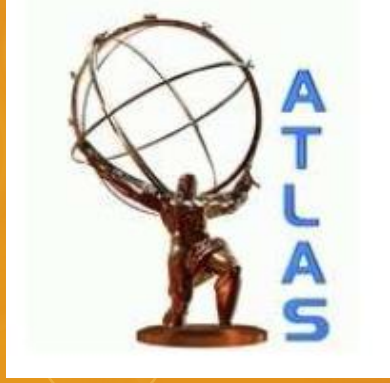

Associated Production $t\bar{t}H$ at ATLAS

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Summary

- The Higgs boson and Top quark
- Associated Production $t\bar{t}H$
- H->γγ channel
- H->$b\bar{b}$ channel
- Multi-lepton channels
  - Backgrounds and systematics
- Conclusions

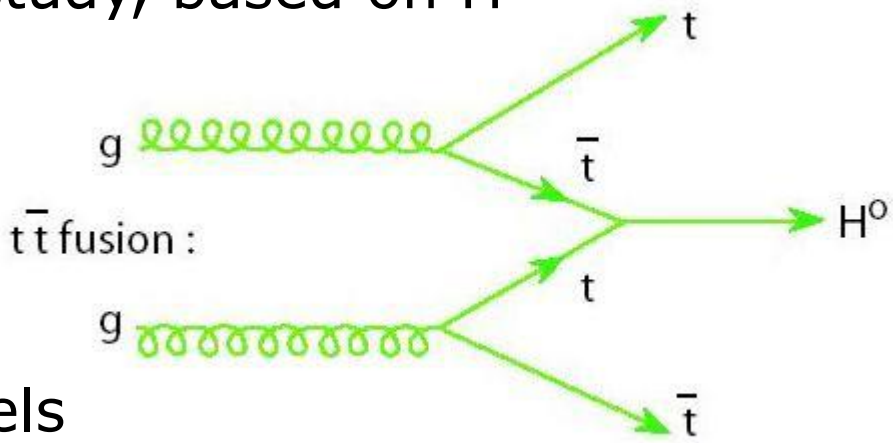
The Higgs Boson and Top quark

- Necessity for Higgs boson in Standard Model for electro-weak symmetry breaking.
- Discovered in July 2012 by ATLAS and CMS collaborations
  - Mass $= 126.0 \pm 0.6\ GeV/c^2$
- Open questions:
  - Properties (SM higgs?)
  - Couplings with SM particles
  - Beyond SM
- Top quark:
  - Heaviest known quark, large coupling with Higgs
  - Decays as t->W+b (99%)
  - Differentiated by W decay:
    - Hadronic W -> quarks
    - Leptonic W -> leptons

Higgs decay	BR
bb	57%
WW	22%
$\tau\tau$	6.2%
ZZ	2.8%
$\gamma\gamma$	0.23%
$Z\gamma$	0.154%

Associated production $t\bar{t}H$

- Higgs produced with $t\bar{t}$ pair
- Several channels under study, based on H decay
- Published channels:
  - H->γγ
  - H->$b\bar{b}$
- Finalizing leptonic channels
- Directly dependent on Higgs couplings
  - Fermion coupling k_f if H -> $b\bar{b}$ or gamma gamma
  - Fermion and boson k_b if H->WW or ZZ
- Sensitive to BSM processes



Gamma channel in ATLAS

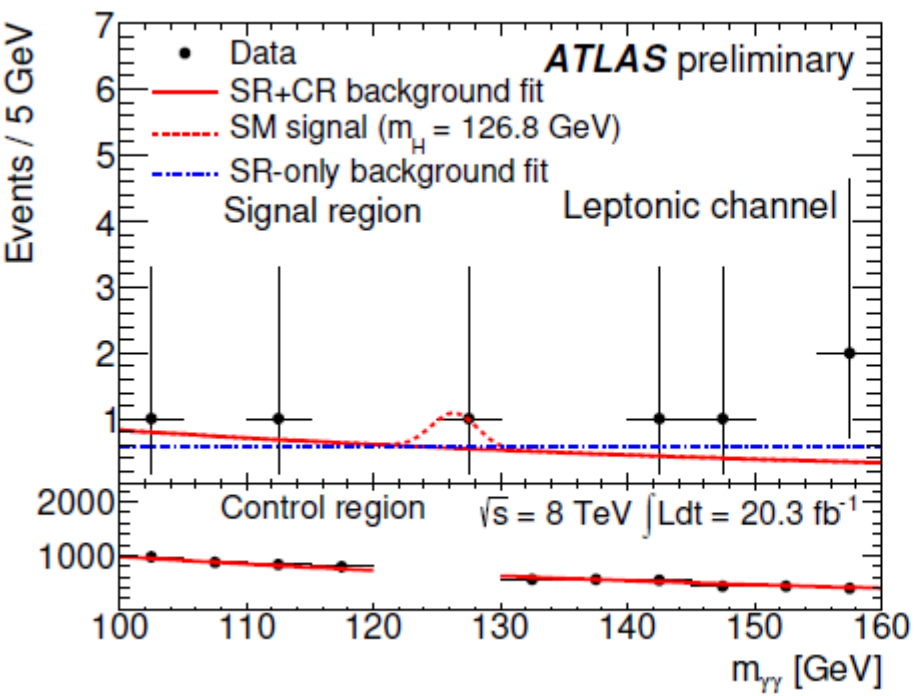
- The H->γγ channel is considered the 'Golden' one for single Higgs
  - Clean signature (2 back-to-back γ)
  - Low branching ratio
- From top decays we evaluate:
  - Lepton channel (single and double)
  - All-hadronic channel
- Reference :ATLAS-CONF-2013-080

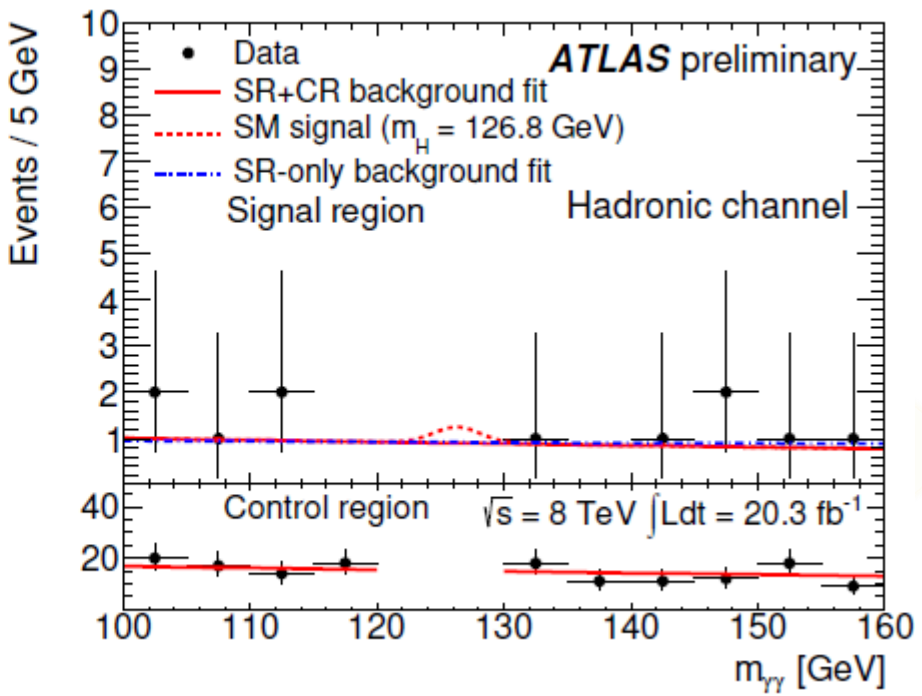
Expected signal and BG events in the two channels

Channel	N_S	$ggF(\%)$	$VBF(\%)$	$WH(\%)$	$ZH(\%)$	$tH(\%)$	$t\bar{t}H(\%)$	N_B	N_S/N_B
Leptonic	0.55	0.6	0.3	7.7	2.4	6.1	82.8	$1.2^{+0.6}_{-0.5}$	0.45
Hadronic	0.36	5.3	1.1	1.1	1.3	—	91.2	$1.9^{+0.7}_{-0.5}$	0.19

Results ttH (H->γγ)

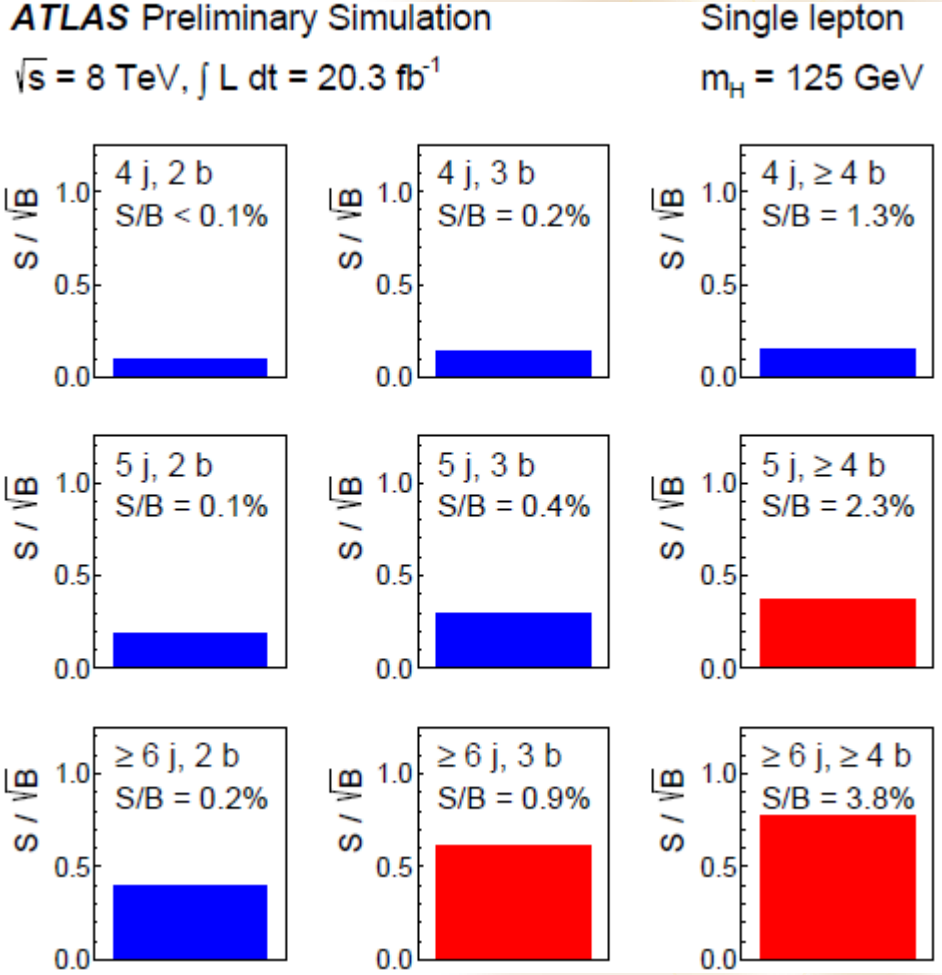
- No excess was observed in ATLAS in the 2012 20.3 fb^{-1} dataset
- A 95% CL limit was set on ttH ($\bar{H}$->γγ) production 5-6 times the SM prediction



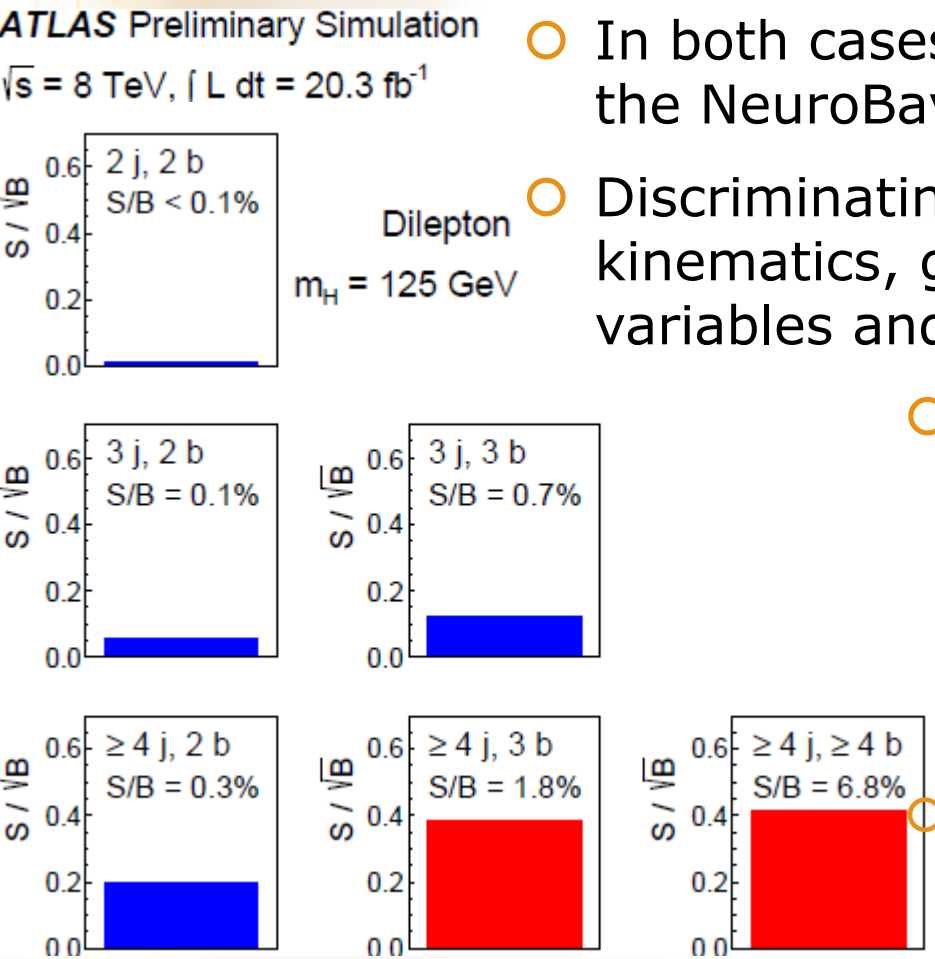


H->$b\bar{b}$ channel (1)

- The channel H->$b\bar{b}$ has the largest branching ratio
- High background due to high $t\bar{t}$+jets production, in particular bb and $c\bar{c}$
- Multivariate analysis used to discriminate Signal (S) and Background (B)
- Events categorized by jet and b-jet multiplicities
- Single-lepton and di-lepton selections applied

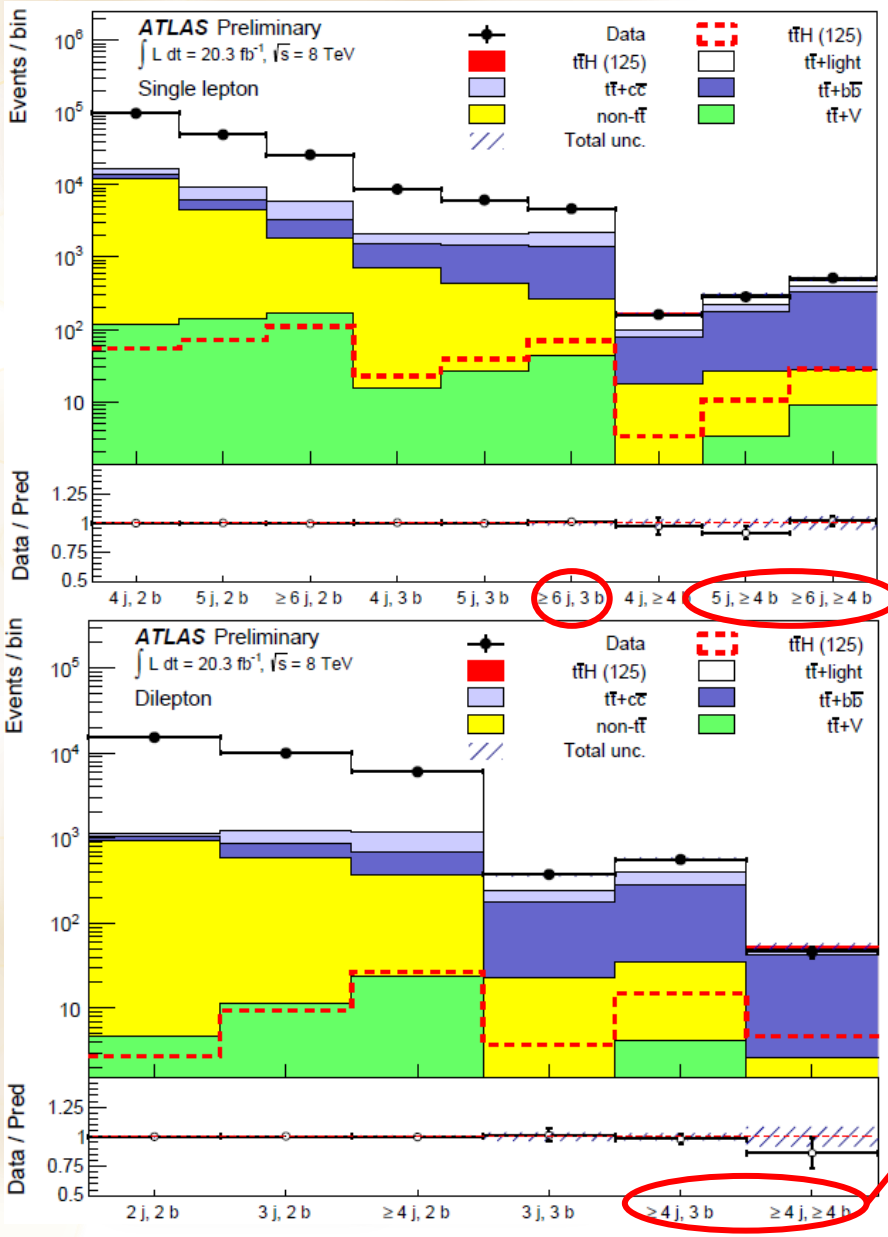


H->$b\bar{b}$ channel (2)



- Topologies with low S/B used as control regions
- In both cases Neural Networks are created using the NeuroBayes package
- Discriminating variables include object kinematics, global event variables, event shape variables and object pair properties
- Main systematic uncertainties:
  - Object reconstruction
  - Jet Energy Scale and Vertex Fraction
  - Flavor tagging
  - Background modelling
- Reference: ATLAS-CONF-2014-011

Results $t\bar{t}H$ ($H \to b\bar{b}$)



- Results are presented for the different categories and regions
- No significant excess is observed wrt SM predictions
- An observed 95% confidence level limit is observed of 4.1 times the SM prediction

Signal regions

Multi-leptonic channles

- To improve sensitivity we aim to extend the analysis to milti-leptonic channels
  - Still ongoing, focusing on background study
- After object selection we identify several signal regions, depending on Higgs decay:

Signature	$H \to WW$	$H \to \tau\tau$	$H \to ZZ$
Same-sign	100%	–	–
1 τ	15%	74%	11%
3 leptons	71%	20%	9%
2 τs	16%	82%	2%
4 leptons	53%	30%	17%

Background (multi-lepton)

- 2 leptons same-sign:
  - Opposite sign events can be read as same-sign when electron charge is mis-identified
    - Data-driven charge mis-identification (Z control region, Likelihood) study
  - 1 fake+1 real lepton can mimick signal
    - Data driven lepton fake rate (Matrix Method)
    - Monte Carlo simulation for remaining BGs
- 2 leptons + τ
  - $t\bar{t}V$ and diboson processes can exactly reproduce signal
    - Unreducible, estimated from MC
  - $t\bar{t}$, single top and Z+jets (fake / τ mis-id dominated)
    - Data-driven estimates using sideband regions
      - Some selection cuts are inverted to remove signal
      - Background is extrapolated to signal region

Background (multi-lepton)

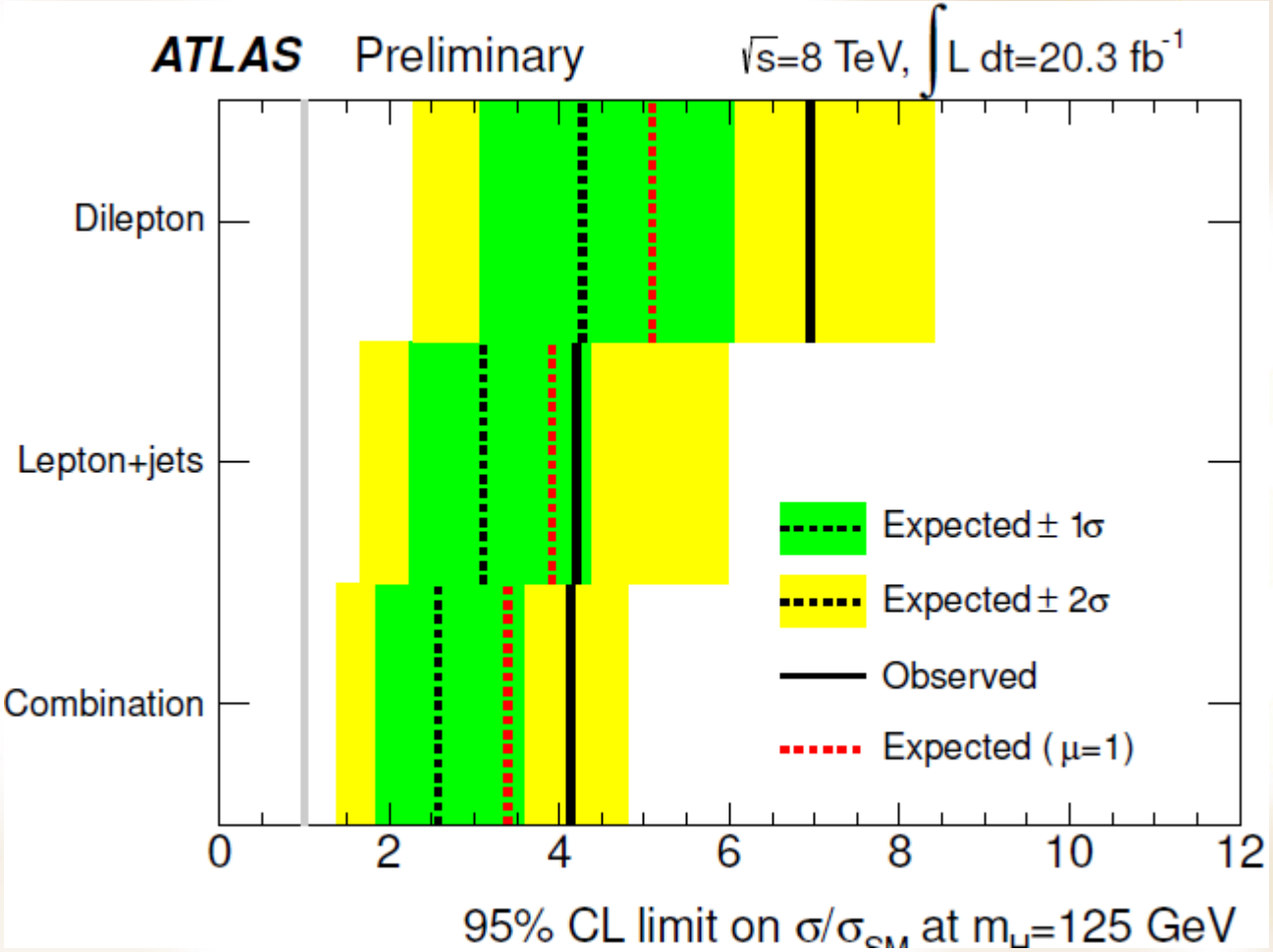
- 3 leptons:
  - $t\bar{t}$ dileptonic + fake lepton
    - Extrapolation from several control regions, with shapes estimated by MC
  - Z+jets, a very low BG for 3-lep
    - Shapes from MC and normalization from data
  - $t\bar{t}V$ and tZ, the dominant BG for 3l
    - Still only MC evaluation
- 4 leptons
  - $t\bar{t}Z$ and ZZ processes can give same signature
    - Z veto applied to reduce BG
- 2 τ + $t\bar{t}$
  - $t\bar{t}Z$, Z -> $\tau\tau$ background

Conclusions

- $t\bar{t}H$ production essential to study SM couplings
- Several analyses complete or ongoing in ATLAS
- H->γγ, clean, low statistic channel
  - No excess observed from SM predictions
- H->$b\bar{b}$, high statistics, high background channel
  - No excess observed from SM predictions
- Ongoing multi-lepton analysis
  - Mainly from H->WW, H-> ττ and H->ZZ decays
- For the future:
  - Preparing for unblinding of multi-lepton channels
  - Preparing for Run 2 (trigger menu, analysis structure)

Thanks!

Backup (bottom channel exclusion)



Backup (Matrix Method)

$$N^{loose} = N^{loose}_{real} + N^{loose}_{fake},$$

$$N^{tight} = N^{tight}_{real} + N^{tight}_{fake},$$

$$N^{tight}_{real} = \epsilon_{real} \cdot N^{loose}_{real},$$

$$N^{tight}_{fake} = \epsilon_{fake} \cdot N^{loose}_{fake},$$

$$N^{tight} = \epsilon_{real} \cdot N^{loose}_{real} + \epsilon_{fake} \cdot N^{loose}_{fake}$$

$$N^{tight}_{fake} = \frac{\epsilon_{fake}}{\epsilon_{real} - \epsilon_{fake}} \cdot (\epsilon_{real} \cdot N^{loose} - N^{tight})$$