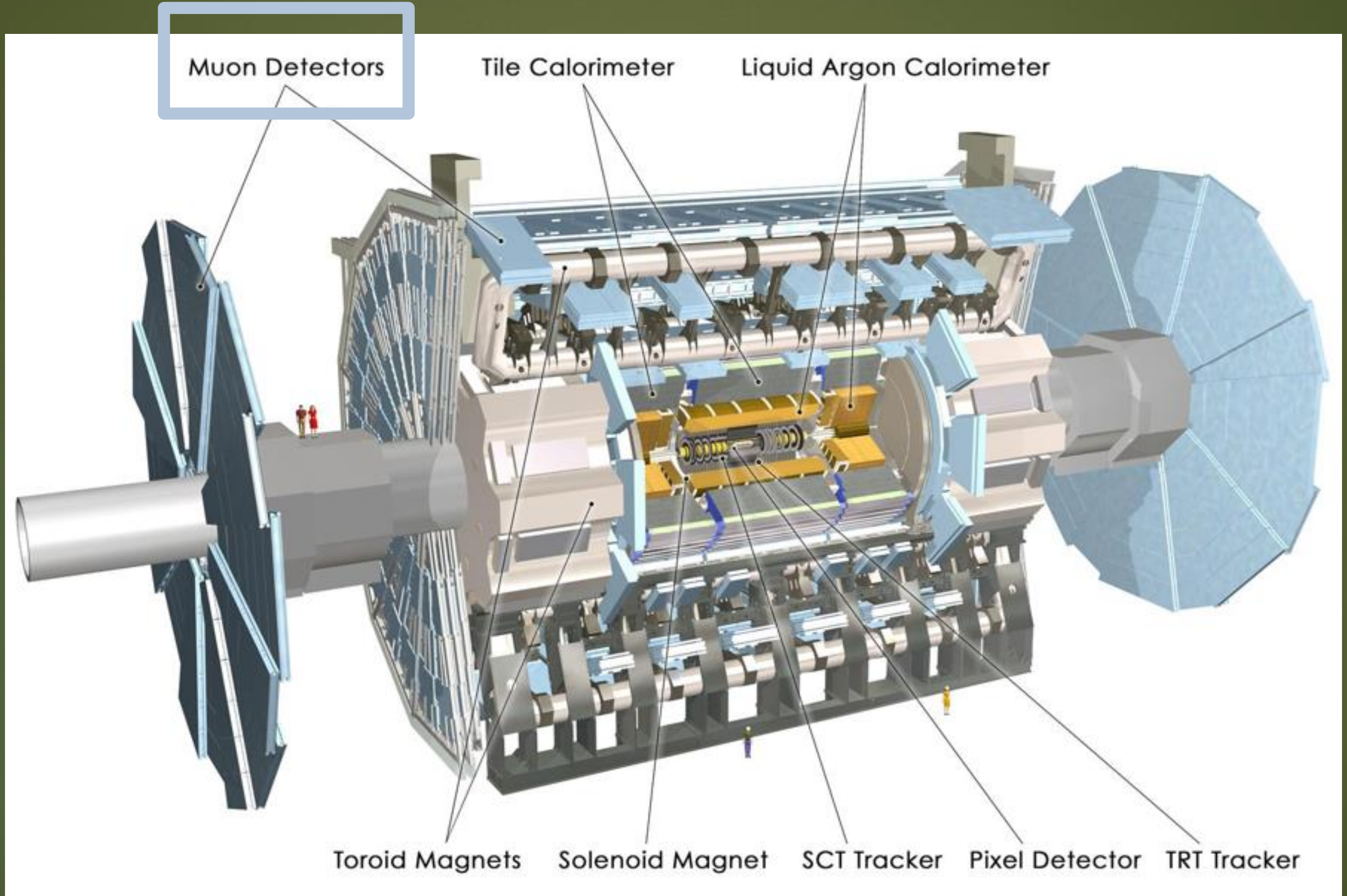
TDAQ upgrade
➔Increased latencies and rates :
--L0[10μs,2-4MHz]
--Possibly L0/L1



The tools for HL-LHC: ATLAS upgrade

TDAQ upgrade
➔Increased latencies and rates :
--L0[10μs,2-4MHz]
--Possibly L0/L1

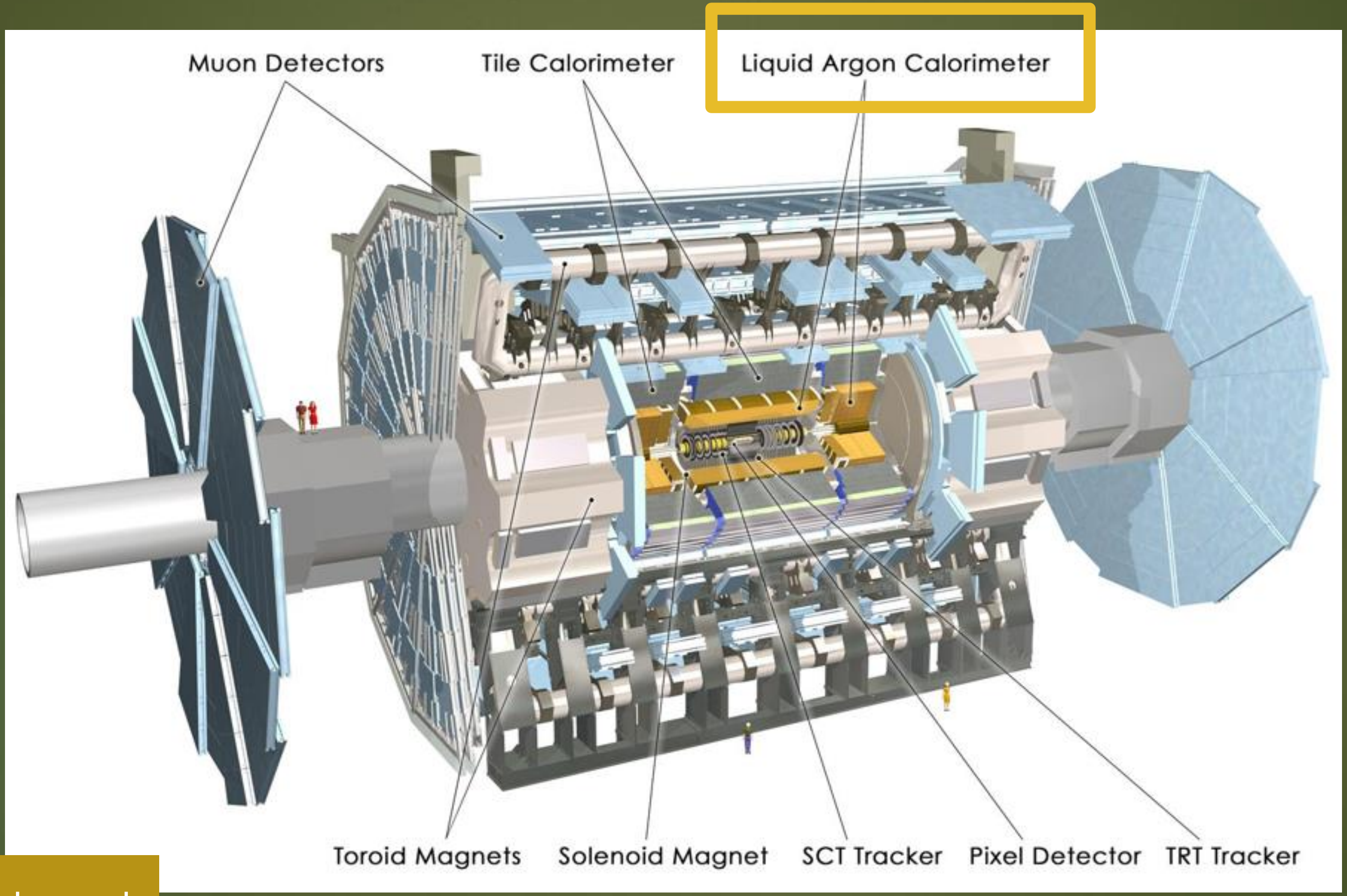
Muon readout and trigger upgrades. New Barrel trigger layer



The tools for HL-LHC: ATLAS upgrade

TDAQ upgrade
➔Increased latencies and rates :
--L0[10μs,2-4MHz]
--Possibly L0/L1

Muon readout and trigger upgrades. New Barrel trigger layer

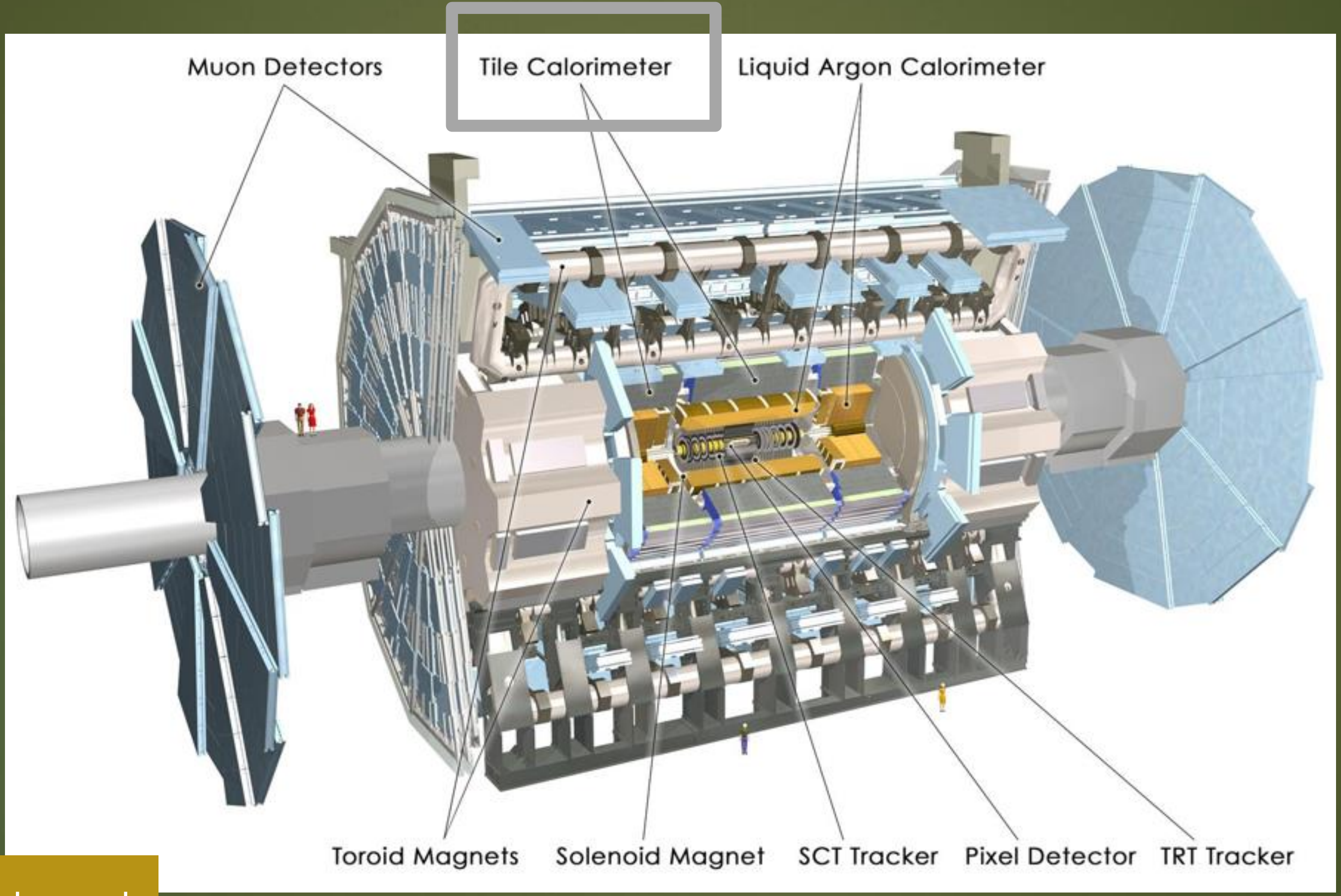


LArg; new FrontEnd and BackEnd electronics for faster readout

The tools for HL-LHC: ATLAS upgrade

TDAQ upgrade
➔Increased latencies and rates :
--L0[10μs,2-4MHz]
--Possibly L0/L1

Muon readout and trigger upgrades. New Barrel trigger layer



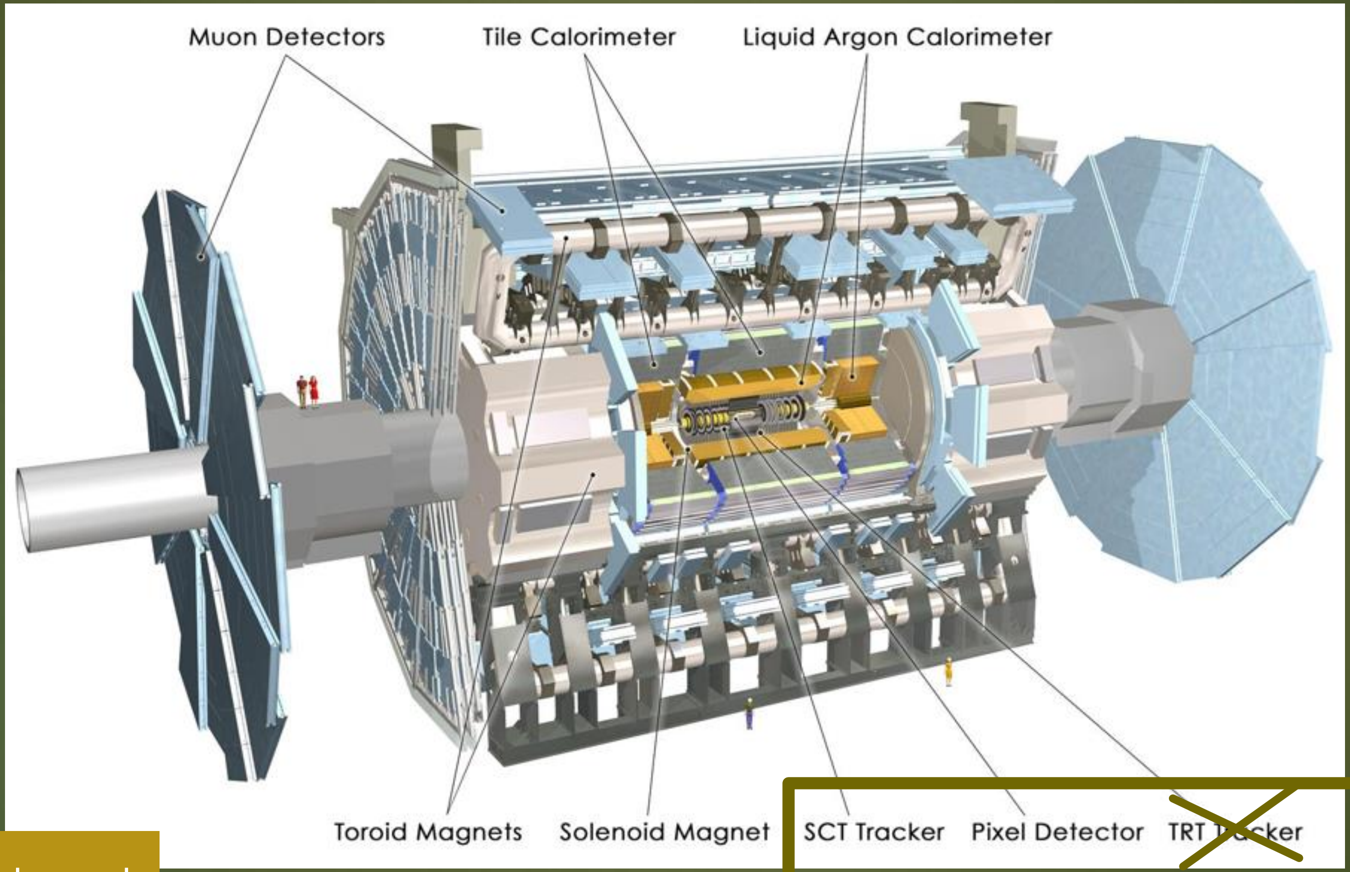
LArg; new FrontEnd and BackEnd electronics for faster readout

Tile Calorimeter : upgrade of electronics and HV distribution

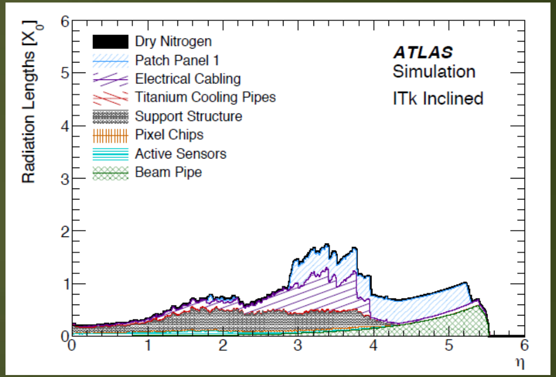
The tools for HL-LHC: ATLAS upgrade

TDAQ upgrade
➔Increased latencies and rates :
--L0[10μs,2-4MHz]
--Possibly L0/L1

Muon readout and trigger upgrades. New Barrel trigger layer



Inner Detector: full replacement by a all-silicon one (165m2), extending up to |η|=4
At most 1.75 X_0



Tracker extension up to |η|=4 crucial for pileup rejection and VBF sensitivity

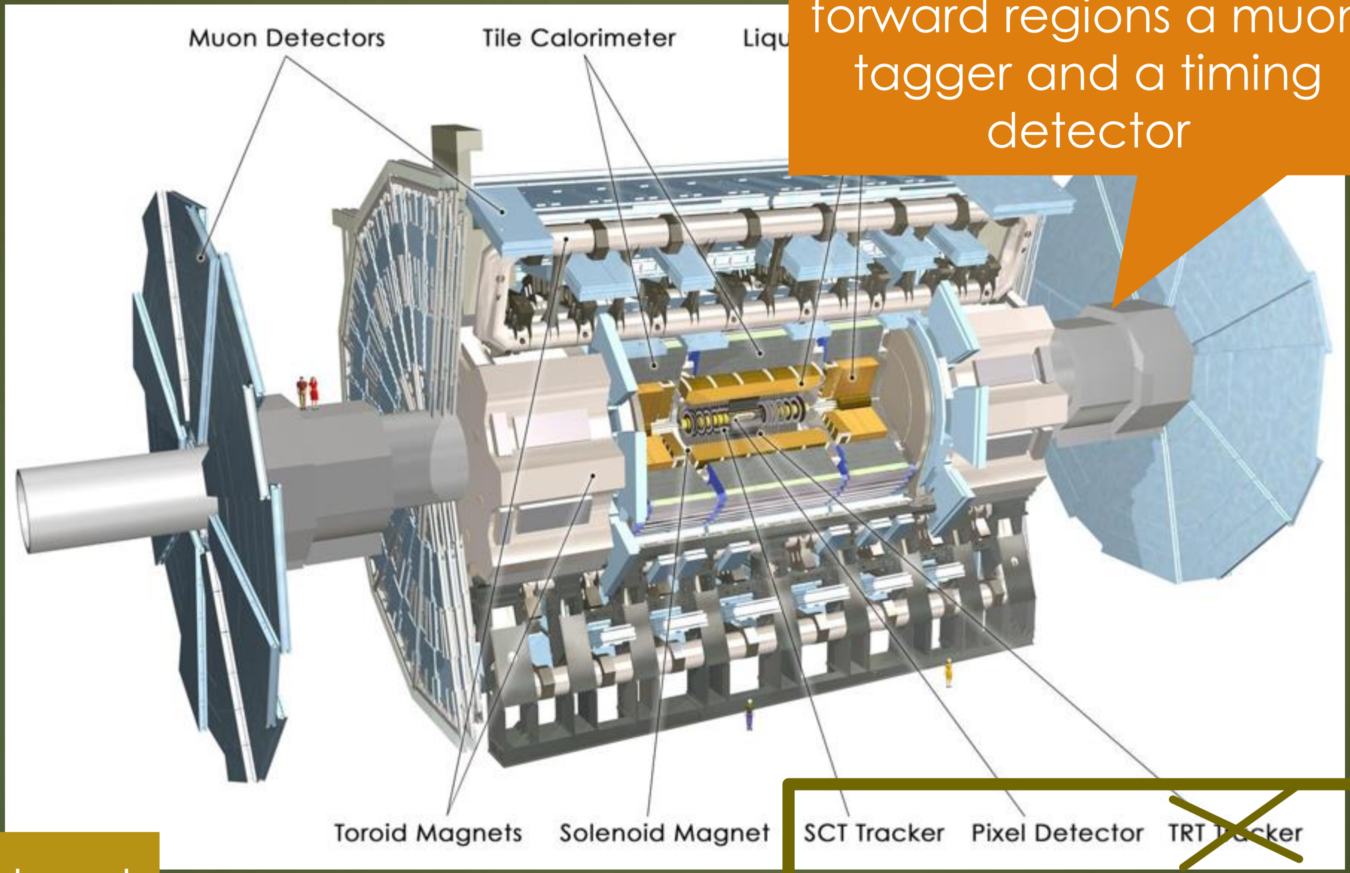
LArg; new FrontEnd and BackEnd electronics for faster readout

Tile Calorimeter : upgrade of electronics and HV distribution

The tools for HL-LHC: ATLAS upgrade

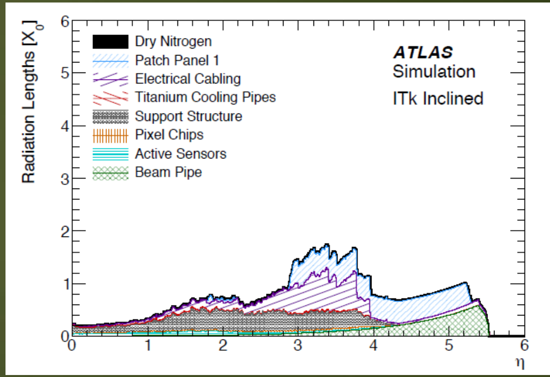
TDAQ upgrade
➔Increased latencies and rates :
--L0[10μs,2-4MHz]
--Possibly L0/L1

Muon readout and trigger upgrades. New Barrel trigger layer



Proposals for adding in forward regions a muon tagger and a timing detector

Inner Detector: full replacement by a all-silicon one (165m2), extending up to |η|=4
At most 1.75 X0



Tracker extension up to |η|=4 crucial for pileup rejection and VBF sensitivity

LArg; new FrontEnd and BackEnd electronics for faster readout

Tile Calorimeter : upgrade of electronics and HV distribution

Simulating Physics channels at HL-LHC

CASE 1

1) Extrapolate from Run1,2 results. Scale both signal and background to 14TeV and 3000fb^{-1}

2) Assume similar detector performances and apply same analyses

Simulating Physics channels at HL-LHC

CASE 1

1) Extrapolate from Run1,2 results. Scale both signal and background to 14TeV and 3000fb^{-1}

2) Assume similar detector performances and apply same analyses

OR

CASE 2

1) Smear event-generator level particles with parameterized functions
2) Functions are determined from full simulation of the upgraded ATLAS detector and reconstructed assuming pileup of 140 ($5x10^{34}$) or 200 ($7x10^{34}$)
3) Analyses as for 8 and (or) 13TeV with some updates for high luminosity

Simulating Physics channels at HL-LHC

CASE 1

1) Extrapolate from Run1,2 results. Scale both signal and background to 14TeV and $3000fb^{-1}$

2) Assume similar detector performances and apply same analyses

OR

CASE 2

1) Smear event-generator level particles with parameterized functions
2) Functions are determined from full simulation of the upgraded ATLAS detector and reconstructed assuming pileup of 140 ($5x10^{34}$) or 200 ($7x10^{34}$)
3) Analyses as for 8 and (or) 13TeV with some updates for high luminosity

What about systematics? Difficult to predict.

Experimental Systematics: so far , scaled from current knowledge
Theory Systematics : current numbers, half of them, or none.

Expected performances at HL-LHC

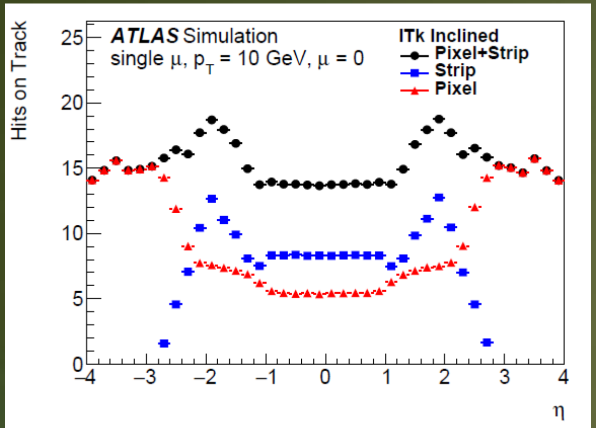
CASE 2 :

Shown next the expectations for the main objects
(tracks, electrons, photons, jets)
Obtained with the most up-to-date detector simulation and fully reconstructed.
Optimization : very likely to improve

Pileup treatment :

Use a library made out of generated and fully reconstructed minimum-bias jets
At <μ>= 140 and <μ>=200
Read one “pileup” event with each “physics” event

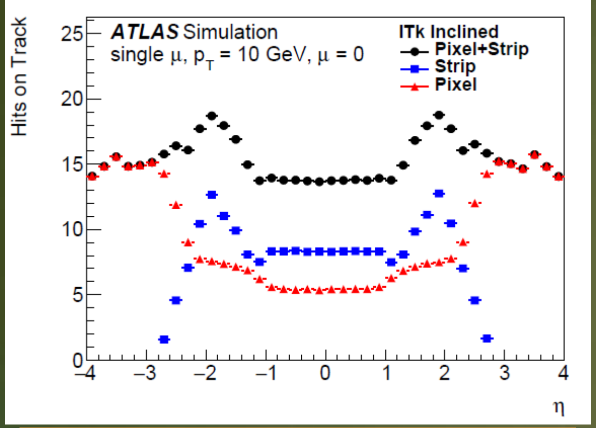
Object performances: Track Reconstruction



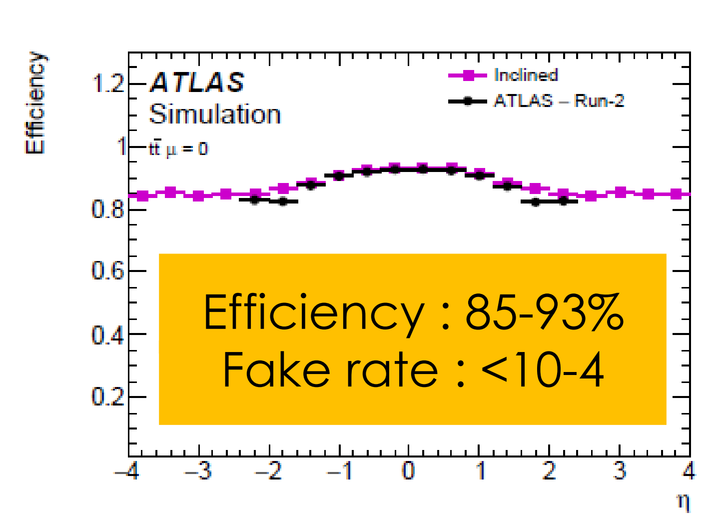
>=14 hits per track

ATL-TDR-025 · LHCC-2017-005

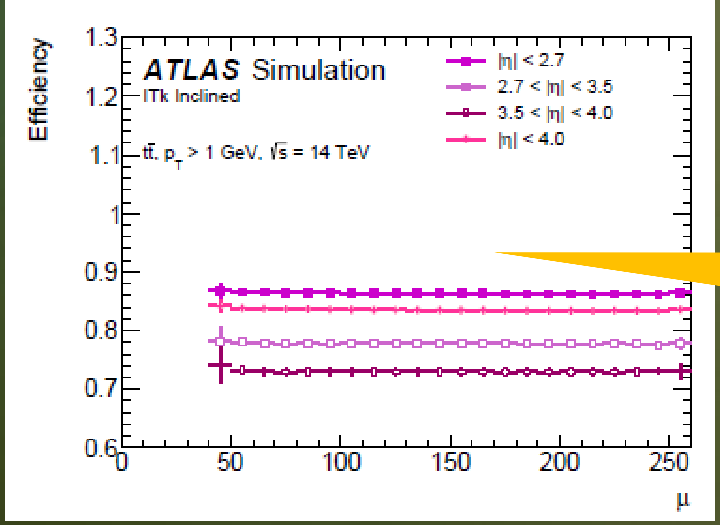
Object performances: Track Reconstruction



>=14 hits per track



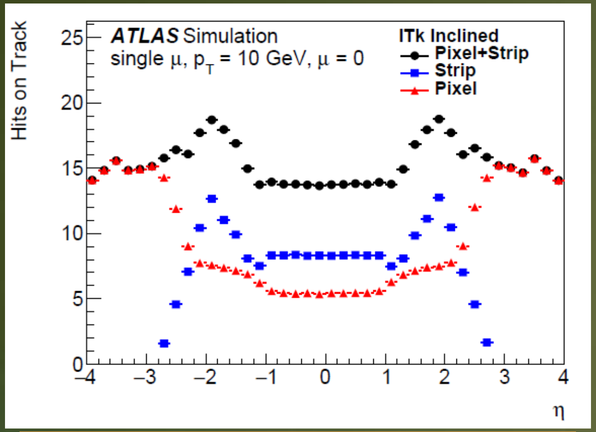
Efficiency : 85-93%
Fake rate : <10-4



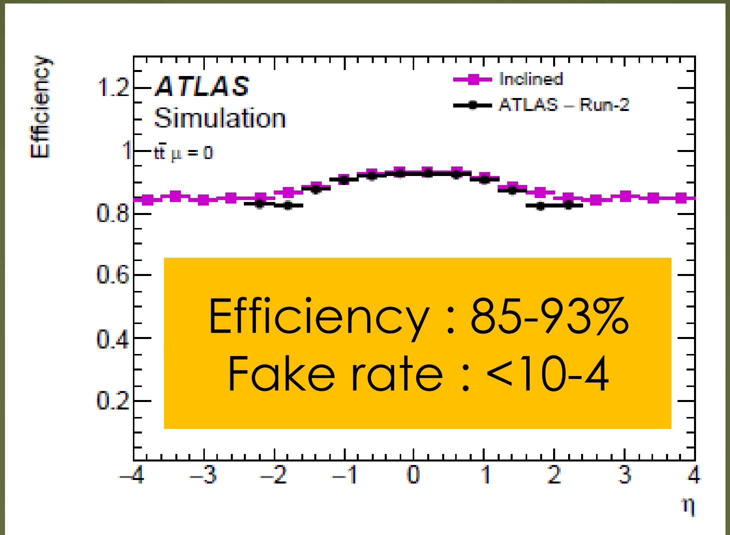
Stable performance
with pileup

ATL-TDR-025 · LHCC-2017-005

Object performances: Track Reconstruction

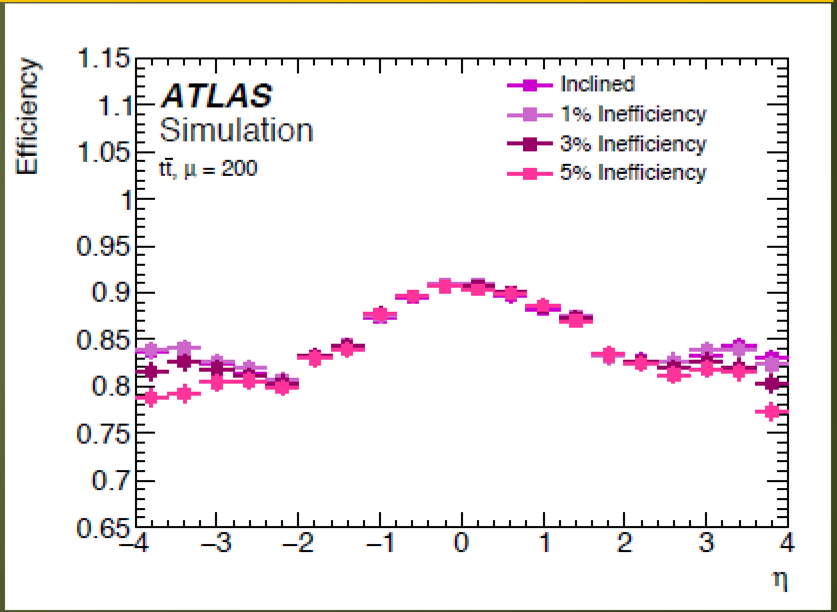


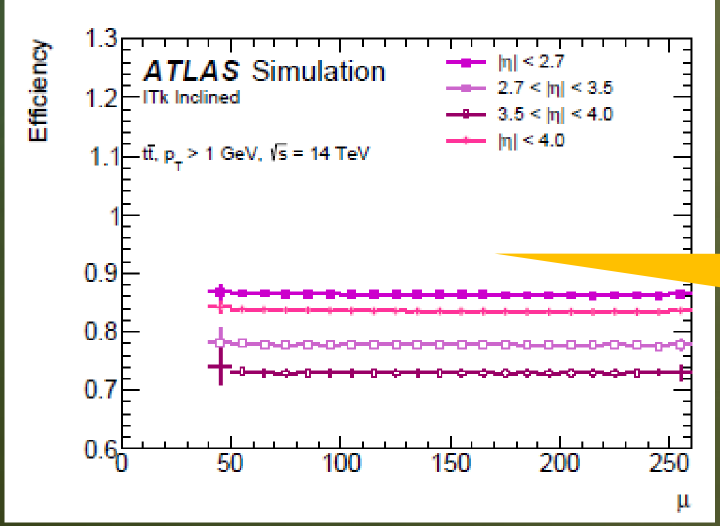
>=14 hits per track



Efficiency : 85-93%
Fake rate : <10-4

Effect of failing sensors





Stable performance
with pileup

ATL-TDR-025 · LHCC-2017-005

Pileup jet mitigation

The high expected pileup (μ=140->200) was one key factor for the design of the upgraded tracker detector (ITK)
Need precise track and Vertex reconstruction

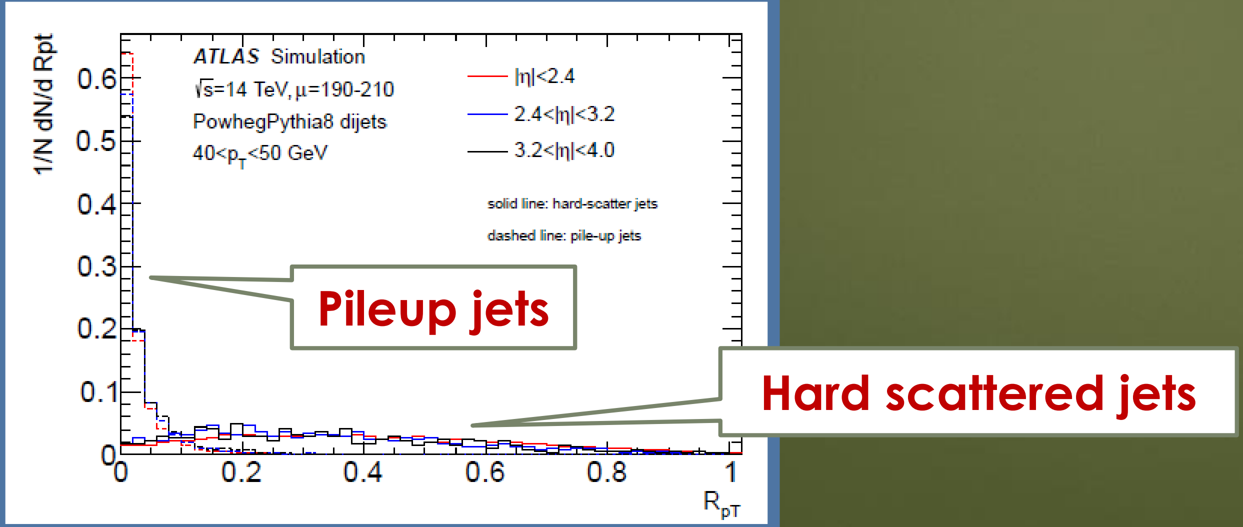
Pileup jet mitigation

The high expected pileup (μ=140->200) was one key factor for the design of the upgraded tracker detector (ITK)
Need precise track and vertex reconstruction

CERN-LHCC-2015-020

At <μ>=200, 5 pileup jets/event with PT>30 GeV
Distinguish between hard scattered and pileup using Rp_T

$$R_{\mathrm{pT}} = \frac{\Sigma_k p_{\mathrm{T}}^{\mathrm{trk}_k}(\mathrm{PV}_0)}{p_{\mathrm{T}}^{jet}}$$

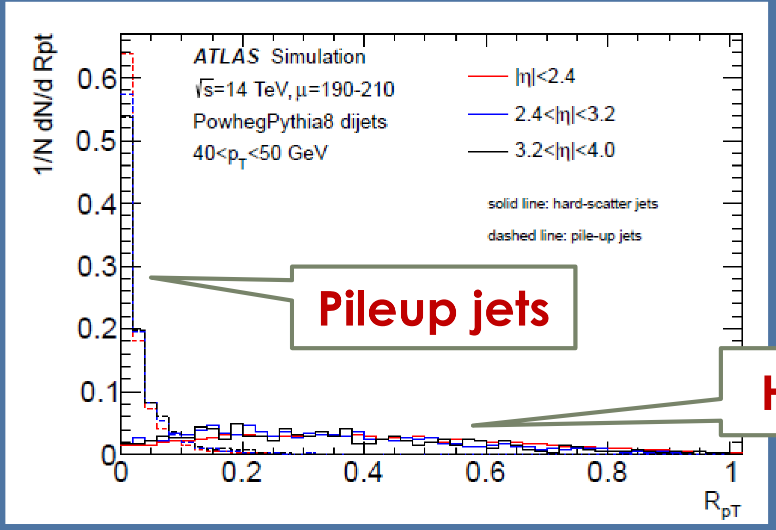


Pileup jet mitigation

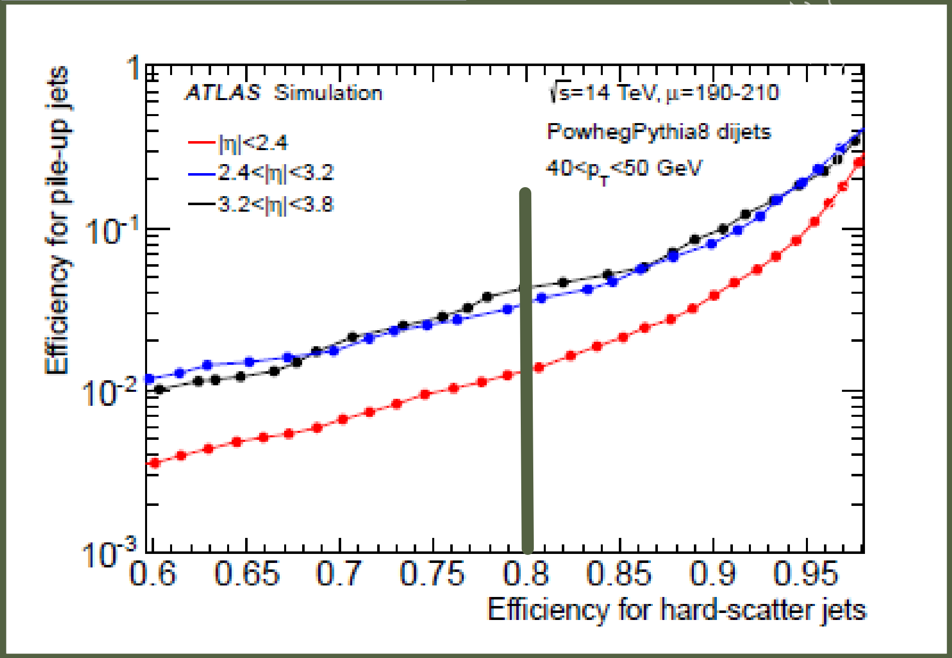
The high expected pileup (μ=140->200) was one key factor for the design of the upgraded tracker detector (ITK)
Need precise track and vertex reconstruction

At <μ>=200, 5 pileup jets/event with PT>30 GeV
Distinguish between hard scattered and pileup using Rp_T

$$R_{pT} = \frac{\Sigma_k p_T^{trk_k}(PV_0)}{p_T^{jet}}$$



CERN-LHCC-2015-020



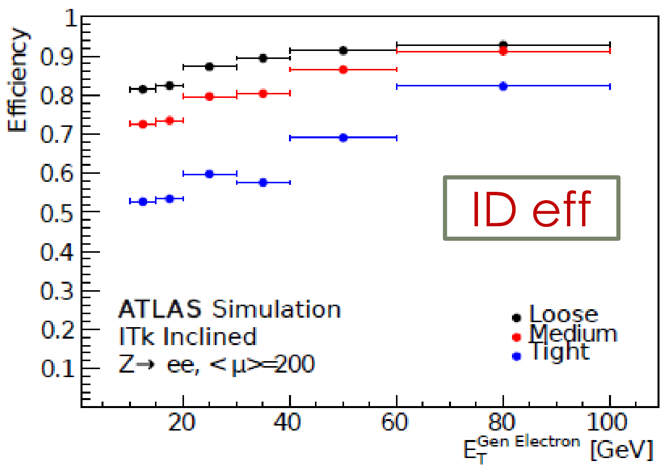
For 80% hard scattered jet efficiency, keep at most 2% pileup jets

Electron Identification efficiencies

➔**Using Z->ee full simulation with pileup ~200**
➔Cut based tuning for 3 working points, Loose, Medium and Tight
➔Pt>7 GeV and |eta|<2.47 (need specific tuning of the Forward Calos to go further)
➔Di-jet sample for studying background rejection

Electron Identification efficiencies

➔**Using Z->ee full simulation with pileup ~200**
➔Cut based tuning for 3 working points, Loose, Medium and Tight
➔Pt>7 GeV and |eta|<2.47 (need specific tuning of the Forward Calos to go further)
➔Di-jet sample for studying background rejection



Almost flat in |η|

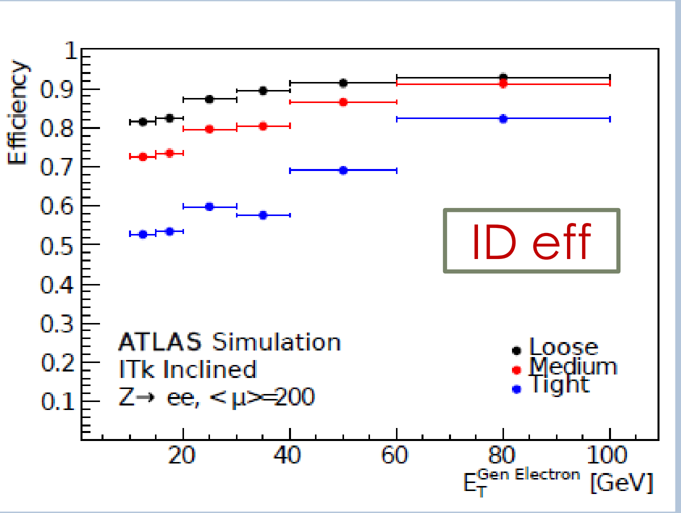
μ =190-210	Loose	Medium	Tight
	Identification Efficiency (%)		
Electrons	92.4±0.1	85.2±0.1	65.3±0.1
Jet Fakes	6.2±0.2	2.7±0.1	0.9±0.1
Hadrons	5.0±0.1	2.0±0.1	0.72±0.04
Conversions	10±2	4.4±1.5	0.6±0.5
Heavy Flavour	42±6	23±5	11±3
	Total Efficiency (%)		
Electrons	88.9±0.1	82.0±0.1	62.8±0.1
Jet Fakes	0.150±0.005	0.065±0.003	0.022±0.002

Total eff= Identification x Reco

ATL-TDR-025 · LHCC-2017-005

Electron Identification efficiencies

➔**Using Z->ee full simulation with pileup ~200**
➔Cut based tuning for 3 working points, Loose, Medium and Tight
➔Pt>7 GeV and |eta|<2.47 (need specific tuning of the Forward Calos to go further)
➔Di-jet sample for studying background rejection

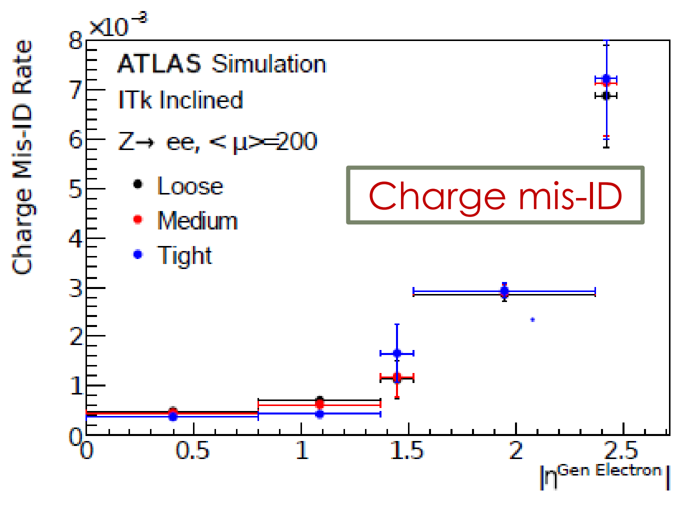


Almost flat in |η|

μ =190-210	Loose	Medium	Tight
	Identification Efficiency (%)		
Electrons	92.4±0.1	85.2±0.1	65.3±0.1
Jet Fakes	6.2±0.2	2.7±0.1	0.9±0.1
Hadrons	5.0±0.1	2.0±0.1	0.72±0.04
Conversions	10±2	4.4±1.5	0.6±0.5
Heavy Flavour	42±6	23±5	11±3
	Total Efficiency (%)		
Electrons	88.9±0.1	82.0±0.1	62.8±0.1
Jet Fakes	0.150±0.005	0.065±0.003	0.022±0.002

Total eff= Identification x Reco

ATL-TDR-025 · LHCC-2017-005



Almost flat in PT

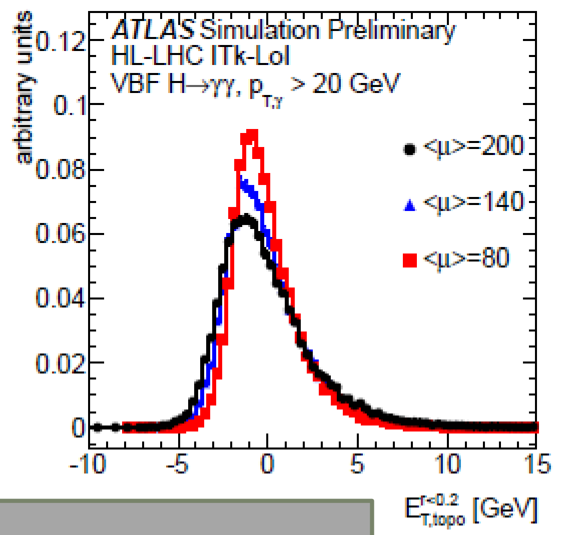
Photon Identification Efficiency

➔ Using H->γγ fully simulated samples with pileup 140 and 200
➔ Distinct identifications for no-converted, single and double conversions
➔ Use Multijet sample for background
➔ Multivariate signal-background separation based on shower shapes in the calorimeter➔Look at photons with P_T>20 GeV, |η|<2.4 excluding crack
➔ Check additional isolation requiring E_T ($R<R_C$, R_C=0.2,0.4) < 6 GeV

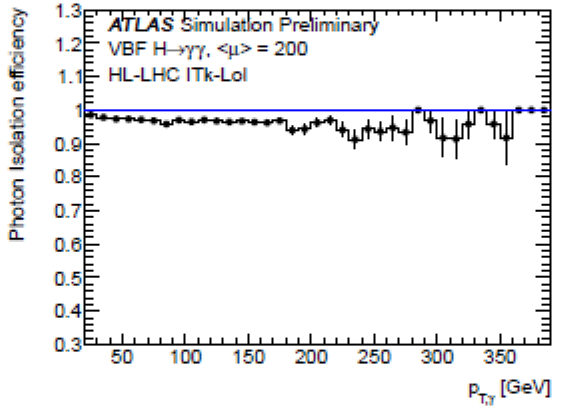
Photon Identification Efficiency

ATL-TDR-025 · LHCC-2017-005

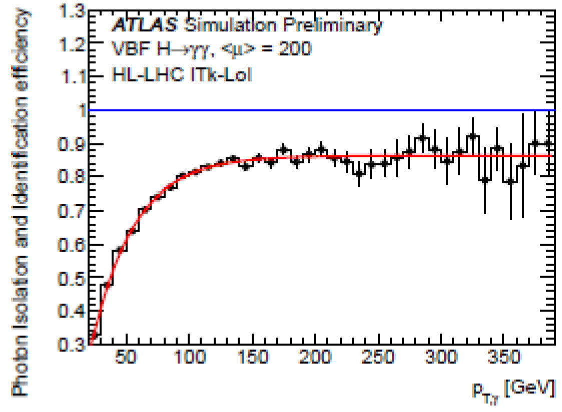
- ➔ Using $H\to\gamma\gamma$ fully simulated samples with pileup 140 and 200
- ➔ Distinct identifications for no-converted, single and double conversions
- ➔ Use Multijet sample for background
- ➔ Multivariate signal-background separation based on shower shapes in the calorimeter➔Look at photons with P_T>20 GeV, $|\eta|$<2.4 excluding crack
- ➔ Check additional isolation requiring E_T ($R<R_C$, R_C=0.2,0.4) < 6 GeV



Energy in a cone R<0.2



Isolation efficiency



Isolation+ID efficiency

B-tagging at HL-LHC

B-tagging== Probability to identify a jet containing a B hadron

➔Evaluated using multivariate techniques applied to the new detector exploiting impact parameter and secondary vertex informations

➔Studied using ttbar events with at least one semi-leptonic decay

➔For fixed b-tag efficiency→ extract light and c-jet mis-tag

B-tagging at HL-LHC

ATL-TDR-025 · LHCC-2017-005

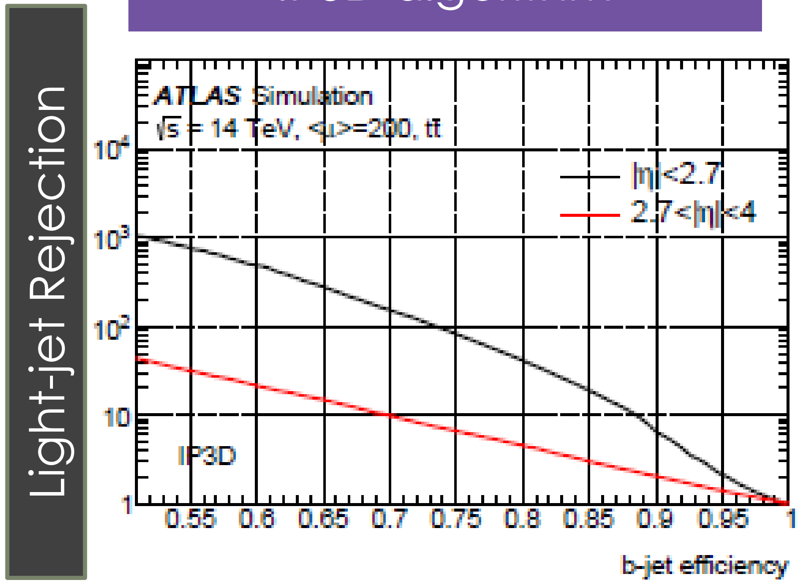
B-tagging== Probability to identify a jet containing a B hadron

➔Evaluated using multivariate techniques applied to the new detector exploiting impact parameter and secondary vertex informations

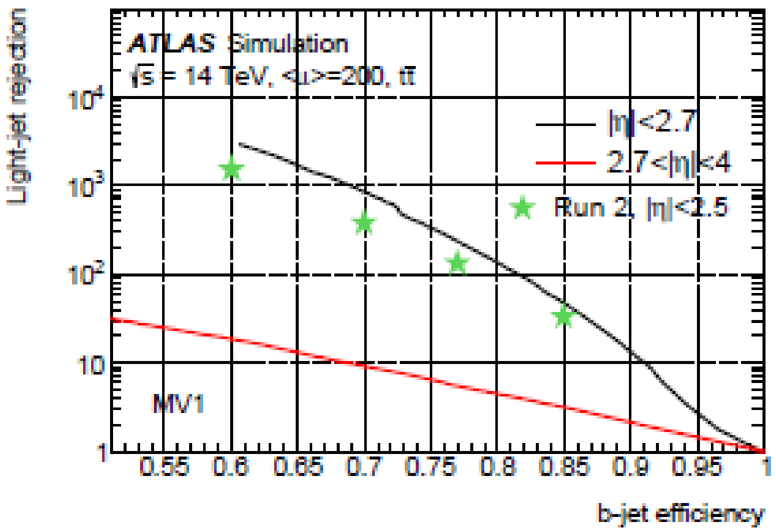
➔Studied using ttbar events with at least one semi-leptonic decay

➔For fixed b-tag efficiency→ extract light and c-jet mis-tag

IP3D algorithm



MV1 algorithm



Both algorithms without any further tuning. Run2 versions

B-tagging at HL-LHC

ATL-TDR-025 · LHCC-2017-005

B-tagging== Probability to identify a jet containing a B hadron

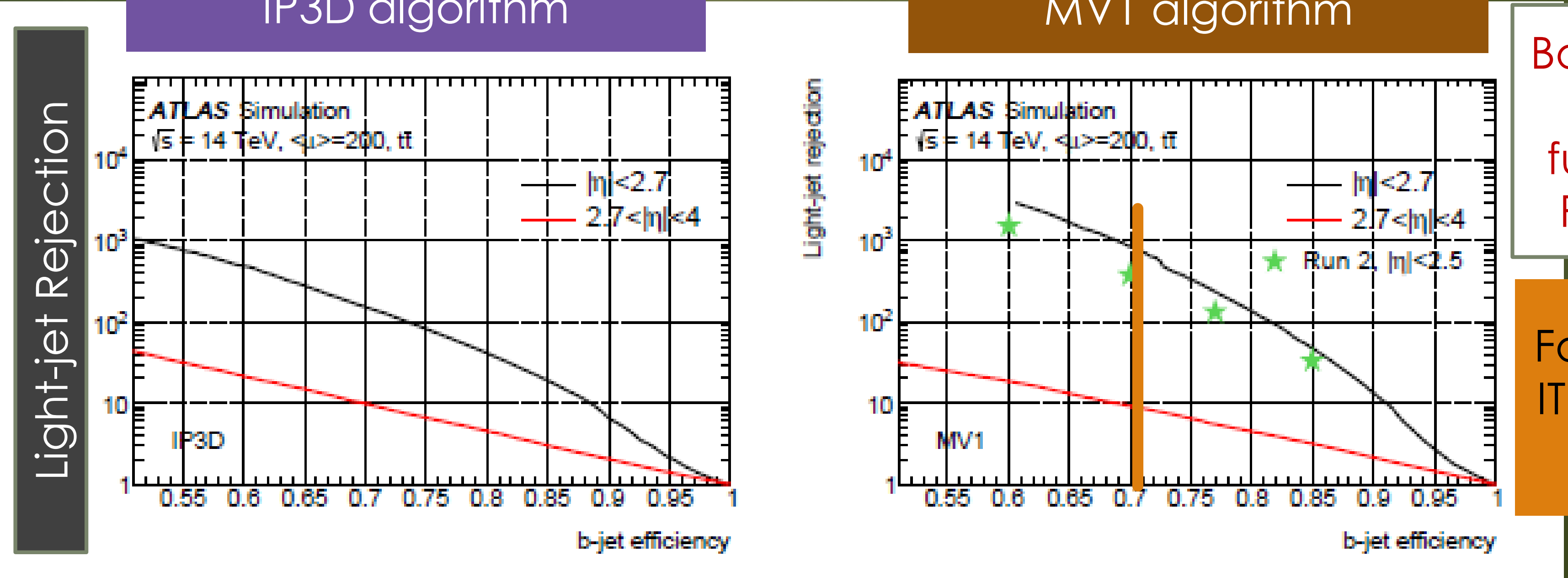
➔Evaluated using multivariate techniques applied to the new detector exploiting impact parameter and secondary vertex informations

➔Studied using ttbar events with at least one semi-leptonic decay

➔For fixed b-tag efficiency→ extract light and c-jet mis-tag

IP3D algorithm

MV1 algorithm



Both algorithms without any further tuning. Run2 versions

For 70% efficiency, ITK gives twice the Run2 rejection

Some physics channels Hi-Lumi LHC for what?

The portal of the Higgs discovery

1) Detect all production modes
2) Its low mass allows a precise study of couplings to fermions and bosons.
3) Investigate differential distributions -> gives also access to eventual BSM effects
4) Study Higgs' rare decays
5) Stress of the Higgs potential: measure the self-coupling

Also

Test further the EWS breaking : Vector Boson Scattering

For more ATLAS results on Higgs (current or prospects)
See the talks of:

Yann Coadou
Antonio de Maria
Chao Wang
Pippa Wells

Higgs couplings: extrapolating from Run1

ATL-PHYS-PUB-2014-016

Full projection from Run1 results. Without upgraded detector simulation nor tuned analyses.
➔"Old" theory uncertainties.
➔2014 experimental uncertainties

Higgs couplings: extrapolating from Run1

ATL-PHYS-PUB-2014-016

Full projection from Run1 results. Without upgraded detector simulation nor tuned analyses.
➔"Old" theory uncertainties.
➔2014 experimental uncertainties

Higgs Production modes

$\Delta\mu/\mu$	300 fb^{-1}		3000 fb^{-1}	
	All unc.	No theory unc.	All unc.	No theory unc.
$gg \to H$	0.12	0.06	0.11	0.04
VBF	0.18	0.15	0.15	0.09
WH	0.41	0.41	0.18	0.18
$qqZH$	0.80	0.79	0.28	0.27
$ggZH$	3.71	3.62	1.47	1.38
ttH	0.32	0.30	0.16	0.10

Higgs couplings: extrapolating from Run1

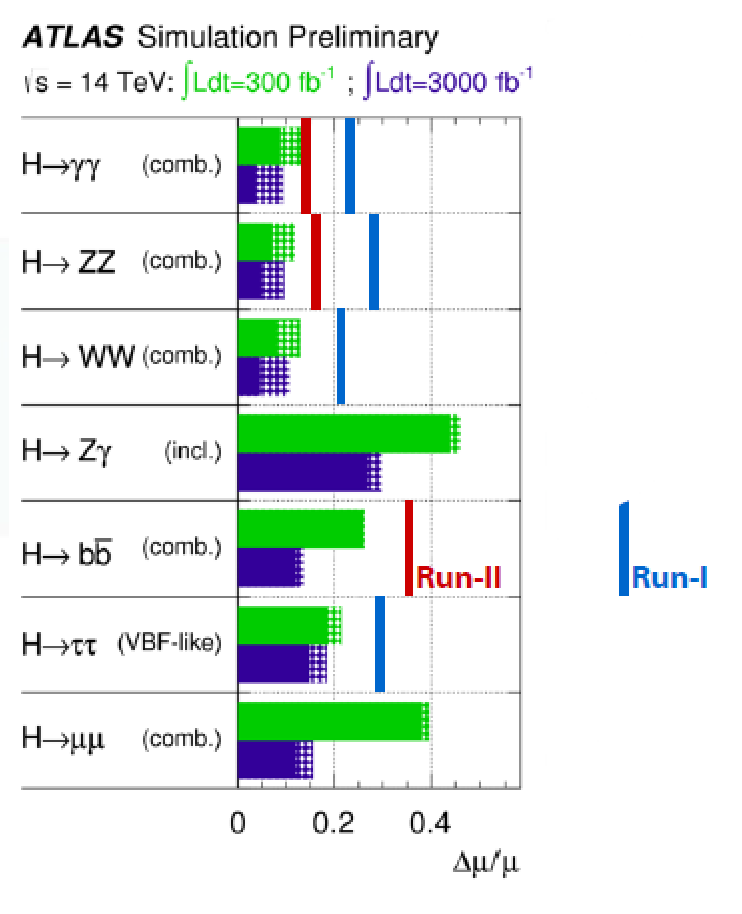
Full projection from Run1 results. Without upgraded detector simulation nor tuned analyses.
➔"Old" theory uncertainties.
➔2014 experimental uncertainties

Higgs Production modes

$\Delta\mu/\mu$	300 fb^{-1}		3000 fb^{-1}	
	All unc.	No theory unc.	All unc.	No theory unc.
$gg \to H$	0.12	0.06	0.11	0.04
VBF	0.18	0.15	0.15	0.09
WH	0.41	0.41	0.18	0.18
$qqZH$	0.80	0.79	0.28	0.27
$ggZH$	3.71	3.62	1.47	1.38
ttH	0.32	0.30	0.16	0.10

ATL-PHYS-PUB-2014-016

Higgs Decay modes



Dashed bands: theory

Higgs couplings: extrapolating from Run1

Full projection from Run1 results. Without upgraded detector simulation nor tuned analyses.
→"Old" theory uncertainties.
→2014 experimental uncertainties

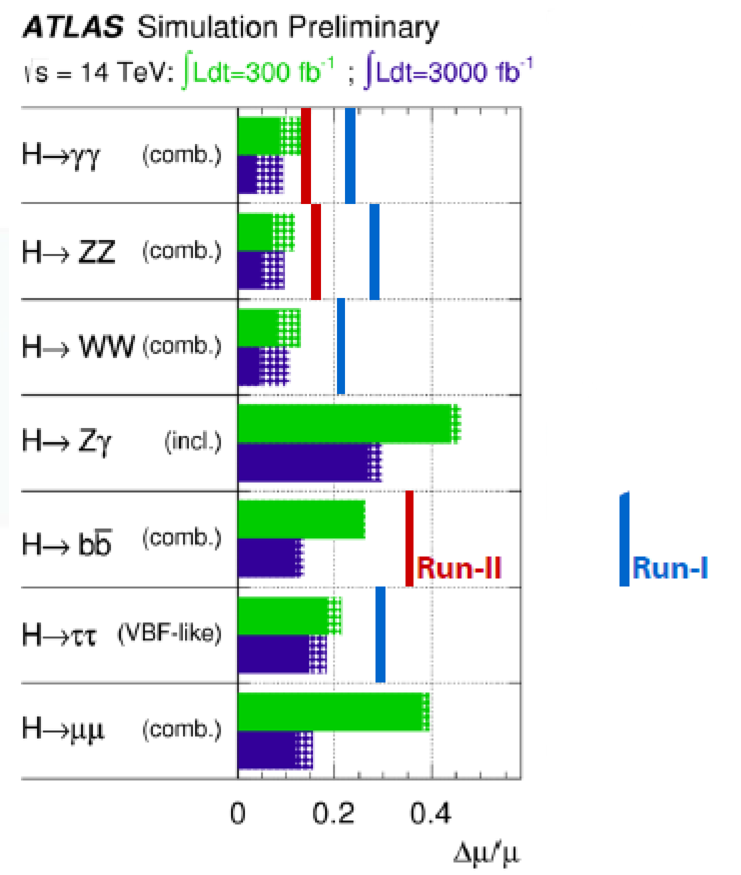
Pessimistic projections
Probably much better in both experimental and theory sides

Higgs Production modes

$\Delta\mu/\mu$	300 fb^{-1}		3000 fb^{-1}	
	All unc.	No theory unc.	All unc.	No theory unc.
$gg \to H$	0.12	0.06	0.11	0.04
VBF	0.18	0.15	0.15	0.09
WH	0.41	0.41	0.18	0.18
$qqZH$	0.80	0.79	0.28	0.27
$ggZH$	3.71	3.62	1.47	1.38
ttH	0.32	0.30	0.16	0.10

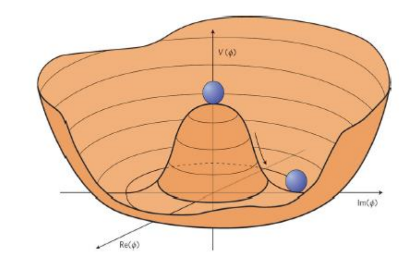
ATL-PHYS-PUB-2014-016

Higgs Decay modes



Dashed bands: theory

The Higgs boson self-coupling

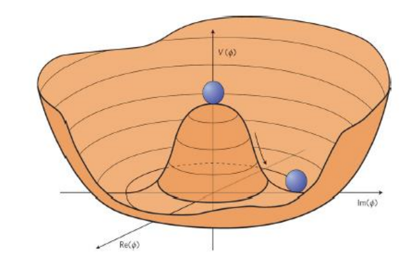


The Higgs potential

$$V_{SM}(H) = -\mu^2 \, |H|^2 + \lambda \, |H|^4$$

$$\lambda = \frac{m_H^2}{2v^2}$$ = ~0.12 in SM

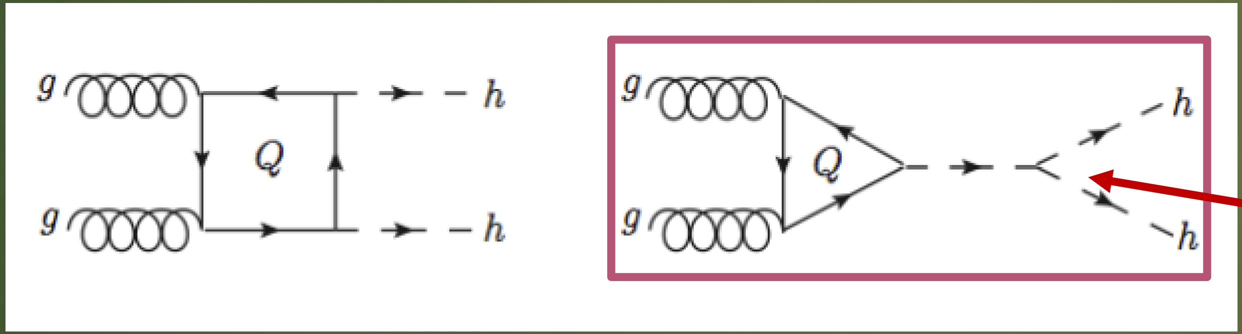
The Higgs boson self-coupling



The Higgs potential

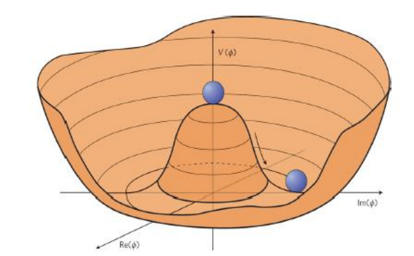
$$V_{SM}(H) = -\mu^2 |H|^2 + \lambda |H|^4$$

$$\lambda = \frac{m_H^2}{2v^2}$$ = ~0.12 in SM



In SM: gg->HH through two diagrams **interfering destructively**, XS=~40fb at 14TeV
Only one is related to trilinear coupling (3H)

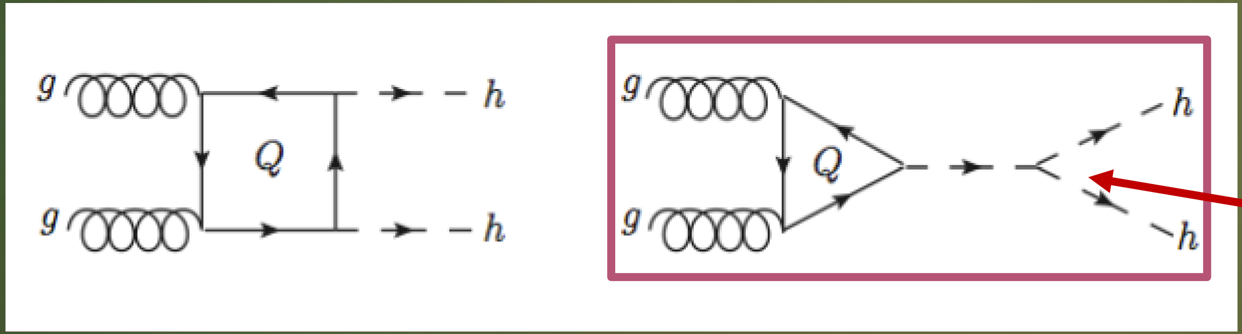
The Higgs boson self-coupling



The Higgs potential

$$V_{SM}(H) = -\mu^2 |H|^2 + \lambda |H|^4$$

$$\lambda = \frac{m_H^2}{2v^2}$$ = ~0.12 in SM

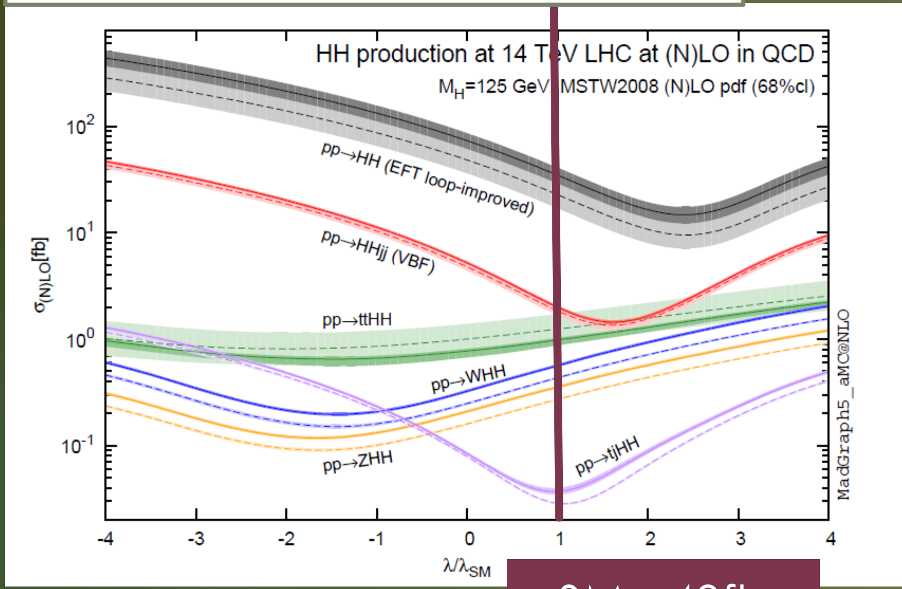


In SM: gg->HH through two diagrams **interfering destructively**, XS=~40fb at 14TeV
Only one is related to trilinear coupling (3H)

After detecting HH events, one has to unfold the box-diagram (dominant) contribution to reach trilinear coupling

The trilinear Higgs coupling

Phys.Lett. B732(2014) 142-149

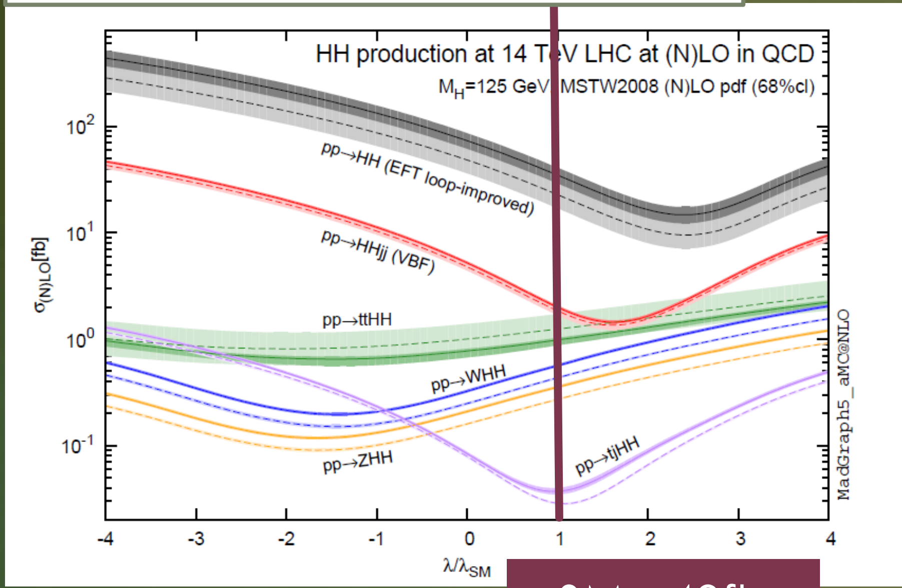


SM~ 40fb

Outside $\lambda=\lambda_{SM}$ the HH cross-section can increase by a factor up to 10 !
Interesting for BSM signals

The trilinear Higgs coupling

Phys.Lett. B732(2014) 142-149



SM~ 40fb

Outside $\lambda=\lambda_{SM}$ the HH cross-section can increase by a factor up to 10 !
Interesting for BSM signals

Expected yields in HL-LHC for 3000fb-1

Decay Channel	Branching Ratio	Total Yield (3000 fb^{-1})
$b\bar{b}+b\bar{b}$	33%	4.1×10^4
$b\bar{b}+W^+W^-$	25%	3.1×10^4
$b\bar{b}+\tau^+\tau^-$	7.4%	9.0×10^3
$W^+W^-+\tau^+\tau^-$	5.4%	6.6×10^3
$ZZ+b\bar{b}$	3.1%	3.8×10^3
$ZZ+W^+W^-$	1.2%	1.4×10^3
$\gamma\gamma+b\bar{b}$	0.3%	3.3×10^2
$\gamma\gamma+\gamma\gamma$	0.0010%	1

Low statistics in the cleanest channels. Combine several decay modes to enhance sensitivity

Trilinear coupling : HH->γγbb (BR=0.3%)

Cut-based analysis

ATL-PHYS-PUB-2017-001

Selection requirement	Efficiency (%)
trigger + ≥ 2 tight photons with $p_T > 25$ GeV	32.0
≥ 2 photon candidates with $p_T > 30$ GeV	27.4
≥ 2 jet candidates	21.7
≥ 2 b-jet candidates	7.73
< 6 jet candidates	7.46
isolated lepton veto	6.96
$0.4 < \Delta R_{b\bar{b}} < 2.0, \Delta R_{\gamma\gamma} < 2.0$	5.25
$122 < m_{\gamma\gamma} < 128$ GeV	3.95
$100 < m_{b\bar{b}} < 150$ GeV	2.90
H candidates $p_T > 80$ GeV	2.89

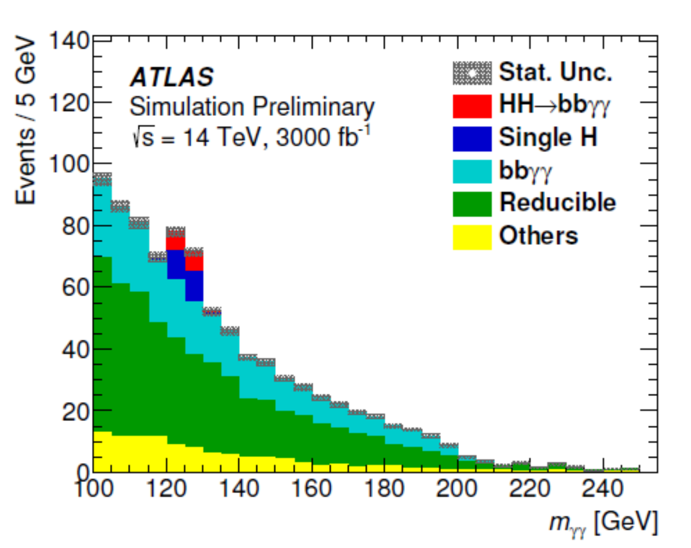
For 3000fb-1, one expects 9.54+-0.03 signal events with 90.9+-2.0 background events
Significance : 1.05 σ

Trilinear coupling : HH->γγbb (BR=0.3%)

ATL-PHYS-PUB-2017-001

Cut-based analysis

Selection requirement	Efficiency (%)
trigger + ≥ 2 tight photons with $p_T > 25$ GeV	32.0
≥ 2 photon candidates with $p_T > 30$ GeV	27.4
≥ 2 jet candidates	21.7
≥ 2 b-jet candidates	7.73
< 6 jet candidates	7.46
isolated lepton veto	6.96
$0.4 < \Delta R_{b\bar{b}} < 2.0, \Delta R_{\gamma\gamma} < 2.0$	5.25
$122 < m_{\gamma\gamma} < 128$ GeV	3.95
$100 < m_{b\bar{b}} < 150$ GeV	2.90
H candidates $p_T > 80$ GeV	2.89



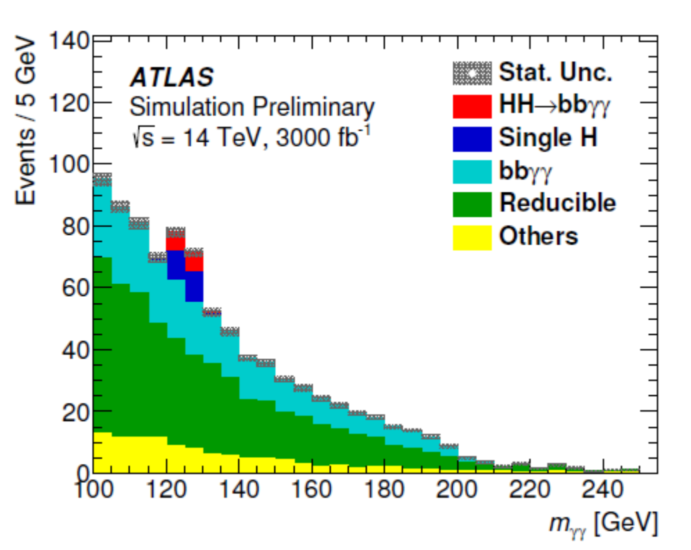
Main reducible backgrounds
bbγj, ccγγ,ccγj, bbjj, jjγγ

For 3000fb-1, one expects 9.54+-0.03 signal events with 90.9+-2.0 background events
Significance : 1.05 σ

Trilinear coupling : HH->γγbb (BR=0.3%)

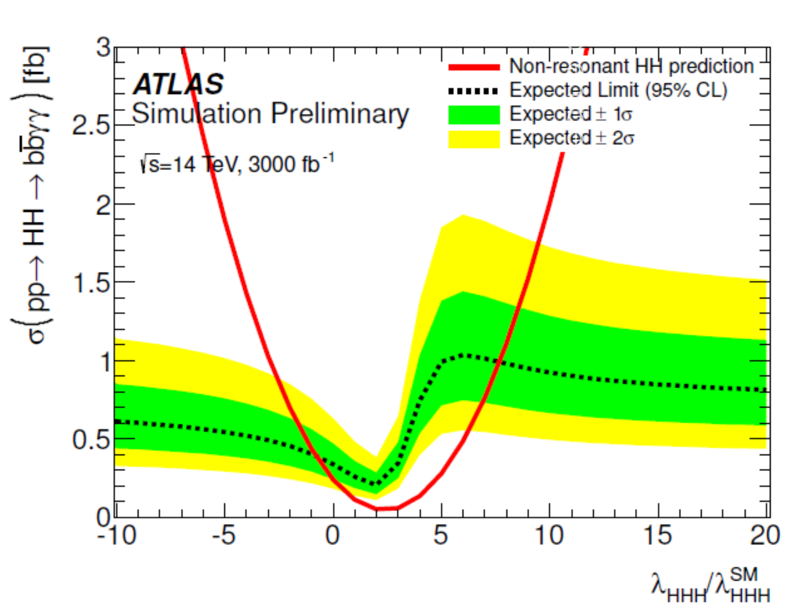
Cut-based analysis

Selection requirement	Efficiency (%)
trigger + $\geq$ 2 tight photons with $p_T > 25$ GeV	32.0
$\geq$ 2 photon candidates with $p_T > 30$ GeV	27.4
$\geq$ 2 jet candidates	21.7
$\geq$ 2 b-jet candidates	7.73
$<$ 6 jet candidates	7.46
isolated lepton veto	6.96
$0.4 < \Delta R_{b\bar{b}} < 2.0, \Delta R_{\gamma\gamma} < 2.0$	5.25
$122 < m_{\gamma\gamma} < 128$ GeV	3.95
$100 < m_{b\bar{b}} < 150$ GeV	2.90
H candidates $p_T > 80$ GeV	2.89



Main reducible backgrounds
bbγj, ccγγ,ccγj, bbjj, jjγγ

ATL-PHYS-PUB-2017-001



For 3000fb-1, one expects 9.54+-0.03 signal events with 90.9+-2.0 background events
Significance : 1.05 σ

-0.8< λ/λ^{SM} < 7.7

Trilinear couplings: HH cumulative

Channel	Significance	Coupling limit	BR	Remarks
HH->bbγγ	1.05 σ	$-0.8<\lambda/\lambda_{SM}<7.7$	0.3%	Reducible background
HH->bbbb	0.6 σ	$-3.5<\lambda/\lambda_{SM}<11.0$	33.%	Ttbar dominant. Sensitivity to PT jet threshold
HH->bbττ	0.6 σ	$-4<\lambda/\lambda_{SM}<12.0$	7.4%	Several categories combined
ttHH (HH->4b)	0.35 σ			Main background mistagged c-jets

For the (near) future:
→Need to include more channels
→Need to optimize the analyses
→Special care to fight the reducible backgrounds
→Develop intelligent MV techniques

Higgs production via VectorBosonFusion H->ZZ*->4leptons

4 leptons (e, μ) and 2 jets
P_T(jet)>30GeV, Mjj>130GeV
Leptons within |η|<2.4, jets up to |η|=4

BDT to distinguish VBF from ggF
Simultaneous fit of 3 BDT regions to take profit from different S/B ratios

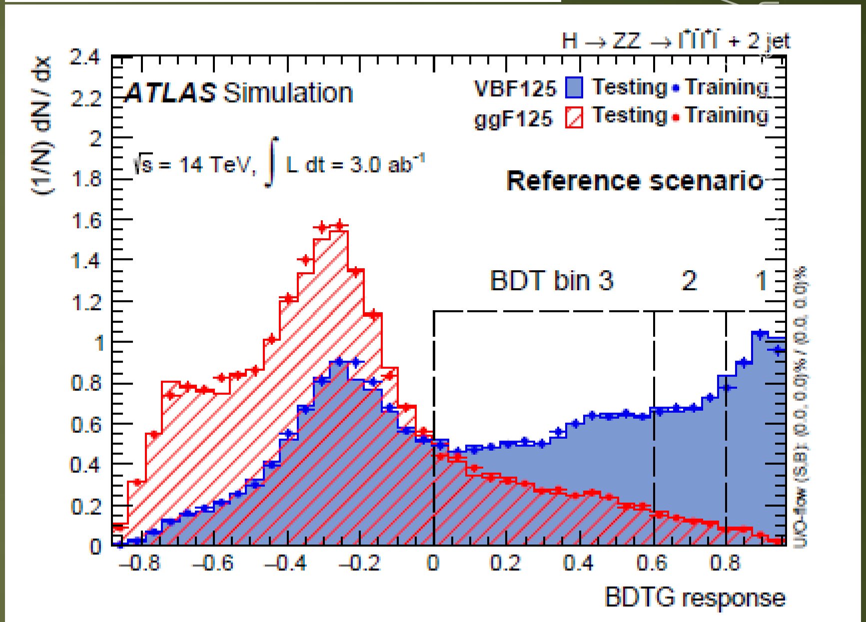
Tracker extension to |η|=4 :
+14% on Z and +6% on Δμ/μ
wrt current geometry

Higgs production via VectorBosonFusion H->ZZ*->4leptons

4 leptons (e, μ) and 2 jets
P_T(jet)>30GeV, Mjj>130GeV
Leptons within |η|<2.4, jets up to |η|=4

BDT to distinguish VBF from ggF
Simultaneous fit of 3 BDT regions to take profit from different S/B ratios

ATL-PHYS-PUB-2016-008



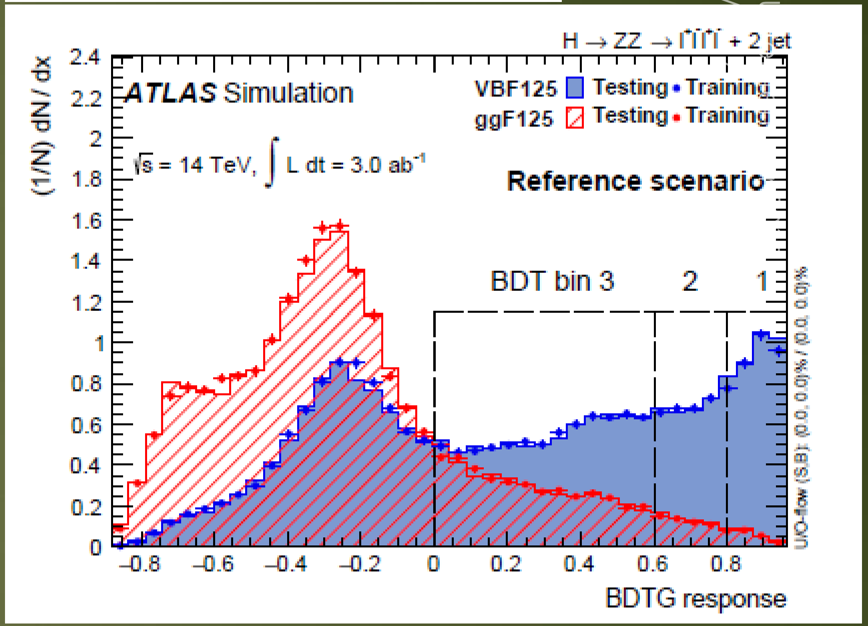
Tracker extension to |η|=4 :
+14% on Z and +6% on Δμ/μ
wrt current geometry

Higgs production via VectorBosonFusion H->ZZ*->4leptons

4 leptons (e, μ) and 2 jets
P_T(jet)>30GeV, Mjj>130GeV
Leptons within |η|<2.4, jets up to |η|=4

BDT to distinguish VBF from ggF
Simultaneous fit of 3 BDT regions to take profit from different S/B ratios

ATL-PHYS-PUB-2016-008



Statistical uncertainty only		With 3000 fb-1	
VBF + 2j events	ggF + 2j events	Z_0 (VBF vs. ggF)	$\Delta\mu/\mu$
237 (206)	324 (159)	11.4	±0.134

Statistical uncertainty + QCD scale var. uncertainty (S-T method)			
VBF + 2j events	ggF + 2j events	Z_0 (VBF vs. ggF)	$\Delta\mu/\mu$
237	324	7.6	±0.167

Tracker extension to |η|=4 :
+14% on Z and +6% on Δμ/μ
wrt current geometry

Higgs production via VectorBosonFusion H->WW*->4leptons

No W resonant mass. High ttbar background
PTJet>60(50) GeV in opposite hemispheres
Require rapidity Gap, Mjj>1250GeV
Cut based analysis

Using jets up to |η|=4 : up to 50% gain in significance

Higgs production via VectorBosonFusion H->WW*->4leptons

ATL-PHYS-PUB-2016-018

No W resonant mass. High ttbar background
PTJet>60(50) GeV in opposite hemispheres
Require rapidity Gap, Mjj>1250GeV
Cut based analysis

N_{VBF}	N_{bkg}	N_{ggF}	N_{WW}	N_{VV}	$N_{t\bar{t}}$	N_t	N_{Z/γ^*+jets}	N_{W+jets}
200	410	57	48	55	146	20	27	0

Δ_μ			Significance (σ)		
Full	1/2	None	Full	1/2	None
0.20	0.16	0.14	5.7	7.1	8.0

Sensitivity given for 3 theoretical uncertainties scenarii

Using jets up to |η|=4 : up to 50% gain in significance

Higgs production via VectorBosonFusion H->WW*->4leptons

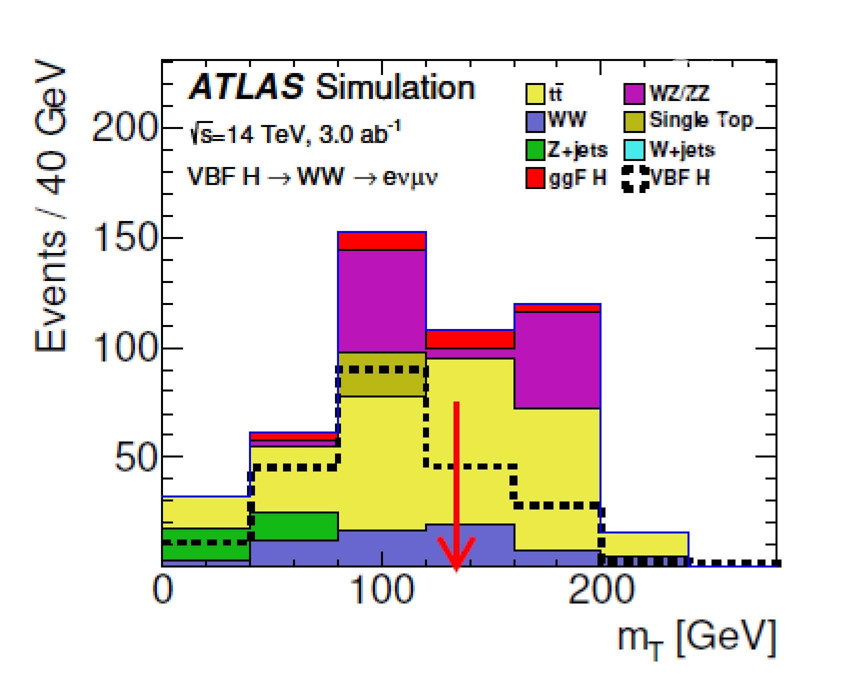
No W resonant mass. High ttbar background
PTJet>60(50) GeV in opposite hemispheres
Require rapidity Gap, Mjj>1250GeV
Cut based analysis

N_{VBF}	N_{bkg}	N_{ggF}	N_{WW}	N_{VV}	$N_{t\bar{t}}$	N_t	N_{Z/γ^*+jets}	N_{W+jets}
200	410	57	48	55	146	20	27	0

Δ_μ			Significance (σ)		
Full	1/2	None	Full	1/2	None
0.20	0.16	0.14	5.7	7.1	8.0

Sensitivity given for 3 theoretical uncertainties scenarii

ATL-PHYS-PUB-2016-018



$$m_T = \sqrt{(E_T^{\ell\ell} + E_T^{miss})^2 - |p_T^{\ell\ell} + E_T^{miss}|^2}$$

Using jets up to |η|=4 : up to 50% gain in significance

Higgs coupling to light leptons: H->μμ

Coupling to second generation
Candle for HL-LHC
Small BR ~ 2x10-4
ATLAS Run2 (36 fb-1) 13 TeV : μ=-0.1+-1.5

ATL-PHYS-PUB-2013-014

Higgs coupling to light leptons: H->μμ

Coupling to second generation
Candle for HL-LHC
Small BR ~ 2x10-4
ATLAS Run2 (36 fb-1) 13 TeV : μ=-0.1+-1.5

Projections for HL-LHC
→With Run 1-like cuts, cut based analysis
→Main background from Z/γ*, ttbar and WW

With 3000 fb-1 → 7.0 σ
Δμ/μ → +- 20%

ATL-PHYS-PUB-2013-014

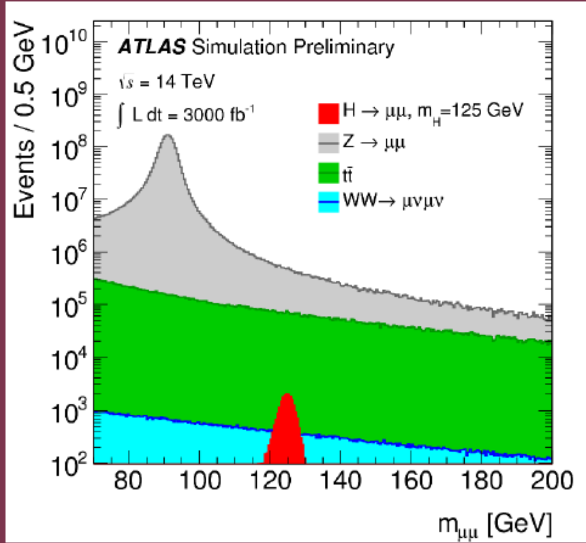
Higgs coupling to light leptons: H->μμ

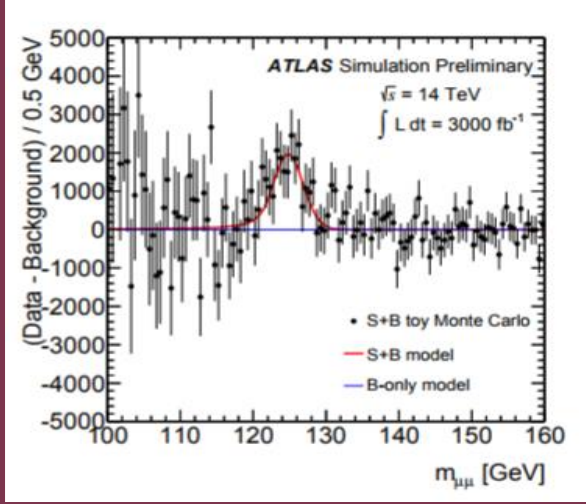
Coupling to second generation
Candle for HL-LHC
Small BR ~ 2x10-4
ATLAS Run2 (36 fb-1) 13 TeV : μ=-0.1+-1.5

Projections for HL-LHC
→With Run 1-like cuts, cut based analysis
→Main background from Z/γ*, ttbar and WW

With 3000 fb-1 → 7.0 σ
Δμ/μ → +- 20%

→Optimized analysis ready, coming soon public in the Muon –TDR.





ATL-PHYS-PUB-2013-014

Higgs coupling to light quarks H->J/Ψ γ

Allows to probe the Higgs coupling to c quark
Very small expected yield in SM, room for BSM

Two OS muons Pt> 20GeV
|M μμ-M (J/Ψ)| <0.2 GeV
Isolated muons and photon
PTγ >36GeV
Δφ(μμ,γ) > 0.5

ATL-PHYS-PUB-2015-043

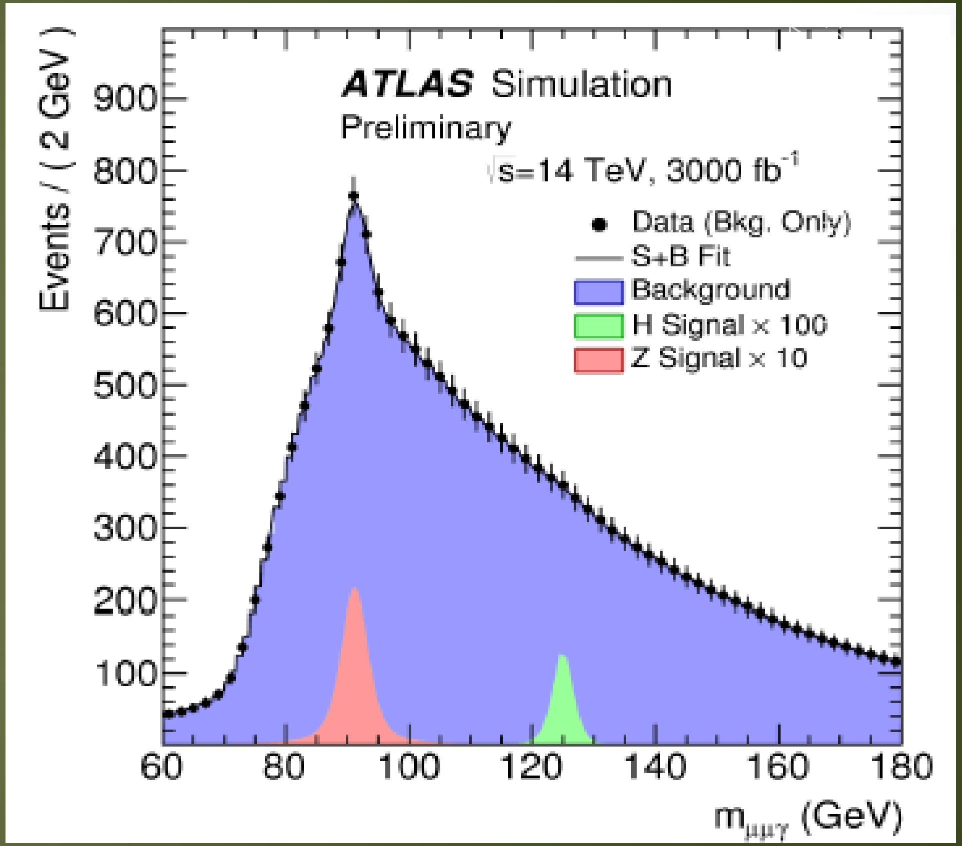
Higgs coupling to light quarks H->J/Ψ γ

Allows to probe the Higgs coupling to c quark
Very small expected yield in SM, room for BSM

Two OS muons Pt> 20GeV
|M μμ-M (J/Ψ)| <0.2 GeV
Isolated muons and photon
PTγ >36GeV
Δφ(μμ,γ) > 0.5

	Expected branching ratio limit at 95% CL		
	$\mathcal{B}(H \to J/\psi\gamma)\,[10^{-6}]$		$\mathcal{B}(Z \to J/\psi\gamma)\,[10^{-7}]$
	Cut Based	Multivariate Analysis	Cut Based
$300\ \text{fb}^{-1}$	185^{+81}_{-52}	153^{+69}_{-43}	$7.0^{+2.7}_{-2.0}$
$3000\ \text{fb}^{-1}$	55^{+24}_{-15}	44^{+19}_{-12}	$4.4^{+1.9}_{-1.1}$
	Standard Model expectation		
	$\mathcal{B}(H \to J/\psi\gamma)\,[10^{-6}]$		$\mathcal{B}(Z \to J/\psi\gamma)\,[10^{-7}]$
	2.9 ± 0.2		0.80 ± 0.05

H-> J/Ψγ : 15xSM Z->J/Ψ γ : 4xSM



ATL-PHYS-PUB-2015-043

Vector Boson Scattering

Check the damping of the longitudinal component boson cross section divergence around ~1TeV

Look at W+-W+-JJ : highest EW production cross-section wrt QCD

VV->WW+ 2jets (V=Z or W)
2 same sign leptons in |η|<4 and pt>25GeV
2 jets in |η|<4.5 and Pt>30 GeV

Profit a lot from ITK extension

Vector Boson Scattering

Check the damping of the longitudinal component boson cross section divergence around ~1TeV

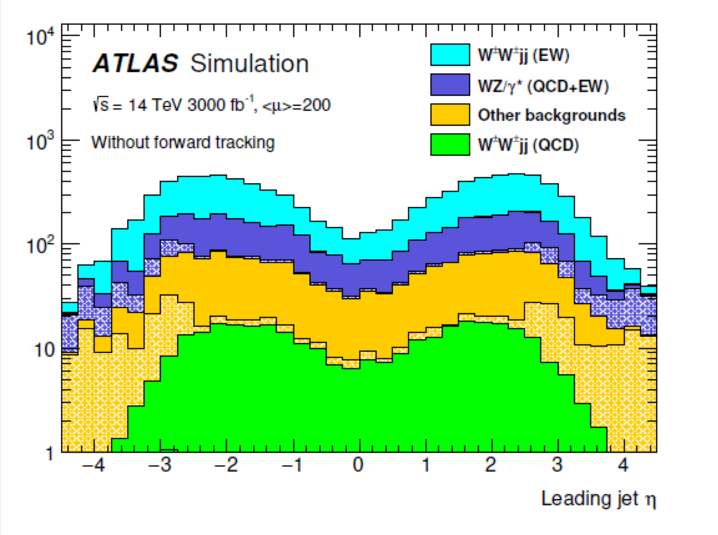
Look at W+-W+-JJ : highest EW production cross-section wrt QCD

VV->WW+ 2jets (V=Z or W)
2 same sign leptons in |η|<4 and pt>25GeV
2 jets in |η|<4.5 and Pt>30 GeV

Z_{σ_B}	$\Delta\sigma/\sigma$
11.3 ± 0.6	5.9%

CERN-LHCC-2015-02

Profit a lot from ITK extension



Vector Boson Scattering

Check the damping of the longitudinal component boson cross section divergence around ~1TeV

Since : optimization of the analysis to deal with pileup

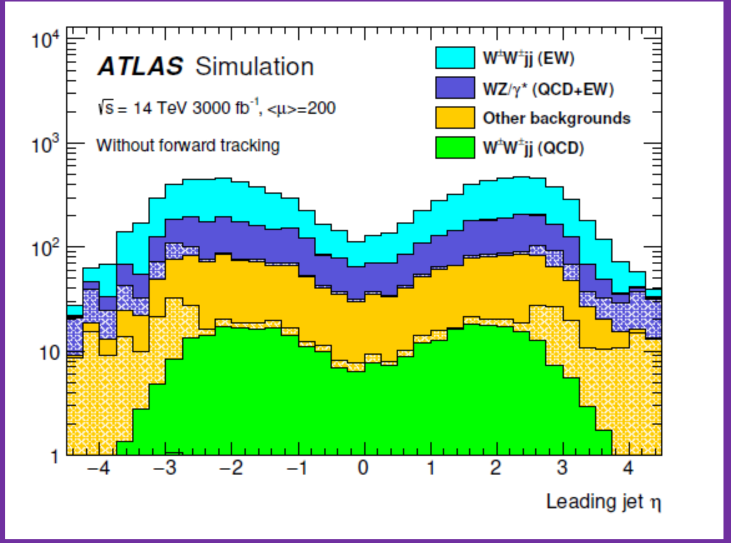
Look at W+-W+-JJ : highest EW production cross-section wrt QCD

ATL-TDR-025 · LHCC-2017-005

VV->WW+ 2jets (V=Z or W)
2 same sign leptons in |η|<4 and pt>25GeV
2 jets in |η|<4.5 and Pt>30 GeV

Z_{σ_B}	$\Delta\sigma/\sigma$
11.3 ± 0.6	5.9%

CERN-LHCC-2015-02



Profit a lot from ITK extension

Conclusions

---HL-LHC will reach unprecedented running conditions, very challenging for the detectors and offering exciting physics perspectives

--- Major upgrades are in preparation for the ATLAS detectors for robuster, faster, lighter and wider components

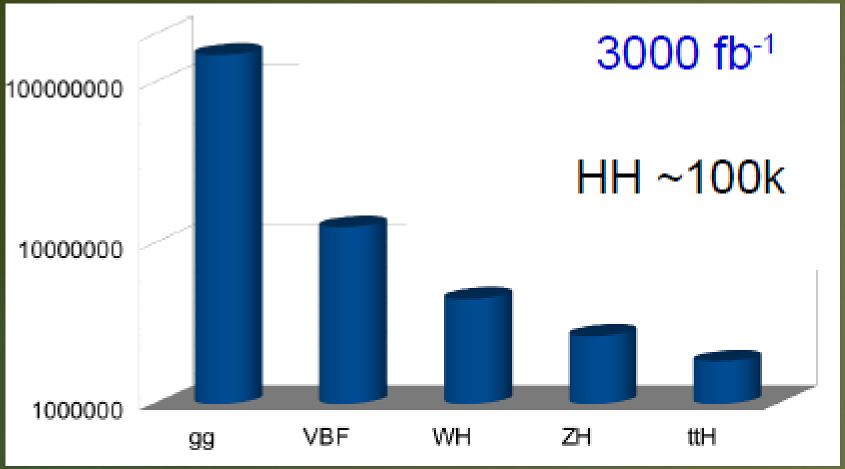
--- Various Physics prospects are under study in ATLAS with simulations that are continuously optimized.

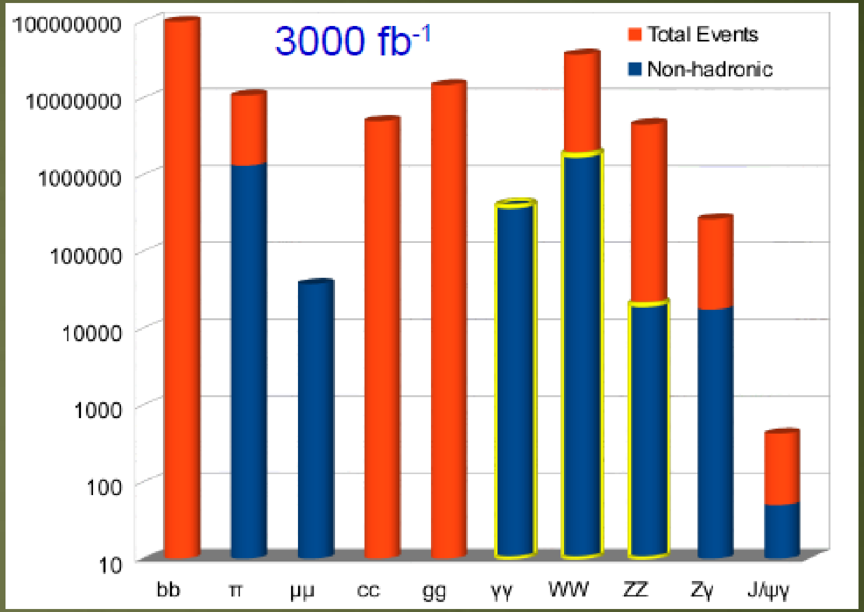
--- Several properties of the Higgs sector will be measured with high precision, testing further the SM and constraining BSM

--- The HL-LHC program is a high-value and flag program of the HEP scientific community.

BACKUP

Few numbers on expected events with 3000fb-1





Decay Channel	Branching Ratio	Total Yield (3000 fb^{-1})
$b\bar{b} + b\bar{b}$	33%	40,000
$b\bar{b} + W^+W^-$	25%	31,000
$b\bar{b} + \tau^+\tau^-$	7.3%	8,900
$ZZ + b\bar{b}$	3.1%	3,800
$W^+W^- + \tau^+\tau^-$	2.7%	3,300
$ZZ + W^+W^-$	1.1%	1,300
$\gamma\gamma + b\bar{b}$	0.26%	320
$\gamma\gamma + \gamma\gamma$	0.0010%	1.2

HH decays

Tracks & vertex finding

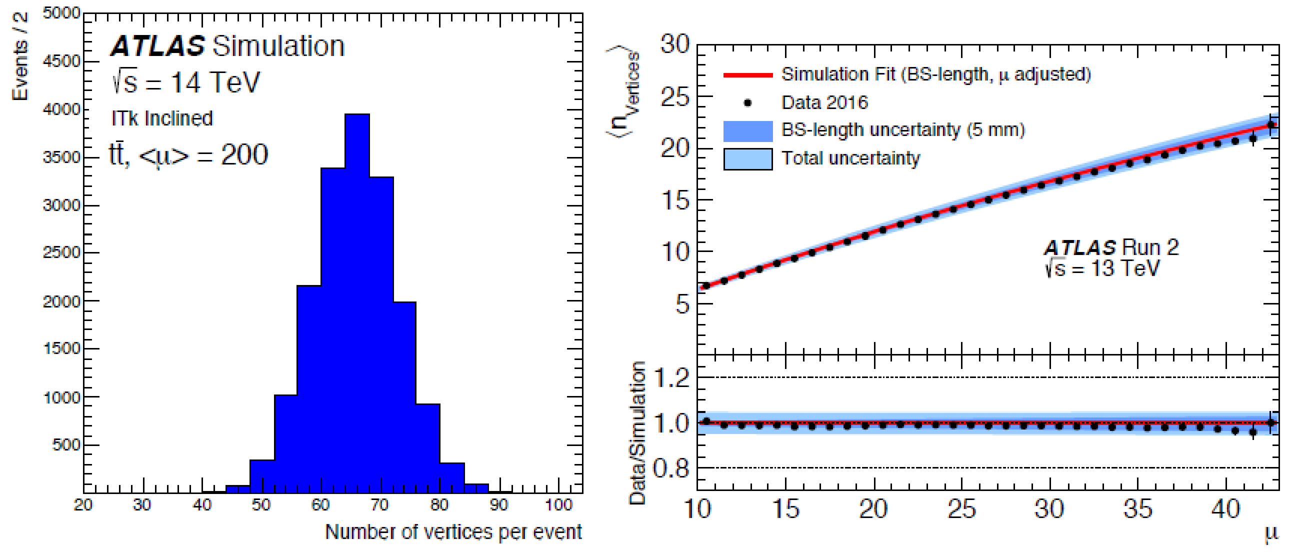
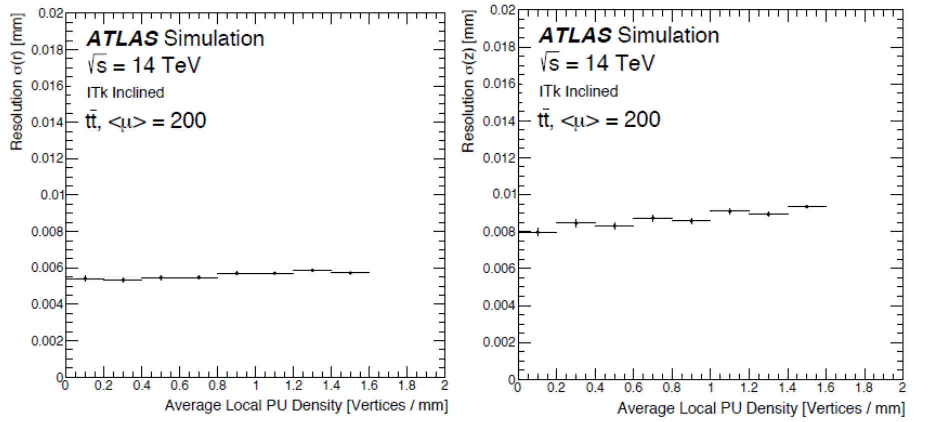
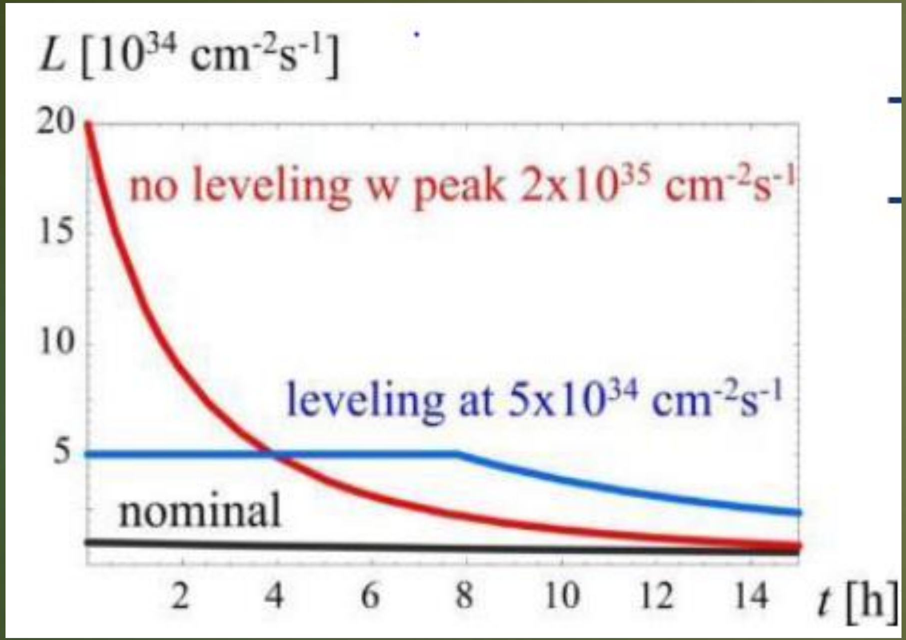


Figure 4.12: **Left:** The number of primary reconstructed vertices per event in a $t\bar{t}$ sample with average $\mu = 200$. **Right:** The number of reconstructed vertices versus μ for Run-2.



Level the luminosity



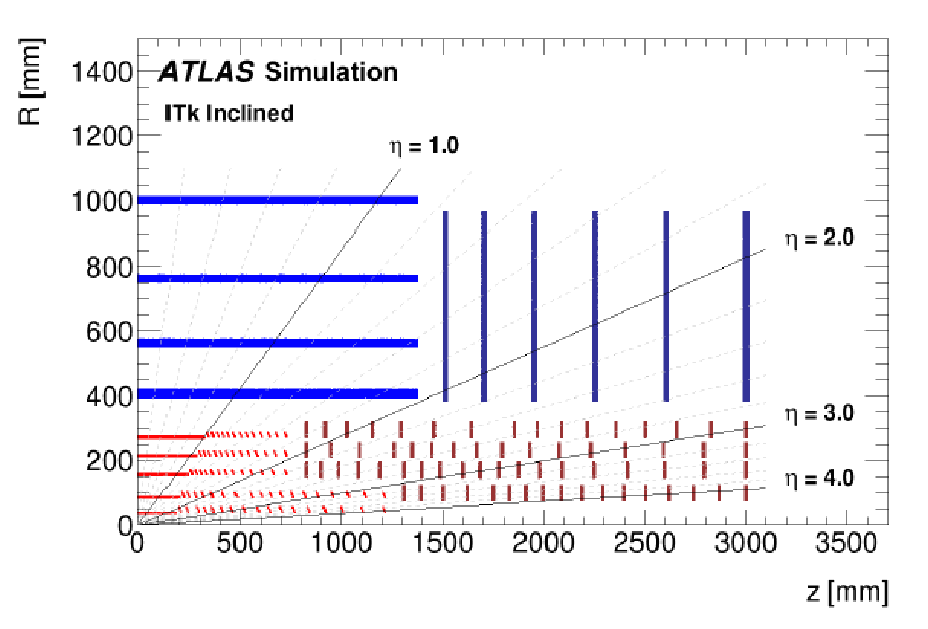
Tune the “crab” angleat Interaction points to

→keep luminosity ~constant along the fil
→Minimize the pileup

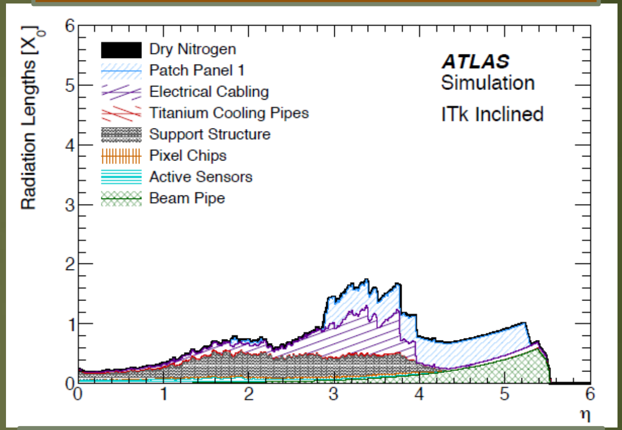
Leveling at 5x10**34 -> pileup ~140
Plan to register 3-4 fb-1/day
250-300 fb-1/year

Can go up to 7x10**34-> pileup ~200

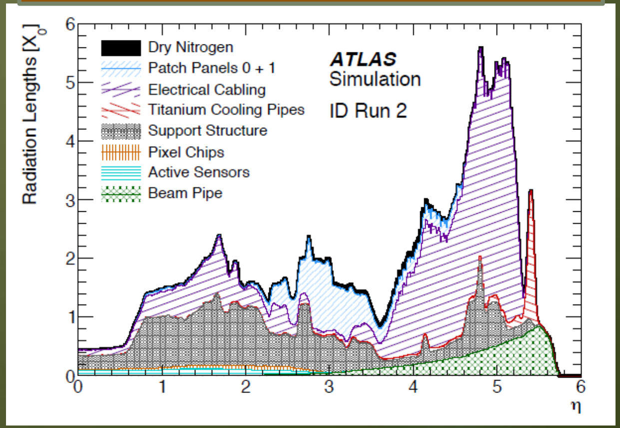
Inclined geometry.



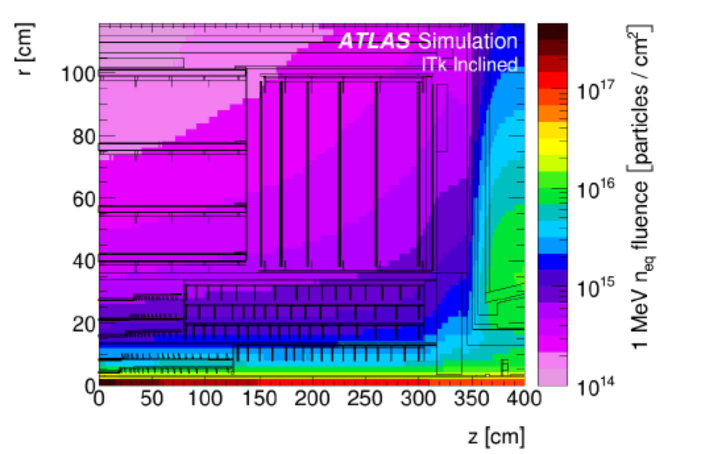
Material in Inclined



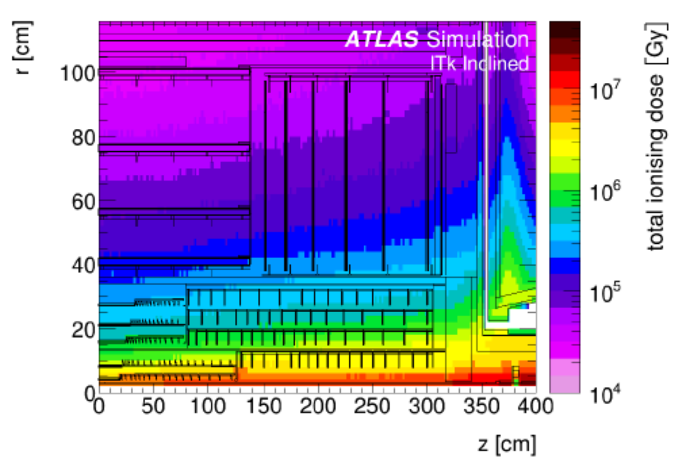
Vs current material



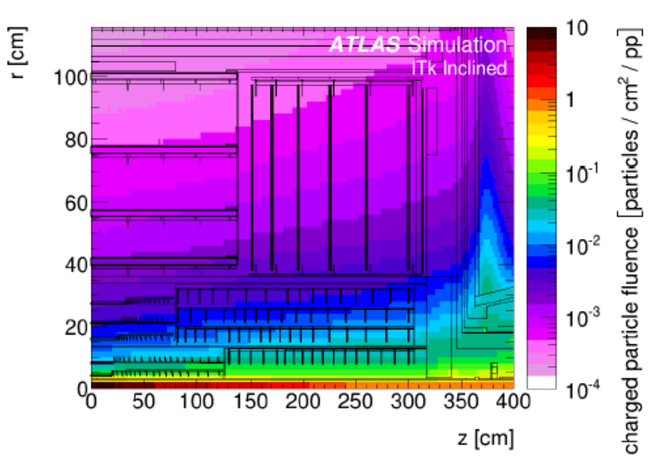
The expected fluences



1 MeV neutron equivalent

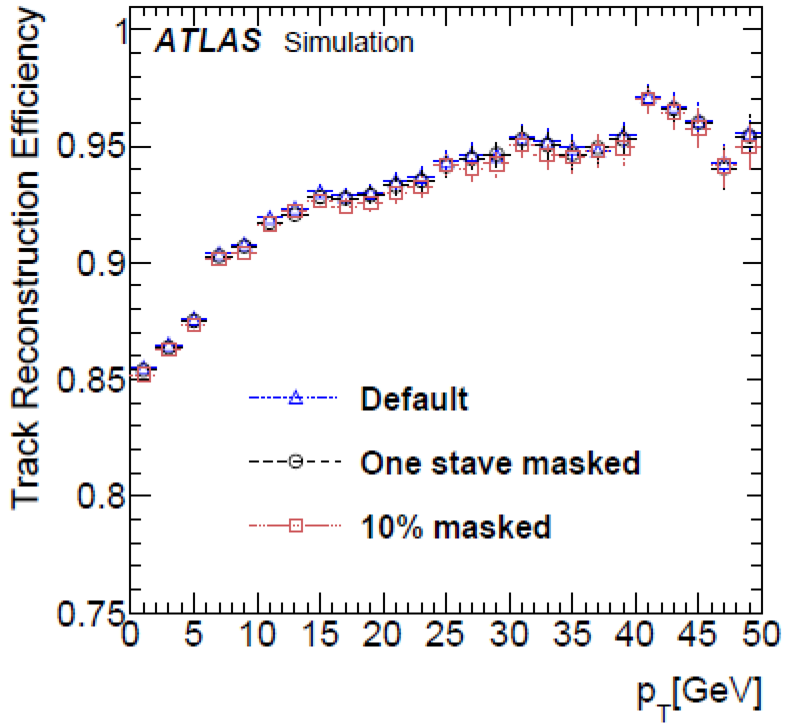


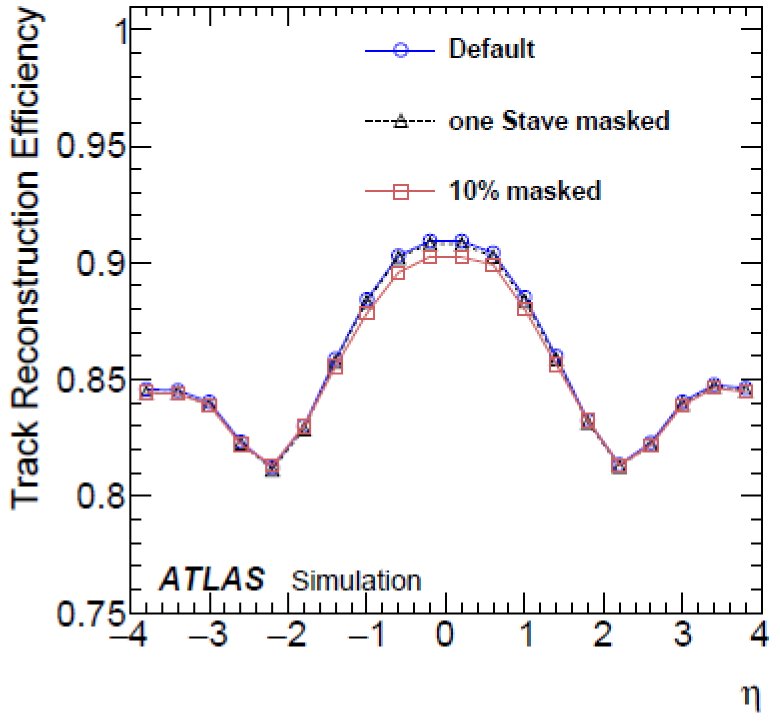
Total ionizing dose



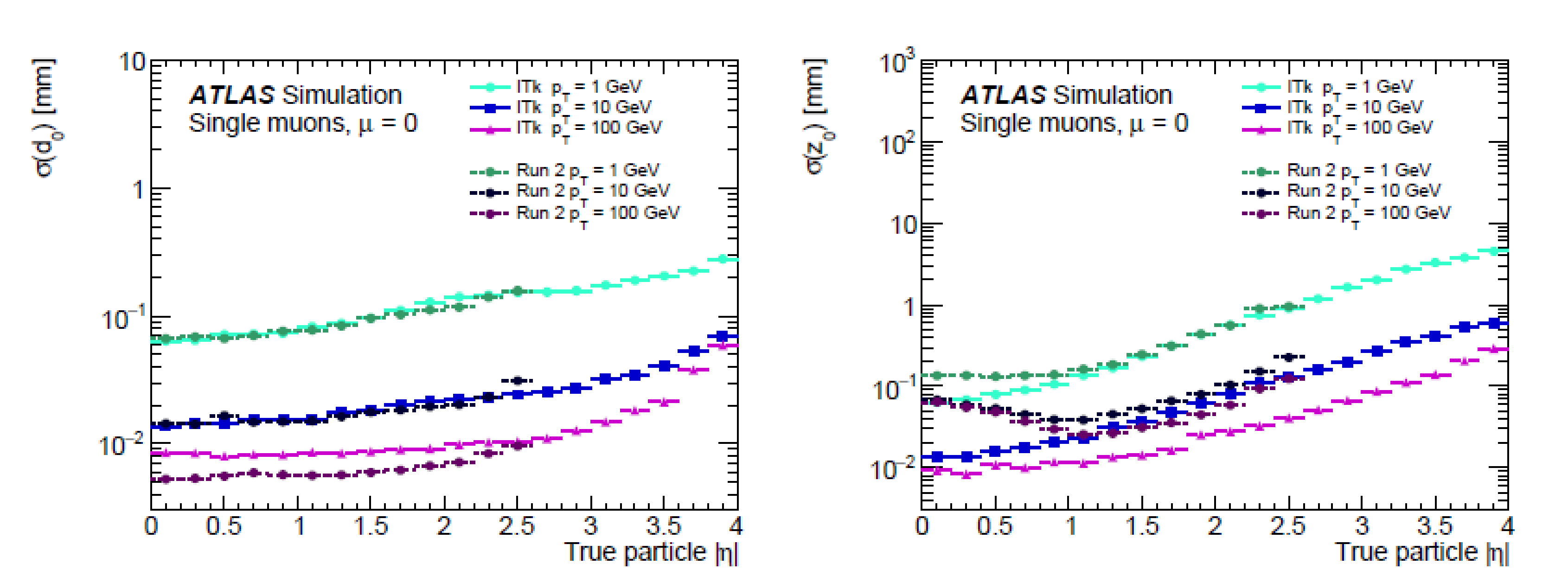
Charge particle fluence

Track reconstruction efficiency vs PT and η





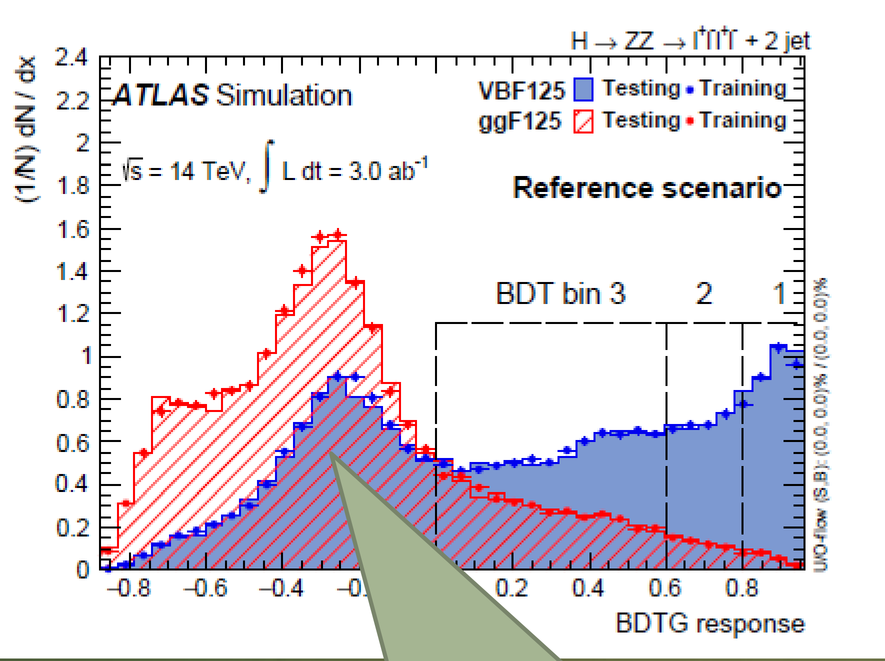
Track resolutions



Transverse (d0) impact resolution : as in Run2 for Pt<100GeV
Longitudinal (z0) impact resolution: Better than Run2 (smaller pixel pitch)
Momentum resolution : 50% better than Run2 thanks to the higher nb of strip layers, degrades in forward regions

VBF H->ZZ*->4l

ATL-PHYS-PUB-2016-008



Pile-up impurity (%)		
BDTG > 0.8	0.6 < BDTG < 0.8	0 < BDTG < 0.6
VBF Sample		
2.0	4.6	13.1
ggF Sample		
23.2	37.9	52.1

Events with >=1 pileup jet, in ggF or VBF

H->J/ψ γ

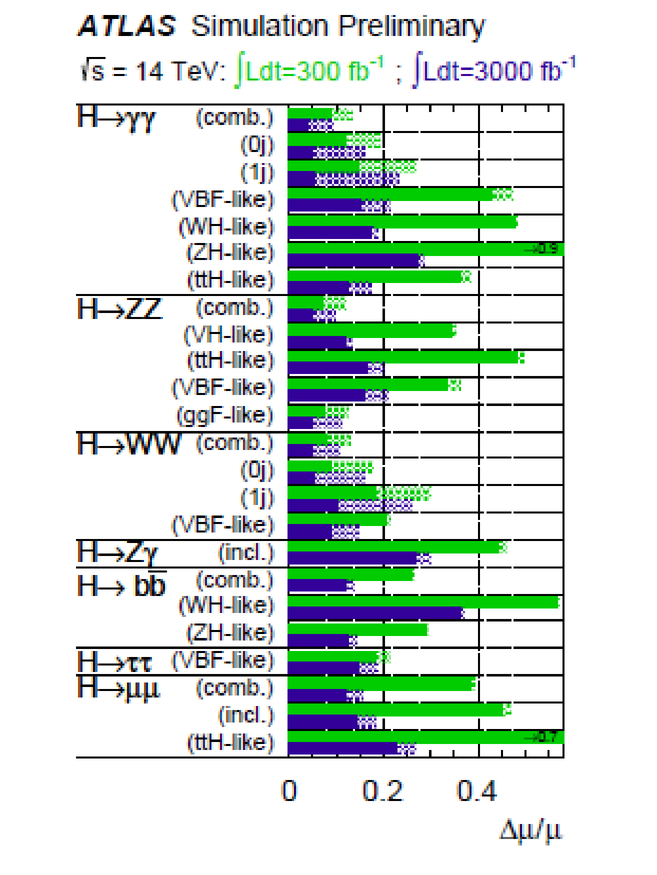
$J/\psi\,\gamma$ Final state						
	Expected Background				Signal	
	Inclusive QCD Mass Range [GeV]		Other Backgrounds			
	80-100	115-135	$Z \to \mu^+\mu^-\gamma$	$H_{\gamma^*\gamma} \to \mu^+\mu^-\gamma$	Z	H
Cut Based Analysis	7800±500	3500±400	780 ±100	15.1 ±1.4	50±3	3.2±0.1
Multivariate Analysis		1700±200		13.7 ±1.3		2.9±0.1

	Expected $\sigma \times \mathcal{B}$ limit at 95% CL $\boldsymbol{\sigma(pp \to H) \times \mathcal{B}(H \to J/\psi\gamma)}$ **[fb]**	
	Cut Based	Multivariate Analysis
300 fb^{-1}	$10.4^{+2.9}_{-4.5}$	$8.6^{+2.4}_{-3.7}$
3000 fb^{-1}	$3.1^{+0.9}_{-1.3}$	$2.5^{+0.7}_{-1.0}$

Higgs couplings: Extrapolating from Run1

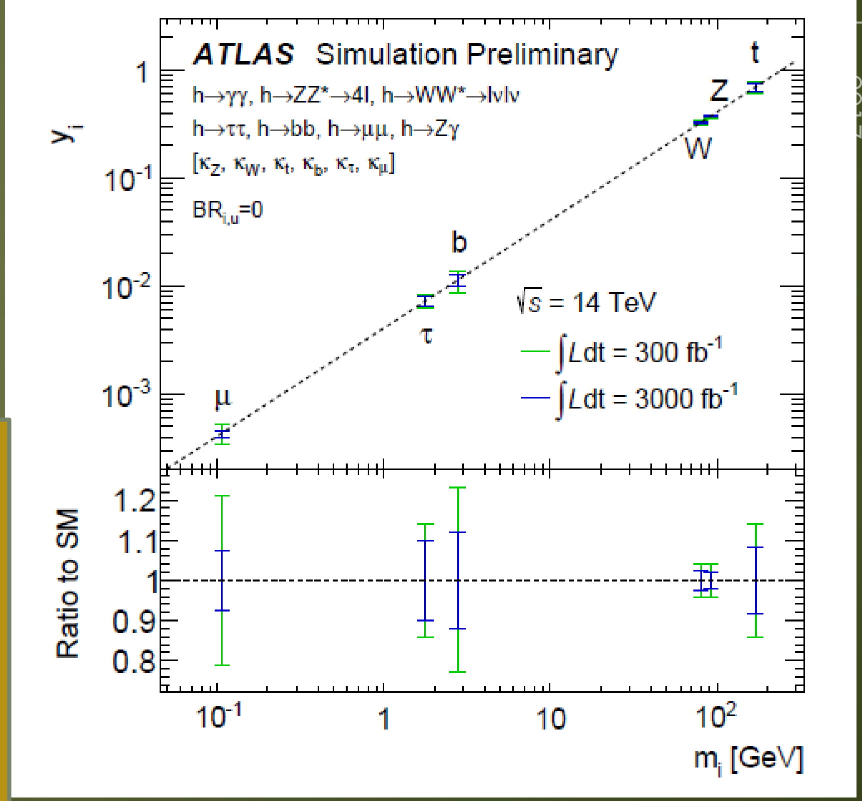
Higgs Decay modes per production

ATL-PHYS-PUB-2014-016

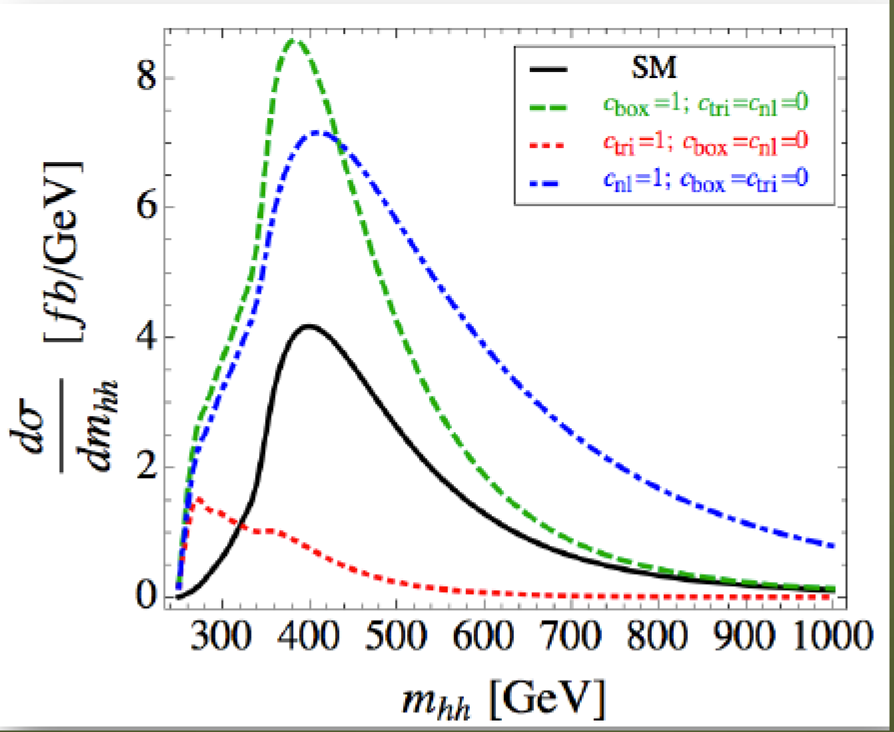


With 3000fb-1 we will achieve
+-3% on bosons couplings
~+-10% on fermion couplings

Bosons	Fermions
$y_{V,i} = \sqrt{\kappa_{V,i}\frac{g_{V,i}}{2v}} = \sqrt{\kappa_{V,i}}\frac{m_{V,i}}{v}$	$y_{F,i} = \kappa_{F,i}\frac{g_{F,i}}{\sqrt{2}} = \kappa_{F,i}\frac{m_{F,i}}{v}$

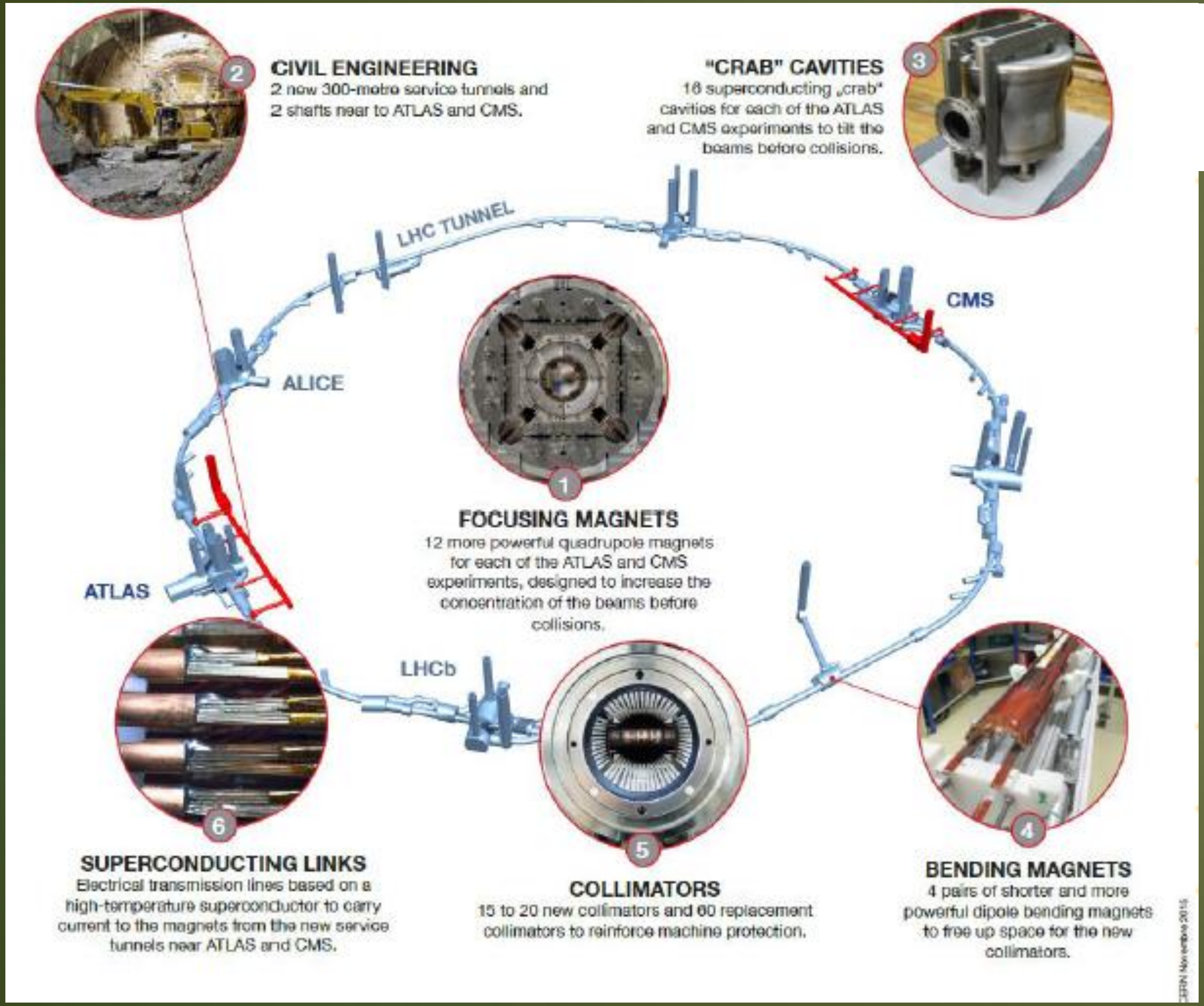


Distinguish BSM from SM in HH looking at Mhh distribution



C.R.Chen and Ian Low

The tools for HL-LHC : the machine



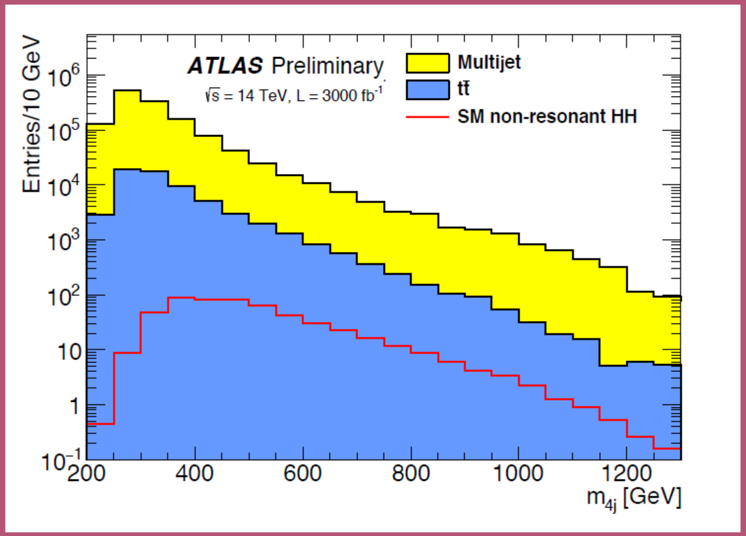
HiLumi
HL-LHC PROJECT

To achieve high luminosities

1) Higher injected power (Linac4 under commissioning)
2) Better focusing (Nb_3Sn triplets)
3) Powerful and longer collimation needs more free space. New 11T shorter dipoles introduced in some places
4) Level the delivered luminosity for the experiment (crab cavities) to deal with rates.

Trilinear couplings: HH->4b (BR=33%)

Require four b-tag jets
Total acceptance ~4%
95% of the background: multijets
5% : ttbar events



ATL-PHYS-PUB-2016-024

Jet Threshold [GeV]	Background Systematics	σ/σ_{SM} 95% Exclusion	$\lambda_{HHH}/\lambda_{HHH}^{SM}$ Lower Limit	$\lambda_{HHH}/\lambda_{HHH}^{SM}$ Upper Limit
30 GeV	Negligible	1.5	0.2	7
30 GeV	Current	5.2	-3.5	11
75 GeV	Negligible	2.0	-3.4	12
75 GeV	Current	11.5	-7.4	14

Sensitivity to P_T(jet) and to systematics

H->μμ: Mass resolution