Search for the Standard Model Higgs boson decaying into $b\bar{b}$ and produced in association with a top quark pair in the ATLAS experiment

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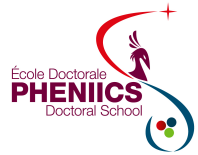
CEA Saclay

July 8, 2016



- Master : HEP in Ecole Polytechnique
- Institute : SPP

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- Institute : SPP
- Supervisors ... $\sim$ 15 years ago

Frederic Deliot

Henri Bachacou

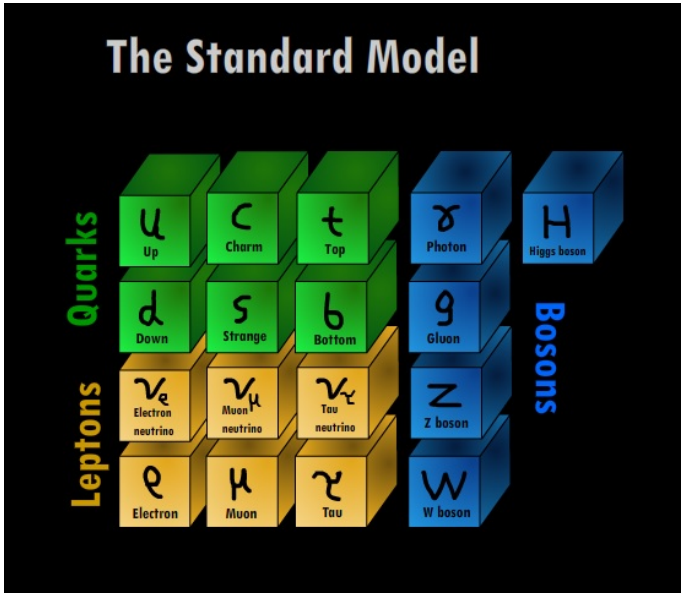
- Thesis tags : Higgs boson, ATLAS, LHC

The Standard Model

Particle physics is described by the Standard Model (SM)

The SM is made of

- particles of matter, quarks and leptons
- force carriers, gluon, photon, W and Z bosons
- Higgs boson



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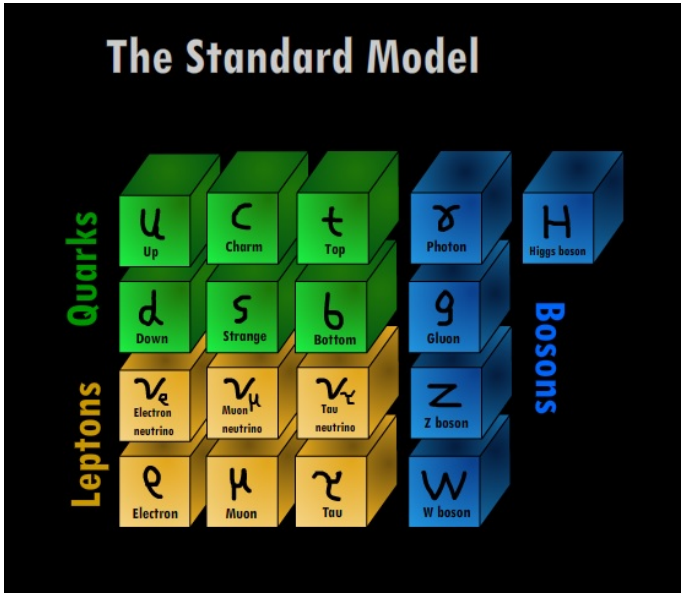


Measurements in laboratories are in agreement with the SM predictions

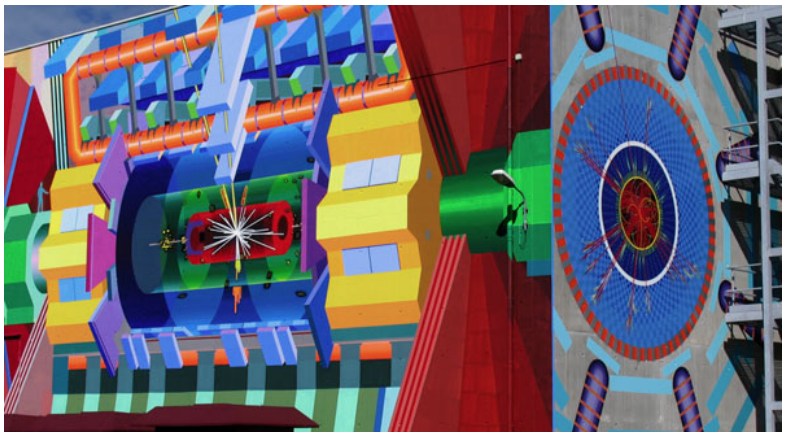
Is the SM the theory of everything ?

No

The ATLAS Experiment at the LHC

Elementary particles are studied in detail in the ATLAS experiment

ATLAS detector records pp collisions provided by the LHC



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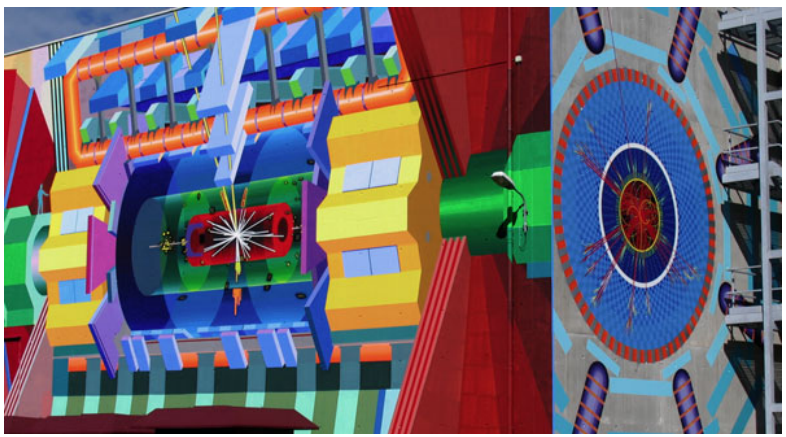
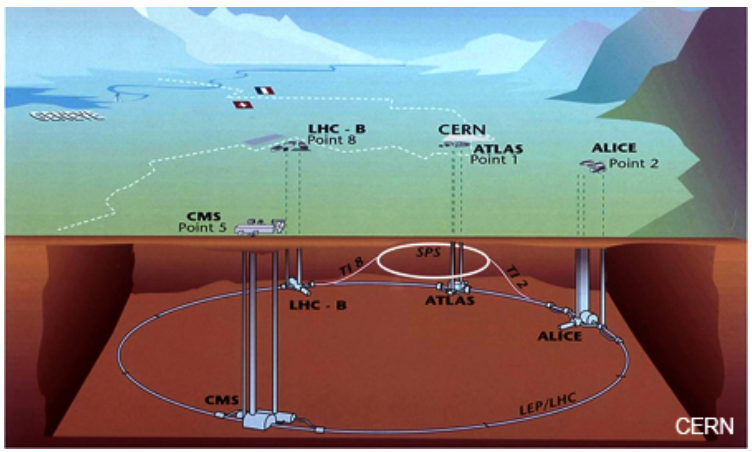
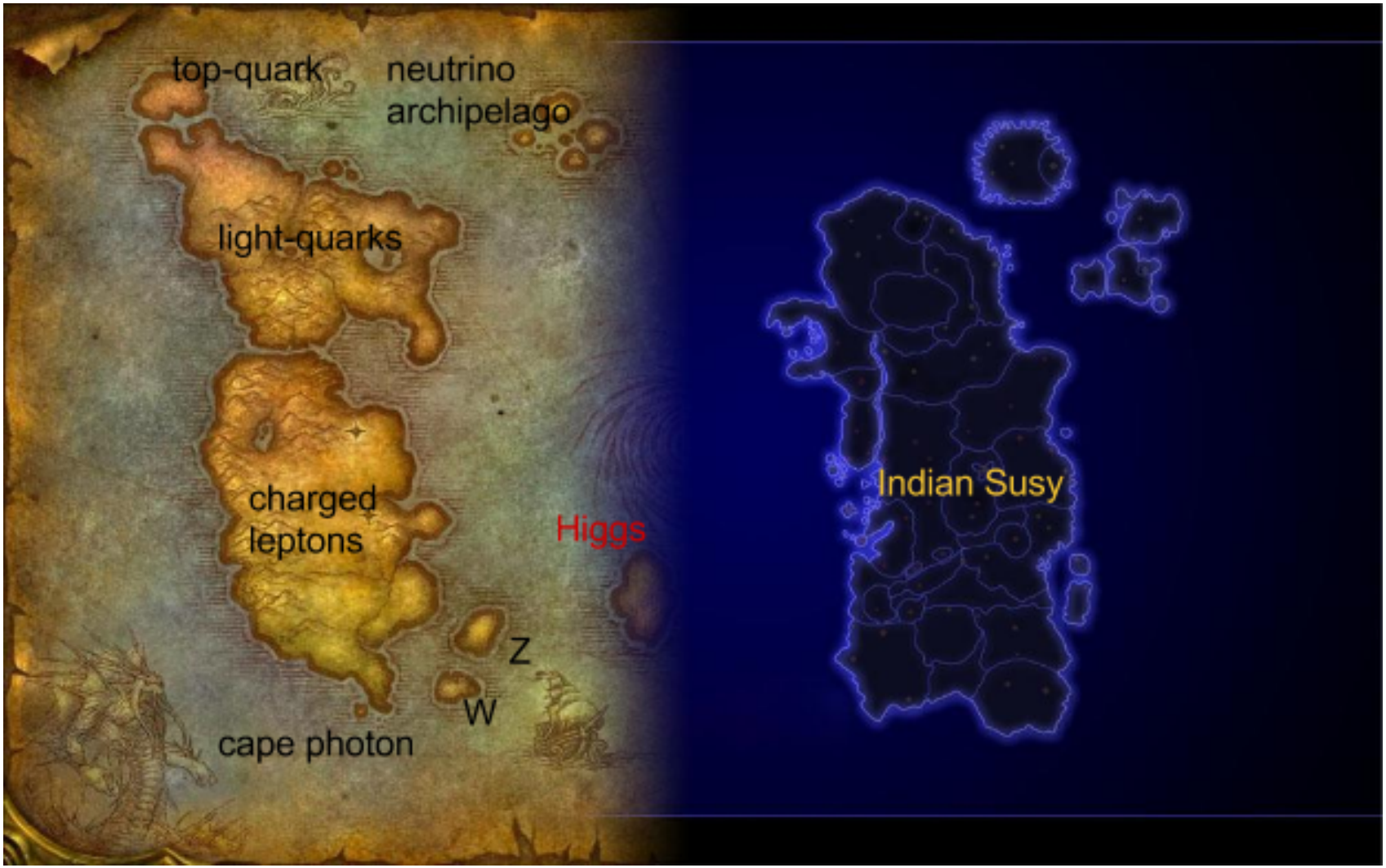




LHC 27 km ring that accelerates proton/ions beams and makes them collide in 4 interaction points

Map of Experimental Particle Physics



The Higgs Coupling to the Top Quark

Why are we looking for the $t\bar{t}H$ final state ?

Extract the Higgs coupling to the t-quark y_t from measurement of the $t\bar{t}H$ cross section $\sigma_{t\bar{t}H}$

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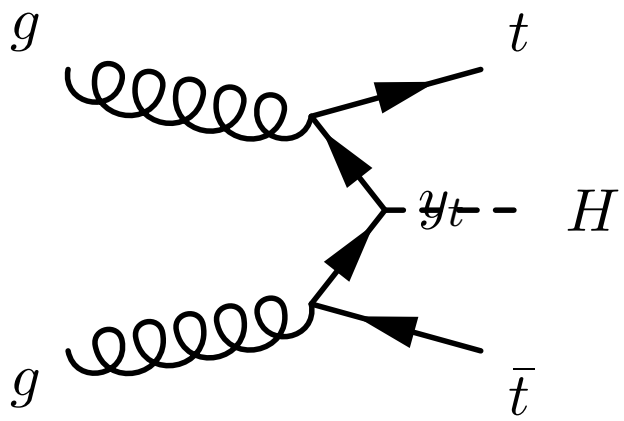

- At tree level, the only way the Higgs boson is produced with a $t\bar{t}$ pair is via its coupling to the t-quark

$$\sigma_{t\bar{t}H} \propto y_t^2$$

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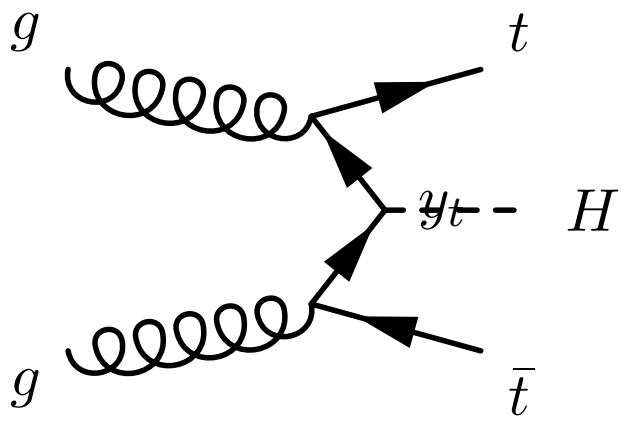

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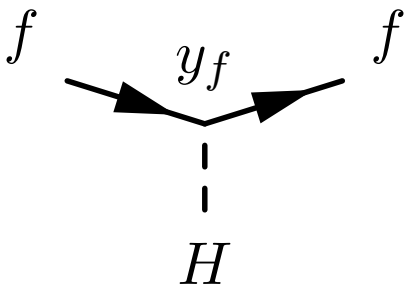
$$\sigma_{t\bar{t}H} \propto y_t^2$$

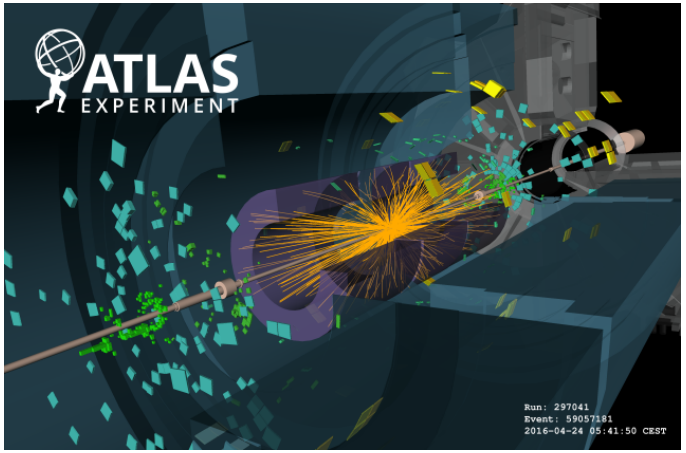
- In the SM, couplings to fermions y_f are proportional to their mass m_f

$$y_f = \frac{m_f}{\sqrt{2}v}$$



Identification of $t\bar{t}H$

- t-quarks and Higgs bosons identified via their decay products
- ... expressed in term of standard physics objects : photons, charged leptons, jets (b-tags), $\not{E}_T$



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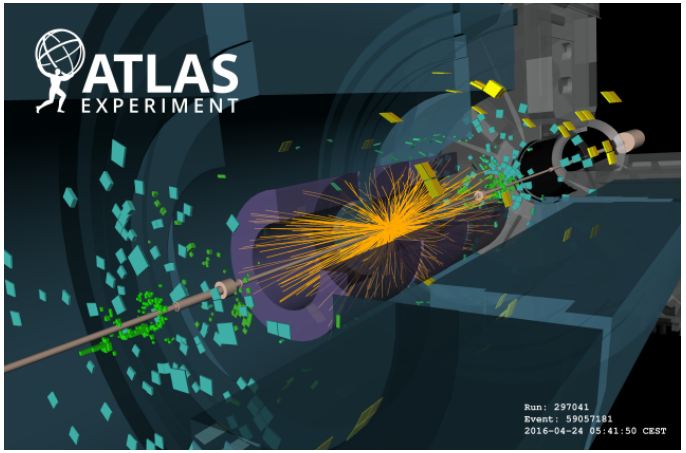

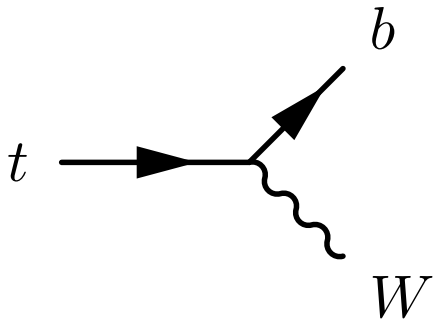

+2 b-tags

$\Gamma_{Wb} = 100\%$

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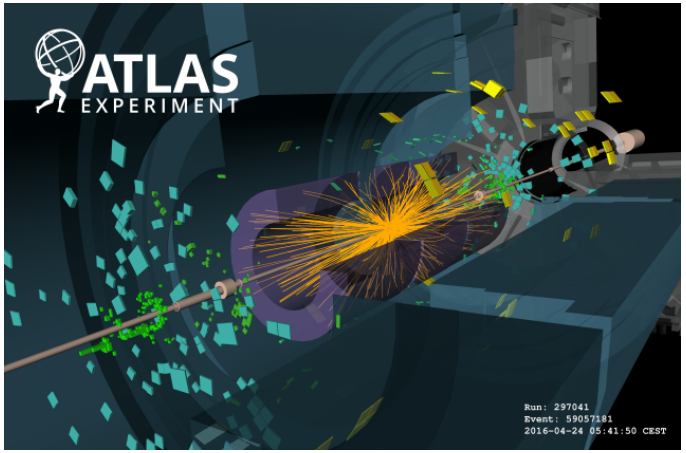

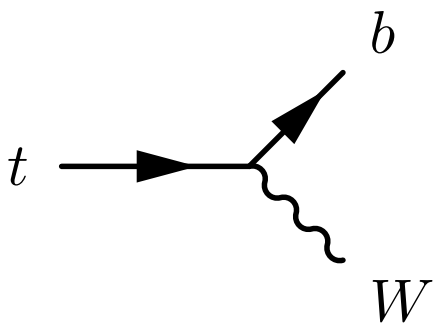

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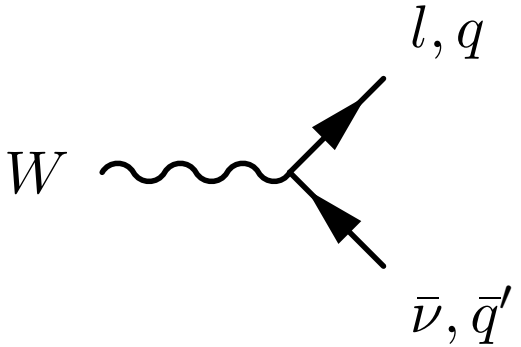

$+1$ e/μ, $+2$ jets

$\Gamma_{e/\mu+qs} = 30\%$

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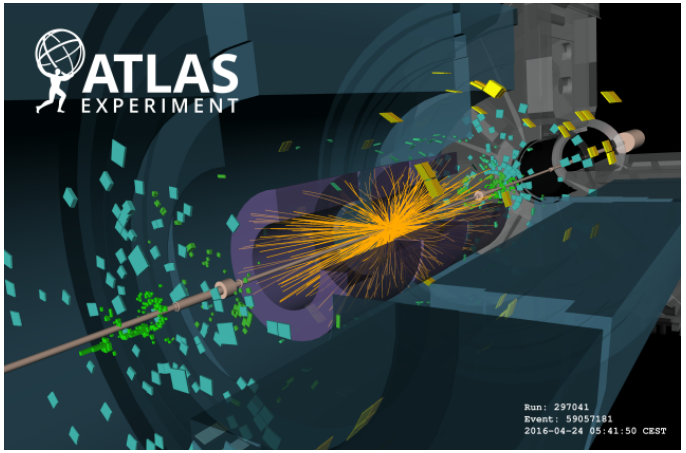

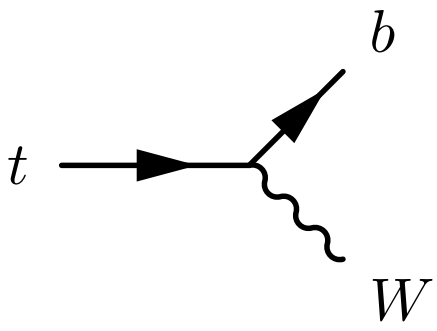

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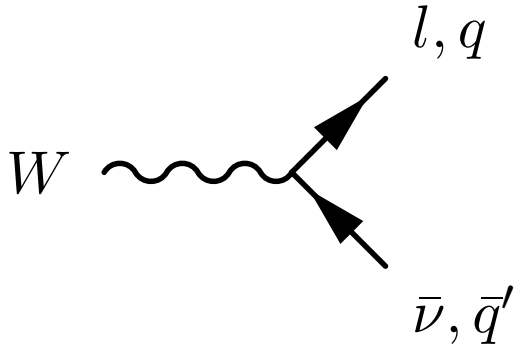

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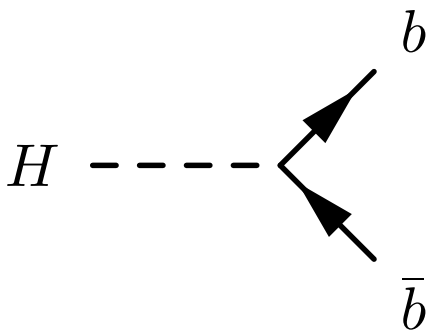

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$\Gamma_{b\bar{b}} = 57\%$

Identification of $t\bar{t}H$

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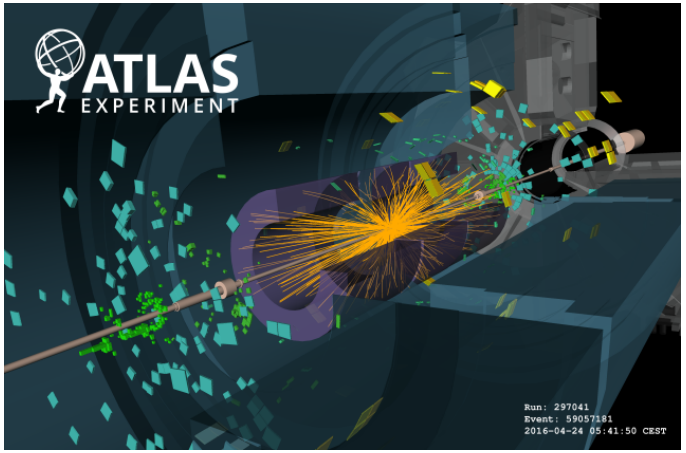

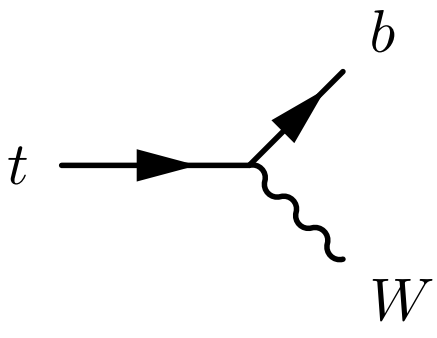

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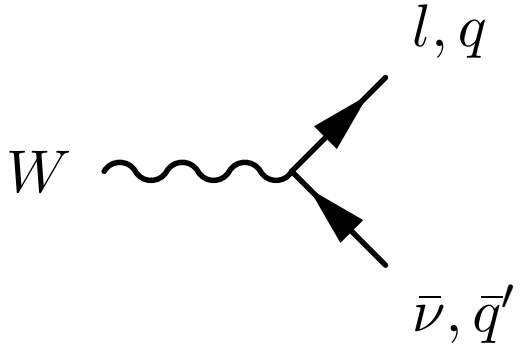

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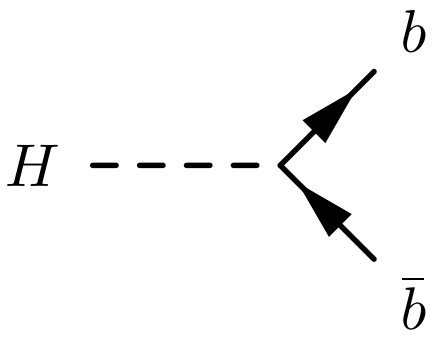

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$t\bar{t}H$ lepton+jets signature 1 e/μ, 4 b-tags, 2 jets

ATLAS Run 1 Results

Main background

The large $t\bar{t} + b\bar{b}$ background has similar features than $t\bar{t}H(b\bar{b})$ and makes the search challenging

Ambiguity when assigning a b-tag pair (among 6 combinations) to the Higgs boson

- poor discrimination based on the Higgs mass

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Run 1 results : signal strength (**Reference** Link)

$$\mu = \frac{\sigma_{measurement}}{\sigma_{SMcalculation}} = 1.2 \pm 1.3(\pm 0.8 stat only)$$

$t\bar{t}H(b\bar{b})$ cross section mesurement compatible with

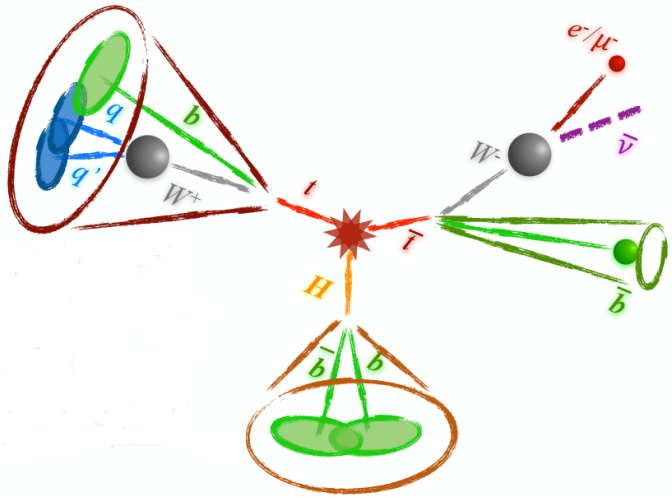
- $\mu = 0$, no signal hypothesis
- $\mu = 1$, SM signal hypothesis

Boosted topology in Run 2

Boosted topology

t-quarks and H bosons are produced at high energy ($E_H > m_H$)

- hadronic t-quark and the H decay products are collimated, therefore enable a better H identification



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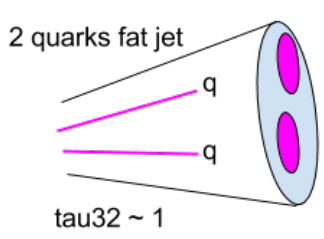
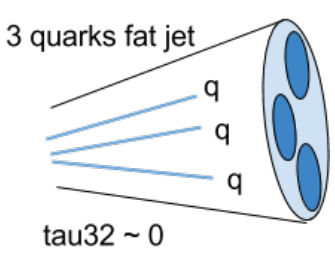
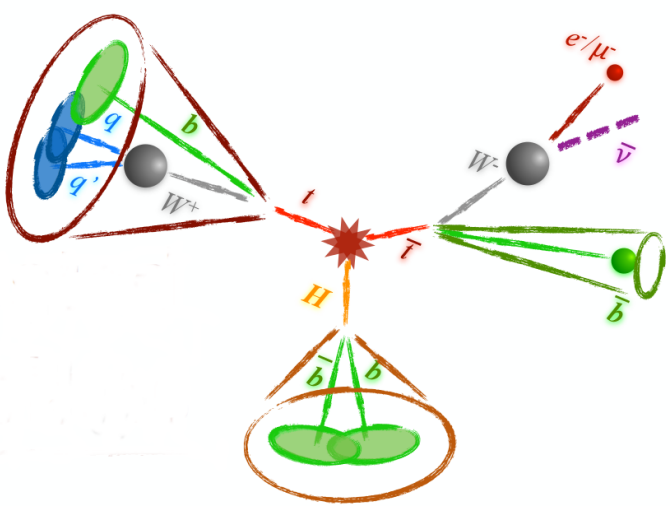
New techniques are applied to identify these collimated objects

- jets with larger size, called fat jets
- fat jet substructures variables (ex τ_{32})







t-tagging studies

t-tagging

Identification of fat jets coming from the hadronic decays of the t-quark, based on the fat jet mass and τ_{32}

t-tagging

- was optimized to reject fat jets from pure strong interaction processes

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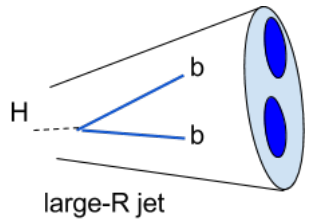
Identification of fat jets coming from the hadronic decays of the t-quark, based on the fat jet mass and τ_{32}

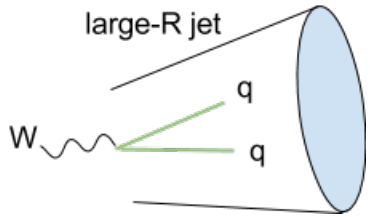
t-tagging

- was optimized to reject fat jets from pure strong interaction processes
- need to adapt it to the $t\bar{t}H$ topology

By combining substructure variables and b-tagging of jets inside fat jets, we reduced the efficiency to t-tagg

- $H \to b\bar{b}$ with a factor ~ 3
- $W \to q\bar{q}'$ with a factor ~ 4





Introduction to b-tagging

b-tagging identification of jets from the hadronisation of b-quarks

background jets from the hadronisation of lighter quarks (u, d, s, c)

Motivation

An important information for high energy physics, especially for SM (top, H$\rightarrow b\bar{b}$), SuSy (stop) and Exotics (VLQ) analysis

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Motivation

An important information for high energy physics, especially for SM (top, H$\rightarrow b\bar{b}$), SuSy (stop) and Exotics (VLQ) analysis

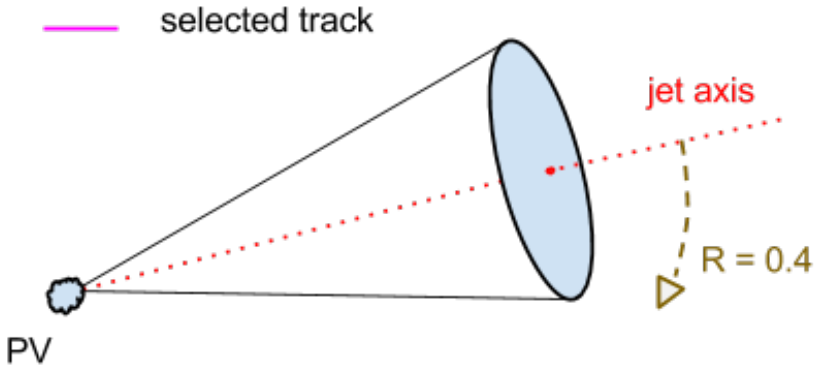
Hadronisation of a b-quark produces a b-hadron with unique properties

- relatively large mass
- lifetime $\sim ps$, typical decay length : few mm

b-tagging alogrithms

b-tagging inputs

- associated tracks to the jet



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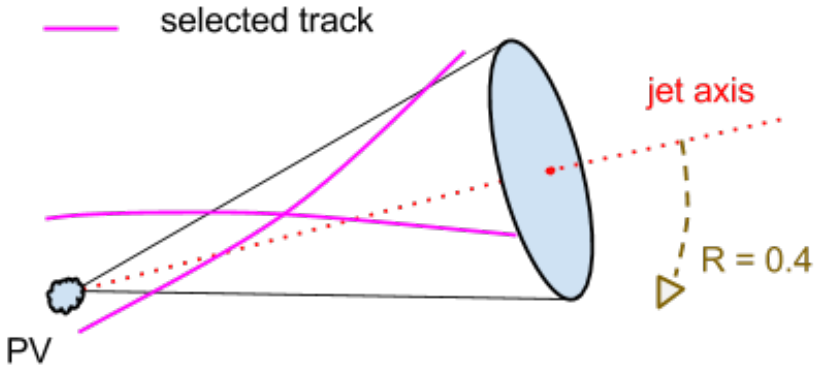

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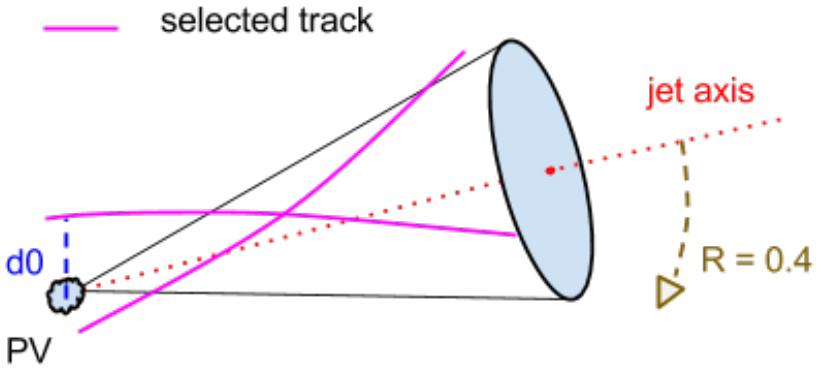


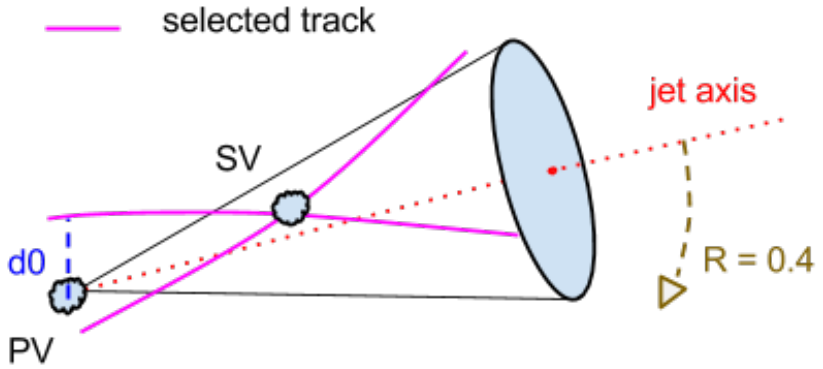
b-tagging is based on

- impact parameters (IP) of associated tracks

b-tagging alogrithms

b-tagging inputs

- associated tracks to the jet



b-tagging is based on

- impact parameters (IP) of associated tracks
- properties of reconstructed secondary vertices (SV)

b-tagging alogrithms

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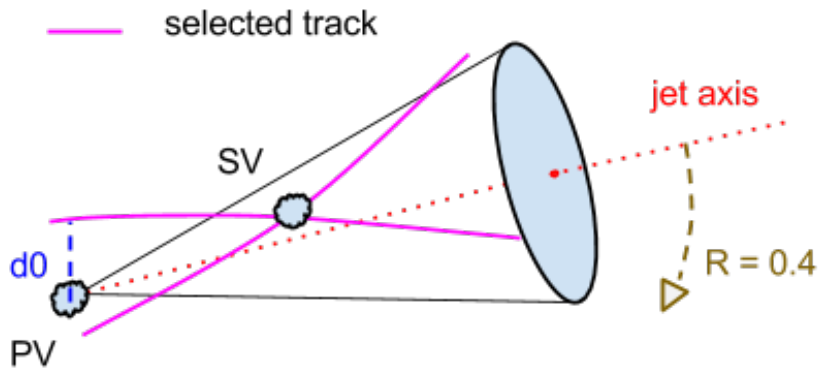

b-tagging is based on

- impact parameters (IP) of associated tracks
- properties of reconstructed secondary vertices (SV)

3 algorithms to identify b-jets

- IP3D : combines impact parameters of associated tracks
- SV1 : reconstructs a single SV from intersection of tracks
- JetFitter : reconstructs the decay chain $PV \rightarrow b \rightarrow c$

Contribution to the JetFitter algorithm

At high energy,

- jets contains more tracks from the PV
- tracks are more collimated

Contribution in optimizing the tracks selection as input to JetFitter (versus jet energy)

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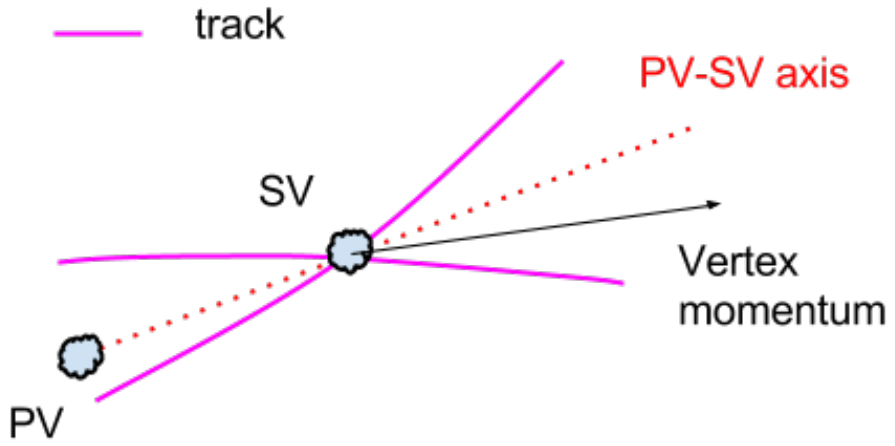
- jets contains more tracks from the PV
- tracks are more collimated

Contribution in optimizing the tracks selection as input to JetFitter (versus jet energy)

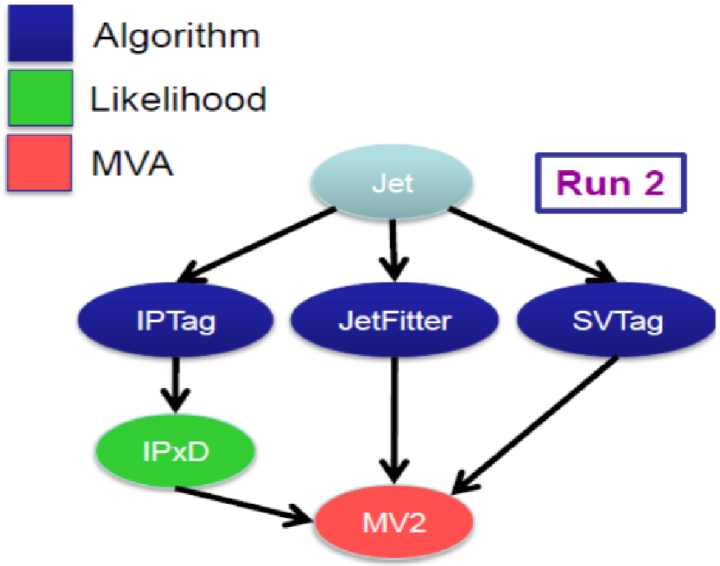
Make use of the SV momentum and direction to reject fake b-hadron vertices from $V0$s



Contribution to the MV2 algorithm

Algorithms

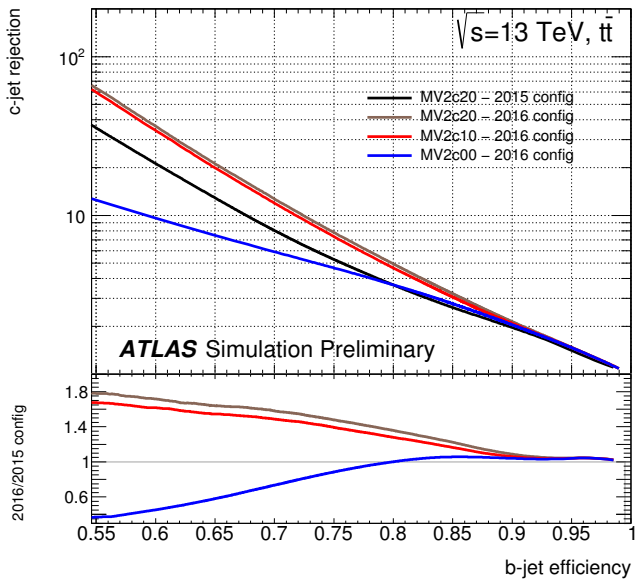
- 3 basics taggers IP3D, JetFitter, SV1
- MV2 combination basic taggers information in Run 2 (BDT)



Reference

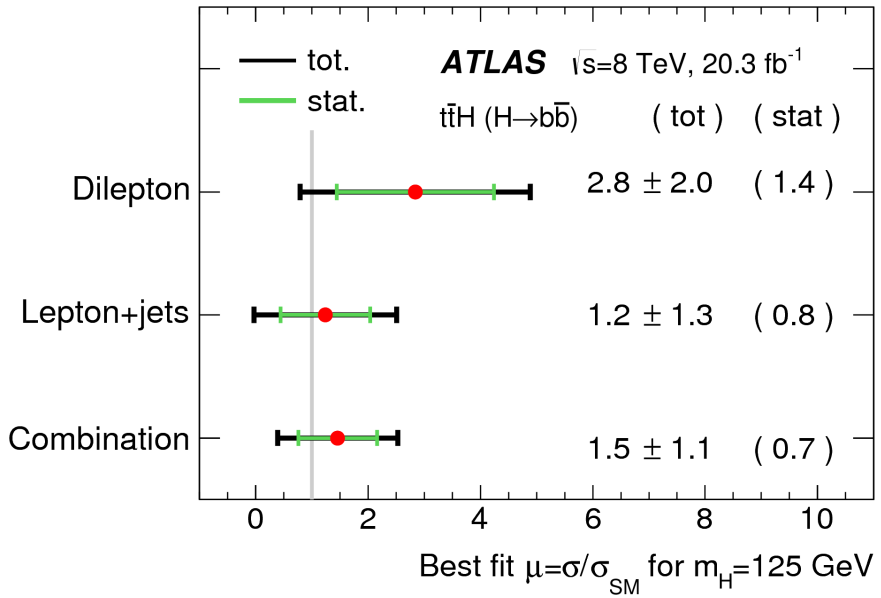
Link

Result : improvement of the c-jet rejection ~ 50 %



Conclusion

- The measurement of $\sigma_{t\bar{t}H}$ enables to determine the Higgs coupling the the t-quark, and to test the SM



- Considering a boosted topology will improve the sensitivity of the analysis in Run 1

- b-tagging is an important ingredient for particle physics in ATLAS, all signatures with b-jets benefits from its optimization

Backup