Search for the Higgs boson in multi-jet events with the ATLAS detector

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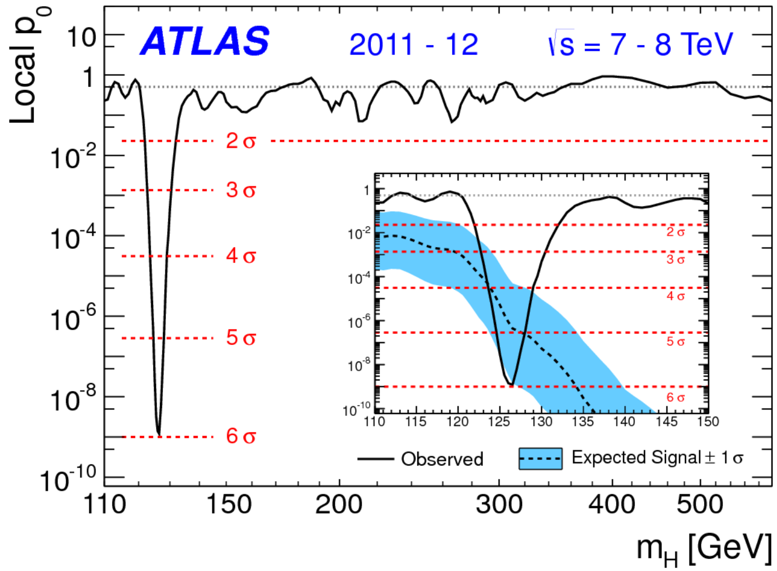
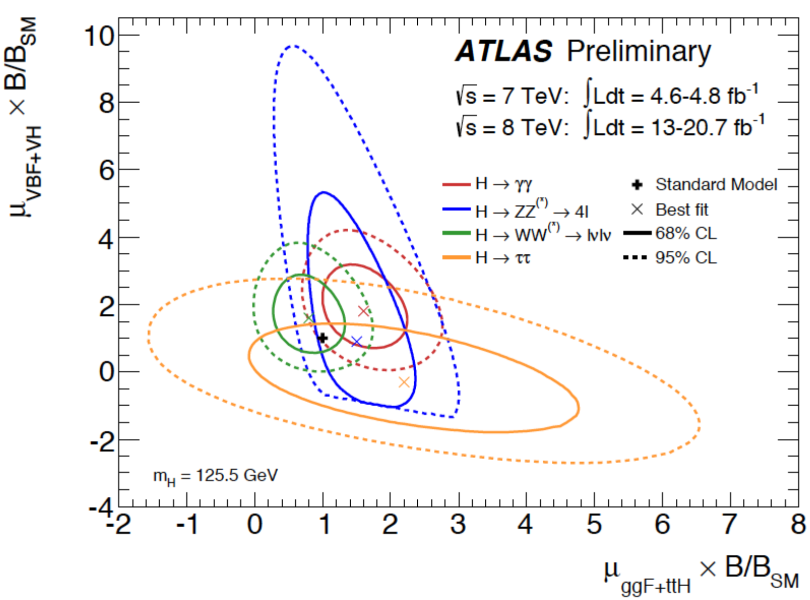
Higgs search @ LHC

- More than one year from the announcement of the discovery at the LHC of a Higgs boson
- First round of property measurements carried out by ATLAS and CMS confirm its SM-likeness
  - M_H =125.5 ± 0.2 (stat) +0.5/-0.6 (sys) GeV: light mass compatible with global EW fit [ATLAS-CONF-2013-014]
  - Spin confirmed: $J^P=0^+$ [ATLAS-CONF-2013-040]
  - Direct measurement of coupling to vector bosons and indirect to fermions: μ=1.43 ± 0.16 (stat) ± 0.14 (sys)
- Still a lot of work to be done:
  - Did we find “THE” or “A” Higgs bosons?
  - MSSM predicts the existence of a spectra of Higgs scalars, the lightest among them could resemble the SM Higgs boson

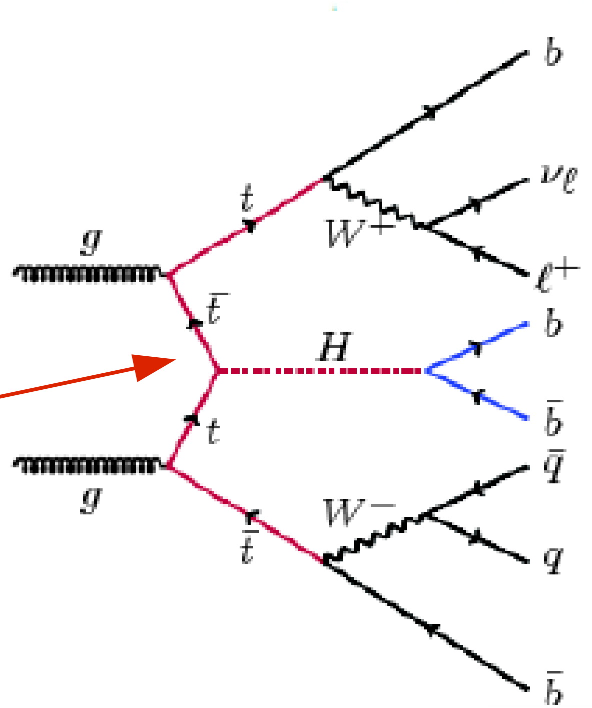
ATLAS-CONF-2013-034
Phys. Lett. B 716 (2012) 1-29



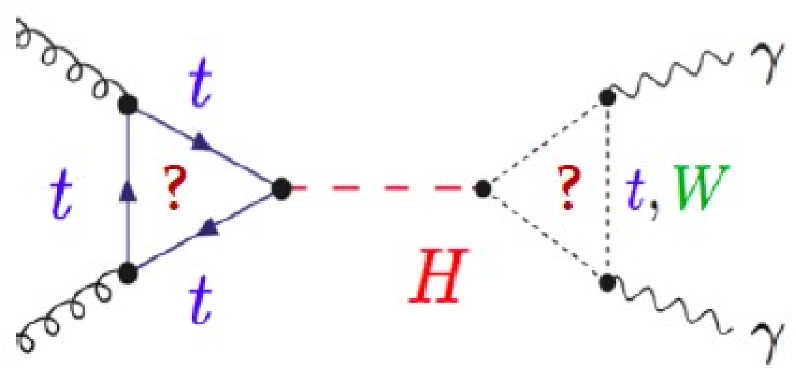


Top Yukawa coupling

- Higgs sector studies : Couplings
  - Coupling measurements are an excellent way to probe deviations from the Standard Model in the Higgs sector
- The $t\bar{t}H$ channel is the only way to directly constrain the top Yukawa coupling @ LHC
  - top quark: largest coupling with the Higgs
- Largest contributions to loops e.g. most sensitive channel, $gg \rightarrow H \rightarrow \gamma\gamma$, contains 2 loops of top quarks
  - Direct constrain on the top Yukawa coupling allows probing for New Physics in the ggH and $\gamma\gamma$H vertices



Higgs production

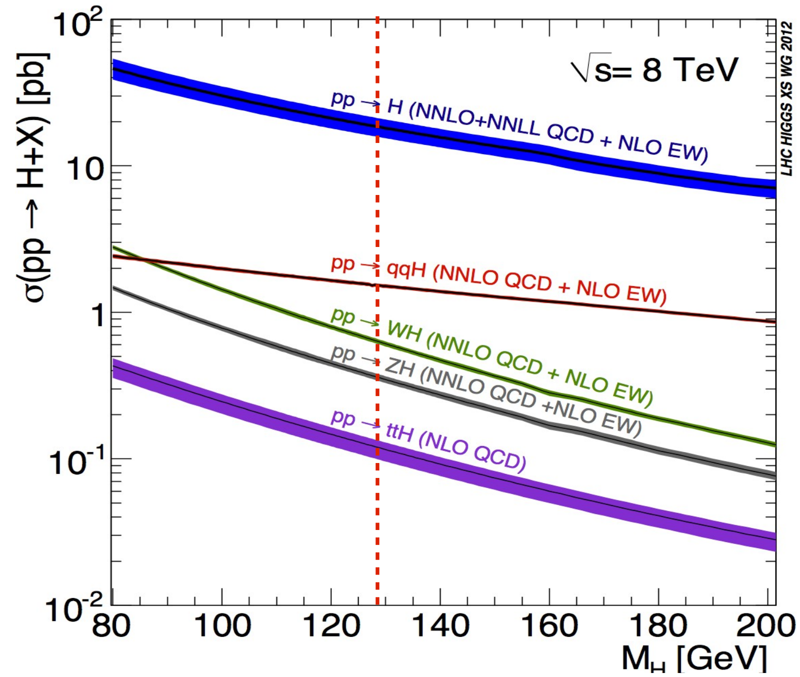


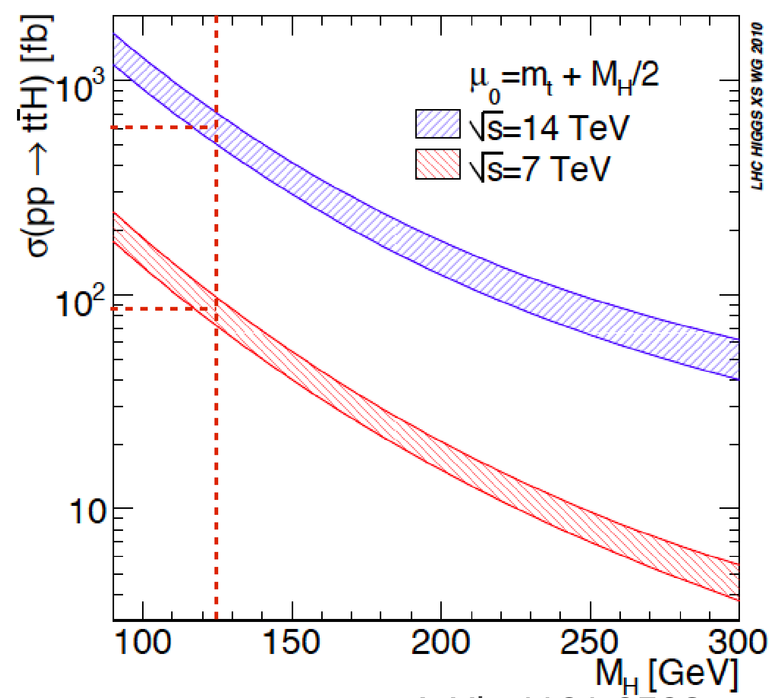
Higgs decay to photons

$t\bar{t}H$ phenomenology

- At the LHC $\sigma(t\bar{t}H)$ known at NLO in QCD.
  - $\sqrt{s}$ = 7 TeV : $\sigma(t\bar{t}H)$ = 86 fb
  - $\sqrt{s}$ = 8 TeV : $\sigma(t\bar{t}H)$ = 130 fb
    - x1.5 wrt 7 TeV
  - $\sqrt{s}$ = 14 TeV : s($t\bar{t}H$) = 611 fb
    - ~x7 wrt 7 TeV
- Strong increase with the centre of mass energy

- For m_H=125 GeV : BR($H \rightarrow b\bar{b}$) = (57.7±1.9)%
  - Highest branching ratio





ArXiv:1101.0593

$t\bar{t}H$ (H → $b\bar{b}$) main background : $t\bar{t}$

Reducible background :

- $t\bar{t}$ + light jets : dominant source of background due to high cross section : σ = 116 pb
- $t\bar{t}$ + W : σ = 232 fb

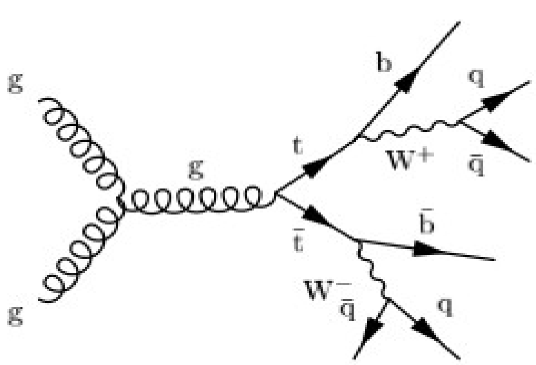
Irreducible background :

- $t\bar{t}$ + $b\bar{b}$: Even at LO it has many diagrams:
  - ➔ 36 for gg → ttbb ; 7 for qq → ttbb ; σ = 2.6 pb
- $t\bar{t}$ + $c\bar{c}$: σ = 4.8 pb
- $t\bar{t}$Z (Z → $b\bar{b}$) : σ * BR = 41 fb

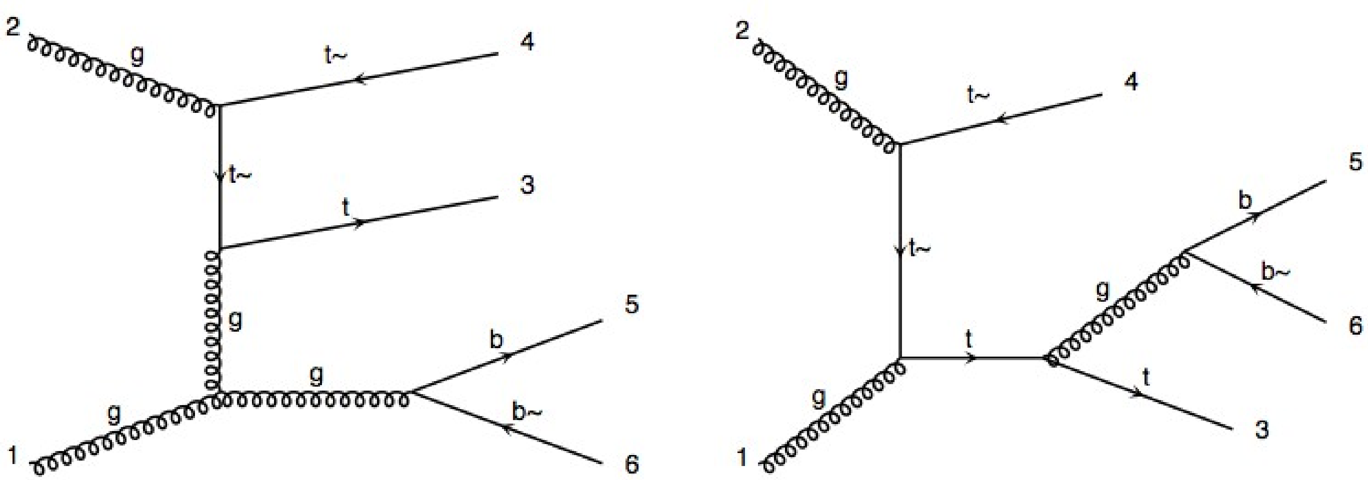
Other backgrounds are:

- W/Z/γ* + jets
- Dibosons
- Singletop

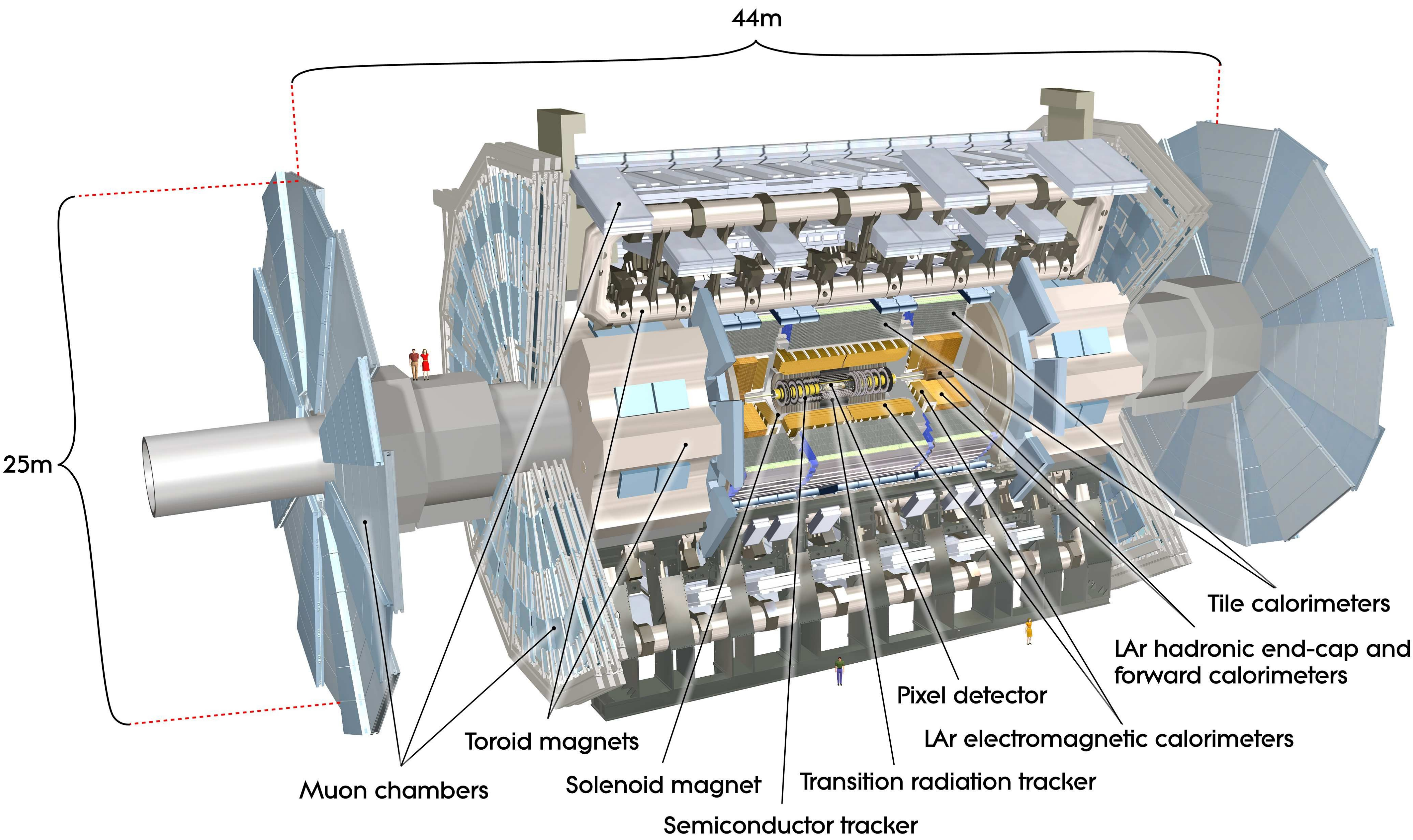
ttbar production



ttbar + bb production

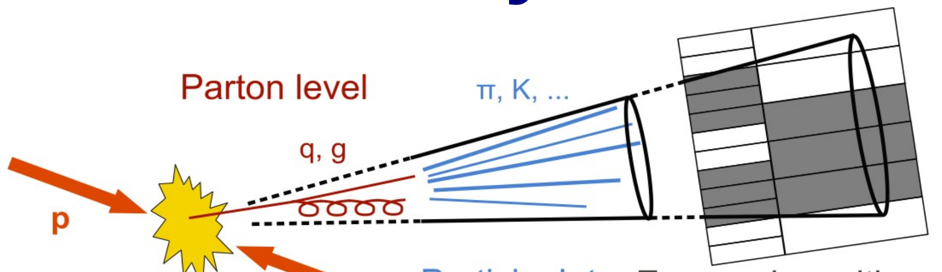


ATLAS detector

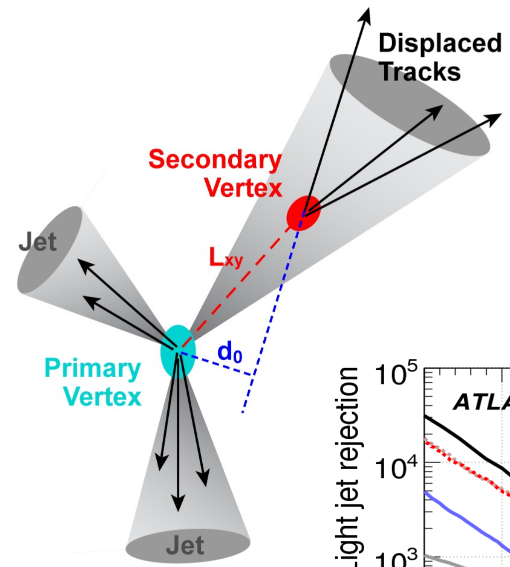


Physics objects used in the analysis

Particle jet: is a narrow cone of hadrons and other particles produced by the hadronization of a quark or gluon

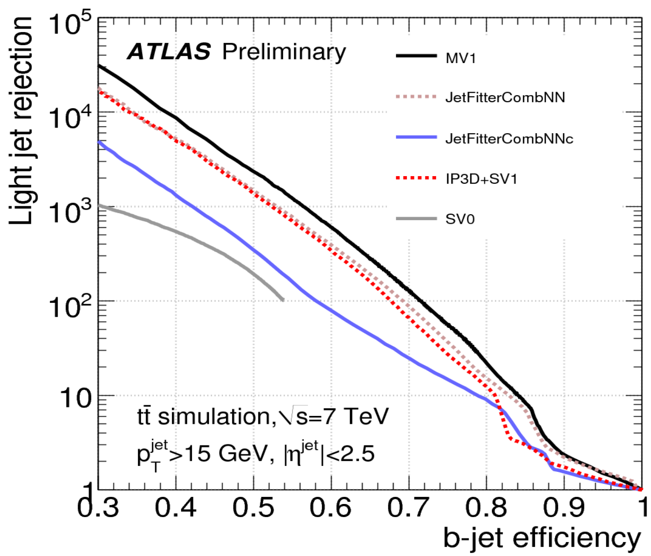


B-tagging: Identify a particle jet as originated from a b-quark



How it works:

- Long lifetime of hadrons containing b-quarks (τ ~ 1.5 ps) corresponding to $c\tau$ ~ 450mm
  - b-quarks decay vertex is displaced from the primary vertex
  - Displaced tracks have large impact parameter (d_0)

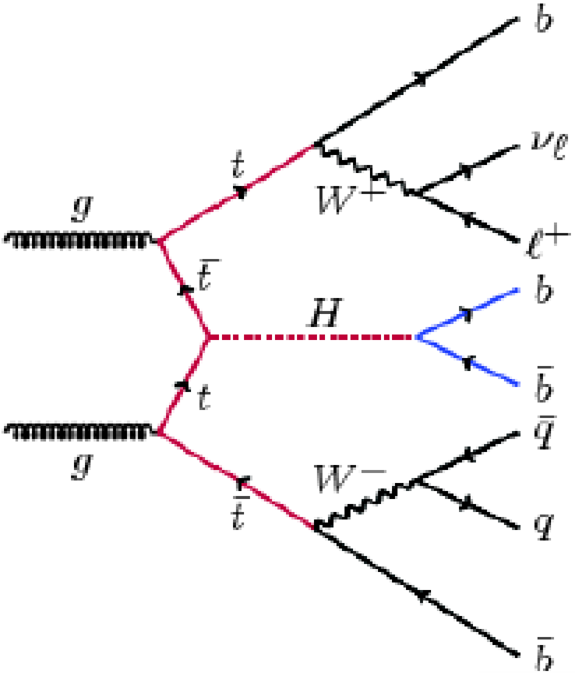


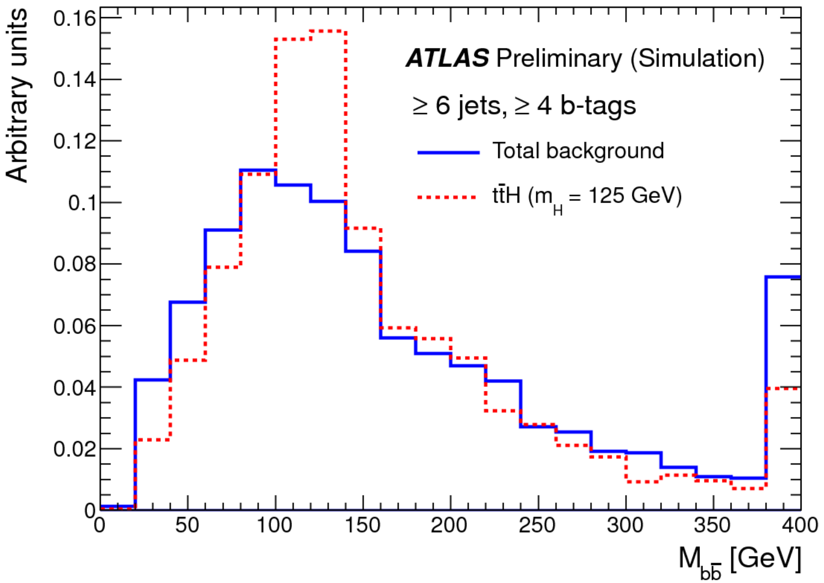
- Identification of jets originating from b-quark is performed using a secondary-vertex-based tagging algorithm
- MVA technique used for computing tagging discriminant variables

Previous search in ATLAS : semileptonic $t\bar{t}H$

ATLAS-CONF-2012-135

- Analysis performed using 4.7 fb^{-1} of pp collision collected at c.o.m. Energy of 7 TeV
- **Event topology** :
  - At least 6 jets, $p_T > 25$ GeV and $|\eta| < 2.5$
    - At least 4 b-jets, WP: 70%
  - 1 Mu (El), $p_T > 20$ (25) GeV ; $|\eta| < 2.5$ (2.47)
  - Missing energy > 30 GeV
- **Strategy** : Categorize events as function of jet multiplicity and number of b-tagged jet
  - **Discriminant variables**:
    - In region with at least 6 jets and at least 3 b-tagged jets using the invariant mass ($m_{b\bar{b}}$) of the two b-jets candidates not assigned to the ttbar system
    - In the rest of the channels : $HT_{had} = \Sigma\, p_T$ jet





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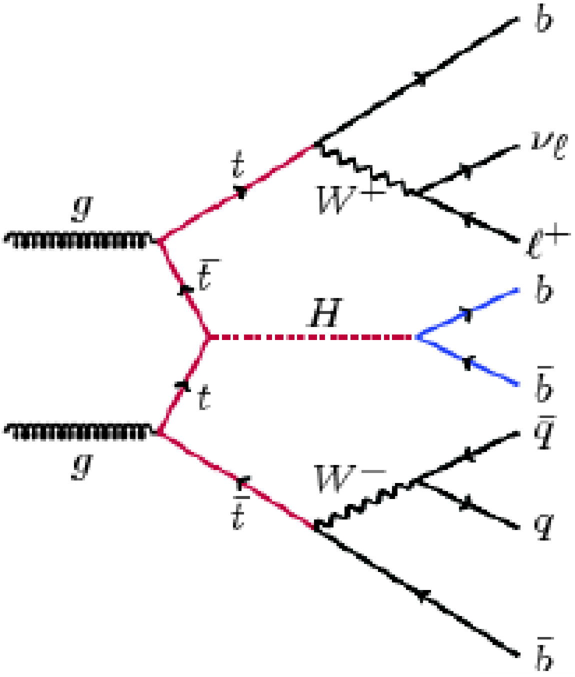

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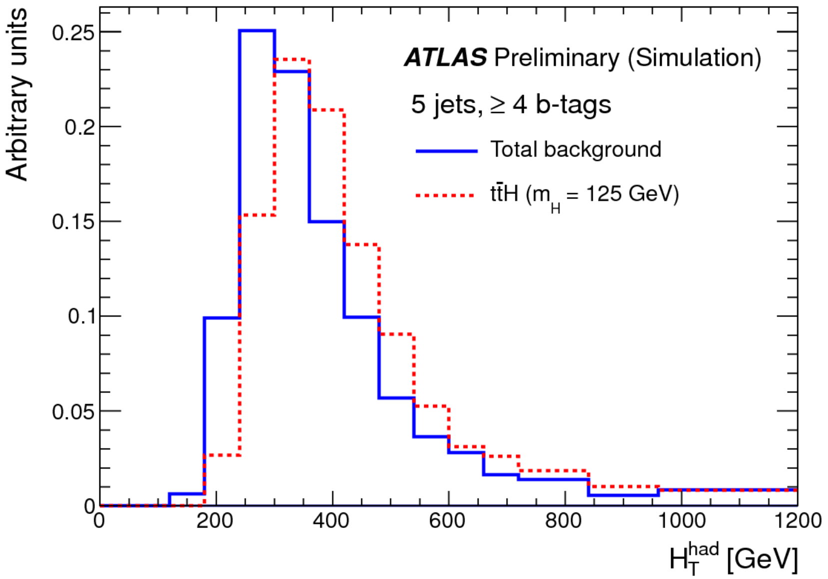


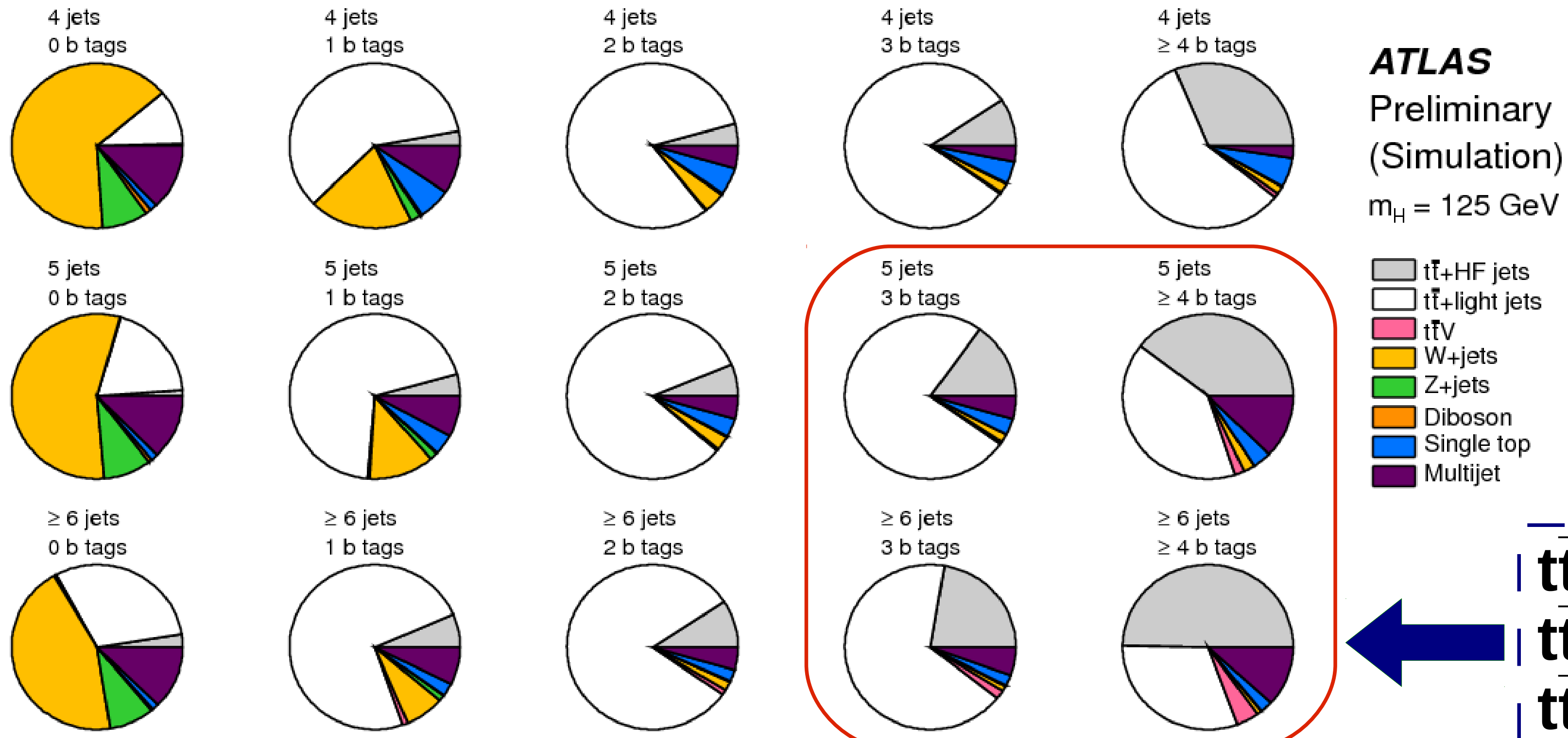
Semileptonic $t\bar{t}H$ ($H \to b\bar{b}$) : analysis strategy

Signal regions

ATLAS-CONF-2012-135

Category	Signal	Bkgrd	S/ √B
5 jets 3 tags	2.3	915	0.08
5 jets ≥ 4 tags	0.74	45	0.11
≥ 6 jets 3 tags	4.0	634	0.16
≥ 6 jets ≥ 4 tags	2.2	62	0.28

Few signal events!!



Bkgr composition

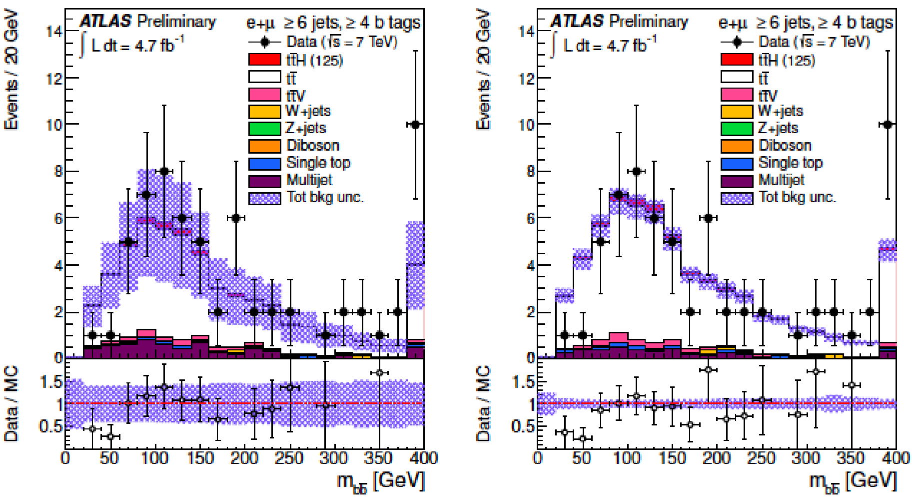
$t\bar{t}b\bar{b}$ (42%)
$t\bar{t}c\bar{c}$ (20%)
$t\bar{t}$+light (38%)

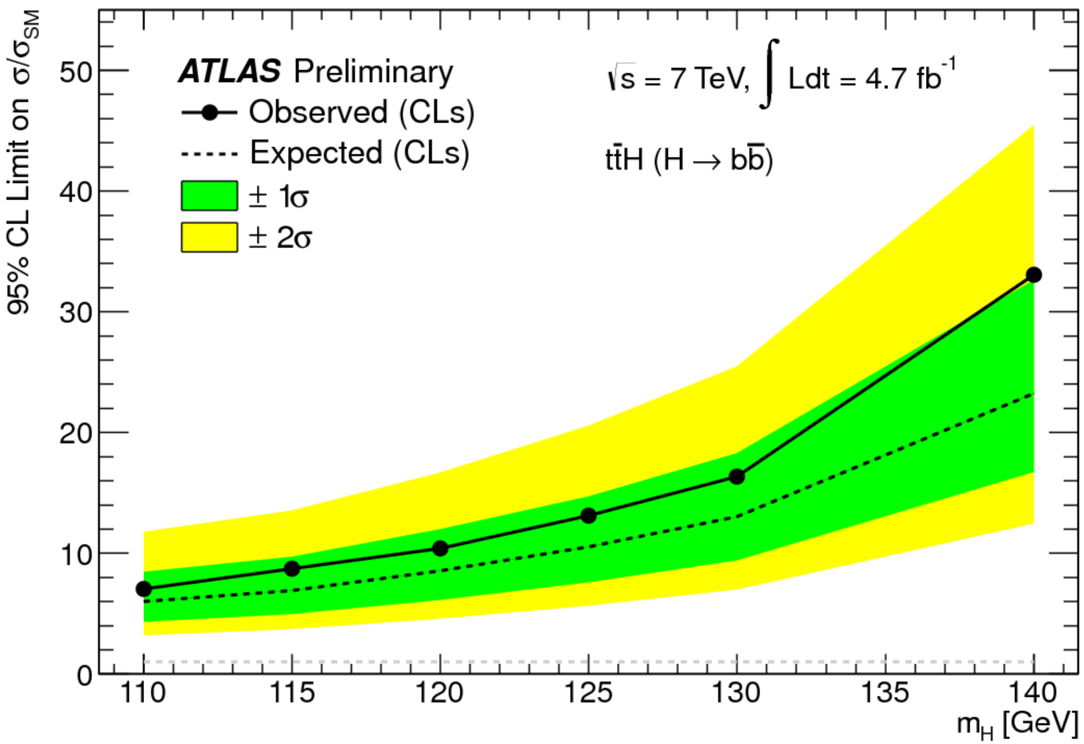
Semileptonic $t\bar{t}H$ ($H \rightarrow b\bar{b}$) : final limits at 7 TeV

ATLAS-CONF-2012-135

- Many systematic uncertainties
  - From experiment
    - B-tagging performance
    - Jet energy scale
  - And theoretical ones
    - Modelling of $t\bar{t}$
    - Heavy flavour content of $t\bar{t}$ extra jet
- Can constrain some of them using nuisance parameters while extracting the limit

Pre fit **Post fit**

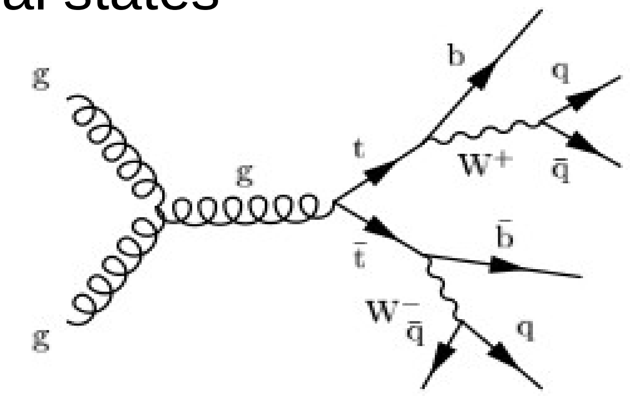




- Lepton + jets channel
  $4.7\ \text{fb}^{-1}$ @ 7 TeV
  - Observed (expected) limit of 13.1 (10.5) x SM at 125 GeV

All-hadronic $t\bar{t}$ signature

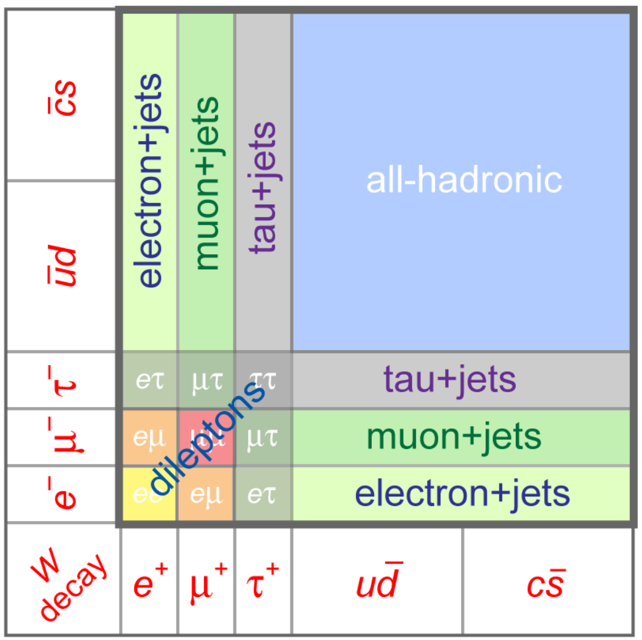
- ATLAS performed a measurment of $t\bar{t}$ cross section in the fully hadronic final state at 7 TeV
  - Possibility of extending $t\bar{t}H$ searches using all $t\bar{t}$ final states



Fully hadronic ttbar topology :

- Highest branching ratio : ~ 47%
- Final state with many jets
  - Trigger : 5 jet p_T > 30 GeV
  - At least 6 jet :
    - 5 jet with p_T > 55 GeV ; $|\eta| < 2.5$
    - 6^{th} jet with p_T > 30 GeV ; $|\eta| < 2.5$
      - High p_T threshold to be at the trigger efficiency plateau
      - Veto on non isolated jets : trigger inefficient region
- At least 2 coming from b-quarks, WP 60%
- No leptons & no missing energy

Top Pair Decay Channels

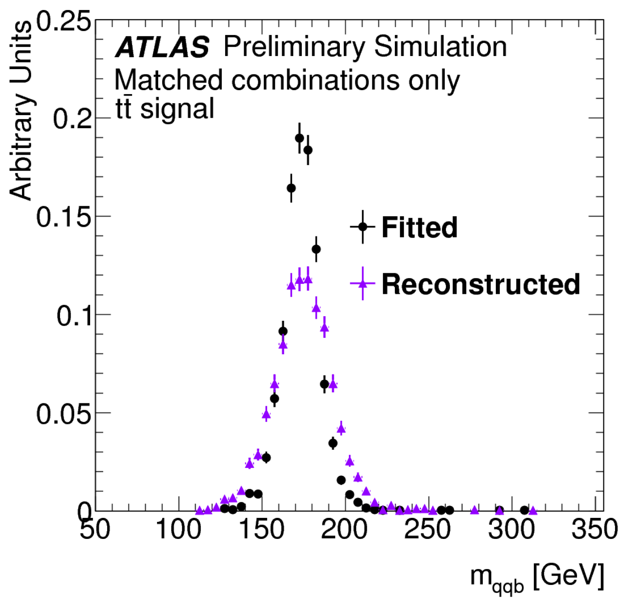


All-hadronic $t\bar{t}$ xsec measurement at 7 TeV

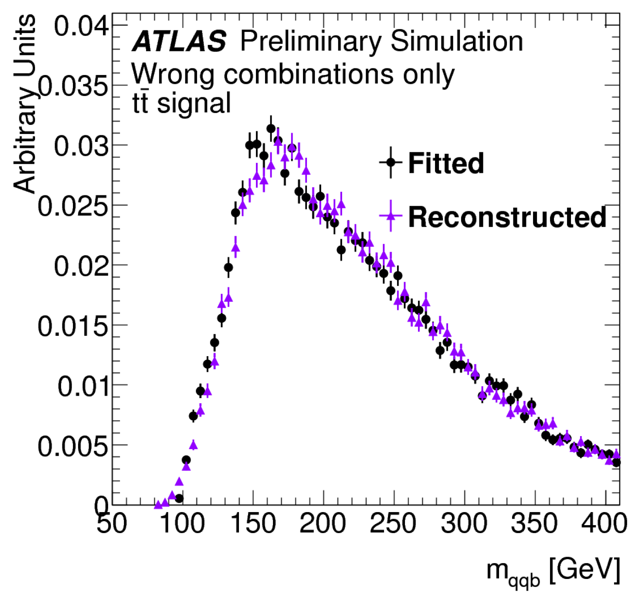
Analysis strategy :

- Using kinematical likelihood fit to reconstruct the event topology
  - It can variate the energy of the jets, inside their uncertainties, to better fit the masses of the W boson and the top quark
- Dominant background is QCD
  - Multi jet background shape extracted from untagged data
- **Result** : $\sigma(pp \rightarrow t\bar{t}) = 168 \pm 12\ (\text{stat.})\ ^{+60}_{-57}\ (\text{syst.}) \pm 7\ (\text{lumy.})$ pb
- **Main systematic uncertainties**: Jet energy Scale (20%), b-tagging (17%), Initial / Final State Radiation (17%)

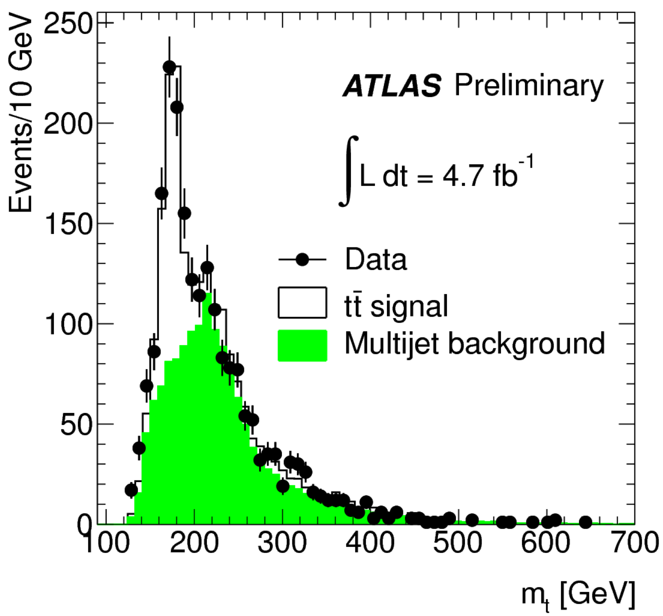
Full match



NOT full match



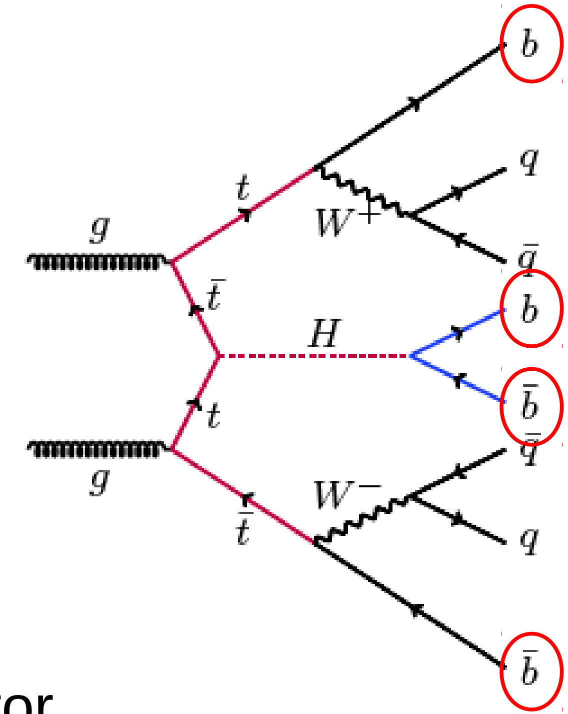
Signal extraction



$t\bar{t}H$ – all-hadronic final state

Event topology : at least 8 jets

- Trigger 4 jet p_T > 45 GeV and 1 b-tagged jet
  - Offline selection:
    - 4 jet p_T > 45 GeV , $|\eta| < 2.5$
    - Remaining jet p_T > 25 GeV , $|\eta| < 2.5$
  - At least 4 jets coming from b-quarks, WP 60%
  - No leptons & no Missing Energy



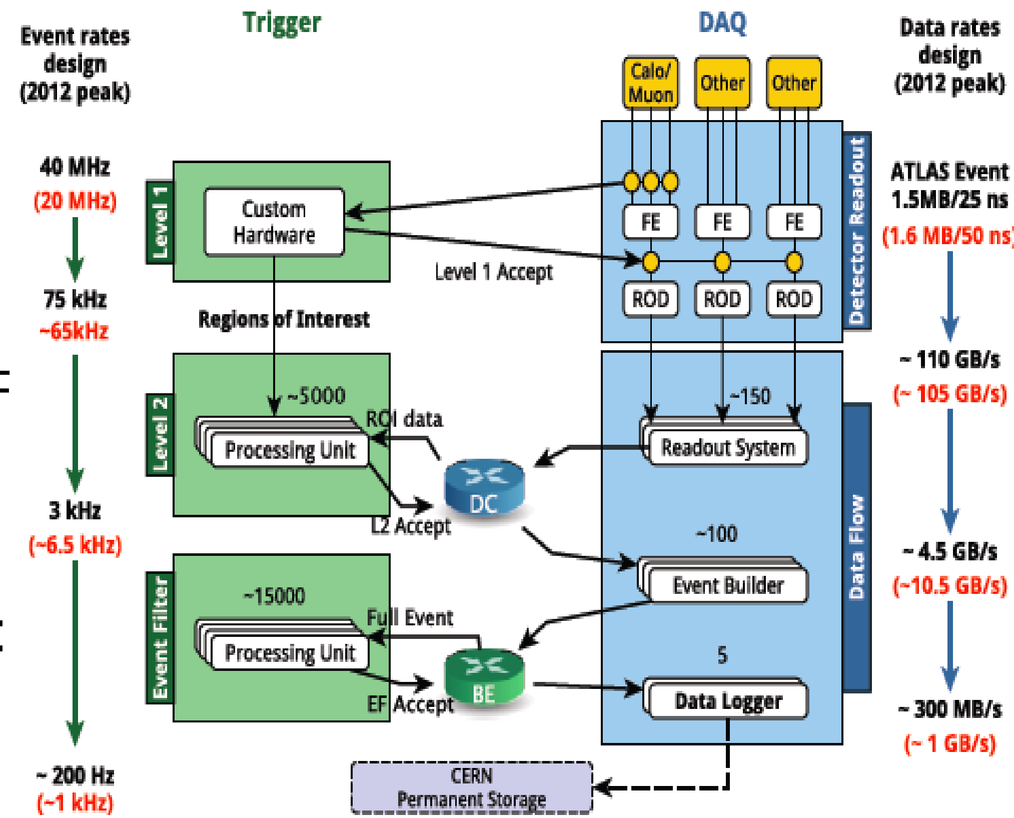
- All the decay products are revealed by the detector
  - Distinctive final states with high jet/b-tag multiplicity and multiple heavy resonances
  - Large combinatorial backround
- Huge multi-jets bkg and $t\bar{t}$ bkg
- Status of the analysis :
  - Started trigger studies to ameliorate signal offline selection efficiency

Event trigger

- Select interesting physics events among the huge amount of collisions produced, going from the rate of 40 MHz to the recording rate of ~200 Hz

Three level design :

- Level 1 built with custom hardware
- Level 2 and Event Filter form High Level Trigger(HLT) and are software triggers running on dedicated computer farms
  - Jets are reconstructed at L1 , L2 and EF
  - Tracking information for b-tagging available at L2 and EF

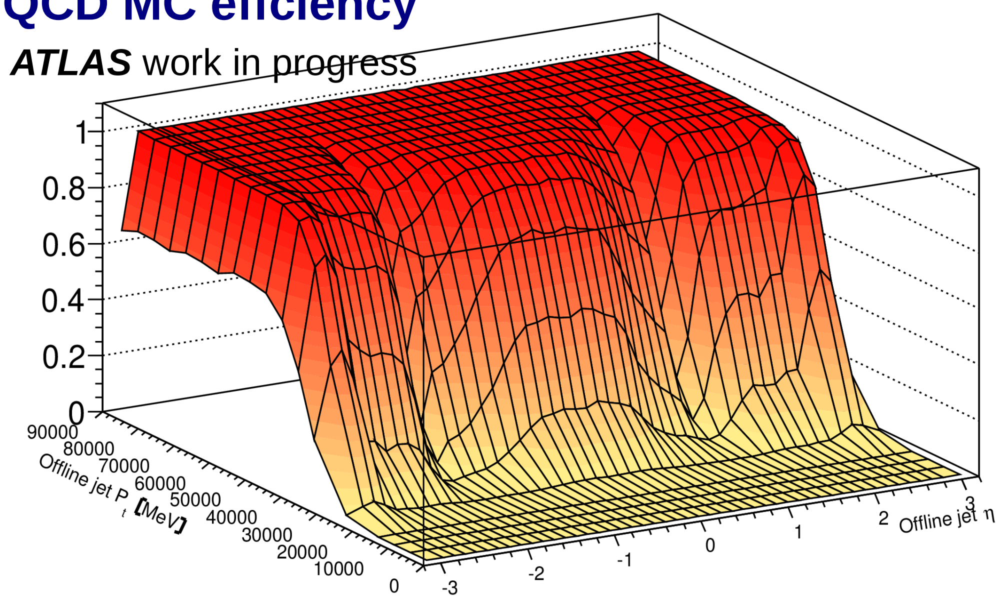


- 3 Working Points for online b-tagging :
  - Loose – efficiency 60 % , rejection 51
  - Medium – efficiency 50 %, rejection 145
  - Tight – efficiency 40 %, rejection 350
- All-hadronic $t\bar{t}H$ use **b-jet multi-jet triggers** :
  - At 8 TeV has twice the efficiency w.r.t. the lowest unprescaled multi jet trigger

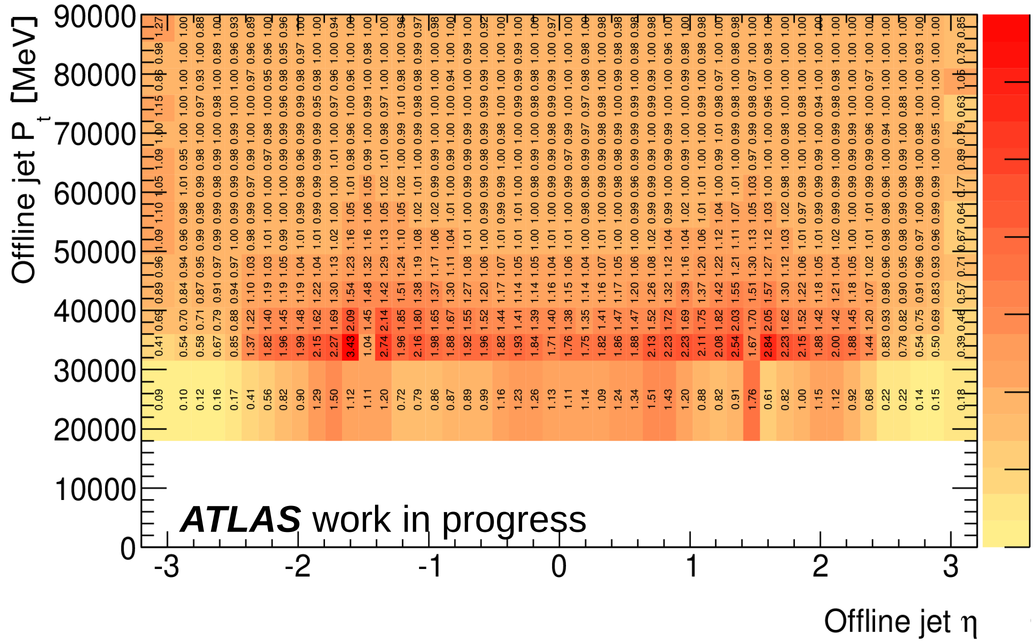
Jet trigger studies

- Observed differences in trigger efficiencies turn-on curve between Data and simulated events
  - Need to apply harsh offline jet p_T requirements in order to be in a fully efficient region → Huge loss of signal efficiency!!
    - Accessing turn-on region gives a factor of two in fully hadronic $t\bar{t}H$ acceptance
- Preliminary study shows that it is possible to introduce a scale factor to compensate for Data / MC difference and avoid this strict requirement
  - Scale factor obtained as a ratio of the parametrized efficiency in Data over the one in Monte Carlo as a function of offline p_T and η
    - Data sample used : Requesting minimum bias trigger

QCD MC effciency



Scale Factor



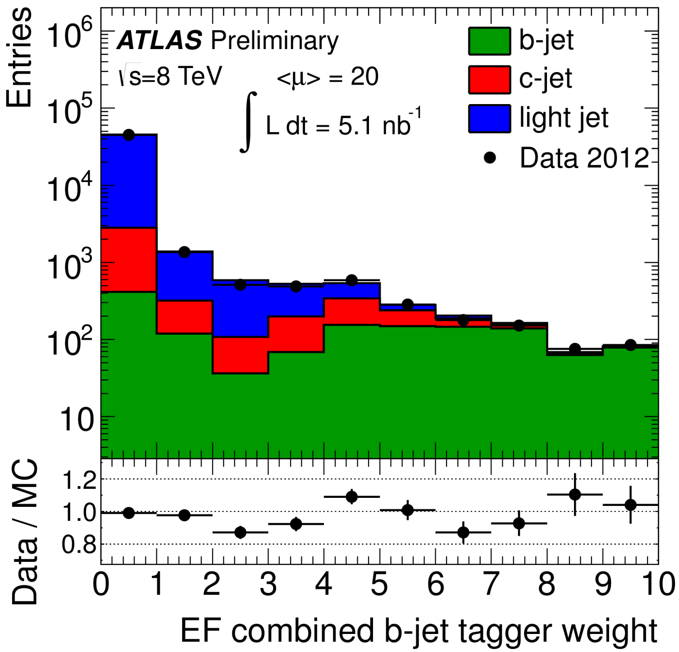
Conclusions and outlook

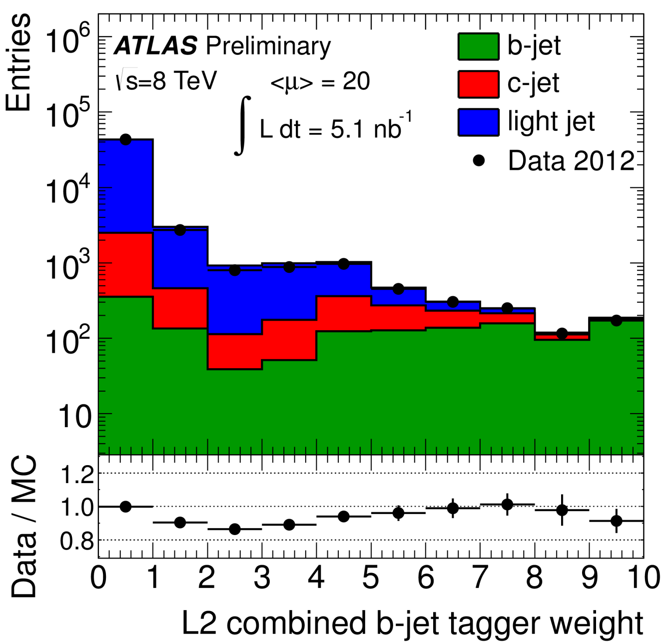
- Higgs discovery performed by ATLAS and CMS experiments has been one of the greatest success of the LHC
  - The era of Higgs precision measurements has started :
    - Mass : 125.5 ± 0.2 (stat) +0.5/-0.6 (sys) GeV
    - Spin : $J^P=0^+$
    - Measure of couplings with gauge bosons and indirectly with fermions
  - Still many unasked questions:
    - Is it the SM Higgs boson? – Is it the only Higgs boson?
    - Top yukawa coupling sensible to new physics
    - ATLAS already looked at $t\bar{t}H$ production using 4.7 fb^{-1} of 7 TeV data : semi-leptonic analysis
      - Observed (expected) limit of 13.1 (10.5) x SM at 125 GeV
- Presented the all-hadronic $t\bar{t}$ analysis which suggest a possible extension of $t\bar{t}H$ to this final state
  - Measured cross section $\sigma(pp \rightarrow t\bar{t}) = 168 \pm 12\ (\text{stat.})\ ^{+60}_{-57}\ (\text{syst.}) \pm 7\ (\text{lumy.})$ pb
- My work is to extend the $t\bar{t}H$ search to the fully hadronic final state

Backup

ATLAS b-jet trigger

- **Multi-jet triggers used in combination with online b-tagging**:
  - Allow to decrease the HLT jet p_T thresholds using the rejection coming from requesting b-jet at trigger level
    - Optimal use in fully hadronic $t\bar{t}H$: 4 b-quark in the final state
- **Ip3d** : combine the impact parameter significance of all the tracks in the jet
- **SV1** : based on the properties of the secondary vertex
  - Invariant mass
  - Ratio of the sum of the energies of the tracks in the vertex to the sum of the energies of all tracks in the jet
  - the number of two-track vertices
- **Combined using a likelihood ratio**





Physics analysis with multi-jet triggers

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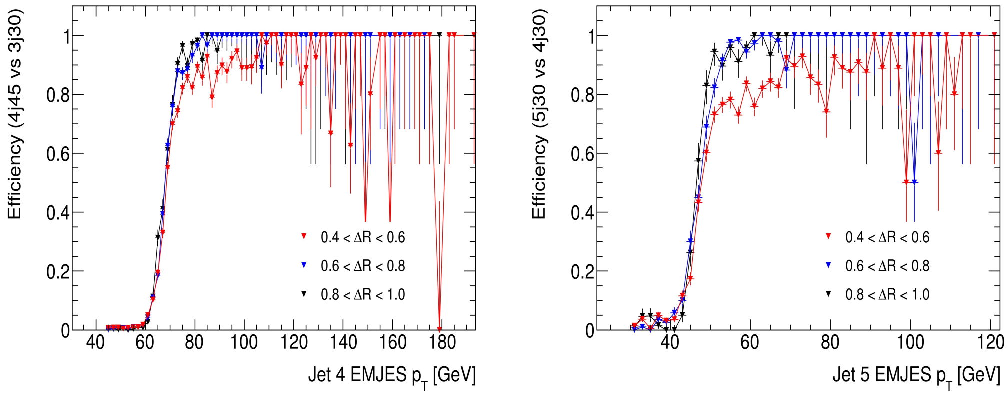


- Many analysis use multi-jet triggers
  - Forced to cut at high offline jet p_T and on jet isolation to be at the plateau of the trigger efficiency and be safe w.r.t. MC mismodeling
  - Problem for the analysis performing searches for new physics in multi-jets final states: consistent loss of signal efficiency
- Need to find a reliable way of using multi-jet trigger in the non fully efficient region in a way the DATA / MC differences are taken into account.

Fully hadronic ttH(H-->bb) cut flow N. Tannoury

cut	ttH	tt MC@NLO	tt POWHEG	ttqqqq Np(0,1,2,3)	ttbb
All Evts	131	362051	358590	359146	7512
Good jet	129	357329	353309	354261	7413
After PV	128	356344	352366	353448	7387
Lepton Veto	128	355337	352199	353261	5617
Trigger	72	65939	67336	68946	1161
Ater HFOR	72	65939	67336	67301	957
ΔR(j,j)>0.6	39	46463	46215	45972	633
>=5jets pT 55GeV	20	15486	15836	16499	229
>=8jets pT>25 GeV	7.5	1766	2614	2453	50
>=8jets,==2 b-tag jets with MV170	1.82	1267	1160	1125	16
>=8jets,==3 b-tag jets with MV170	2.8	386	372	345	18
>=8jets,>=4 b-tag jets with MV170	2.3	51	65	46	9

Jets cases

- This study has been performed in two steps
  - 1: Trigger efficiency parametrization for events with only isolated jets
  - 2: Trigger efficiency parametrization for events with non-isolated jets
- This will allow to take into account for the presence of n jet with $p_T > p_T$(threshold) in a n multi-jet triggered event where the efficiency w.r.t. The n-th jet is achieved at p_T(plateau)>p_T(threshold)
- This trigger is fully efficient at 55 GeV offline jet pT we will use it for jet having at least 45 GeV

Event Selection

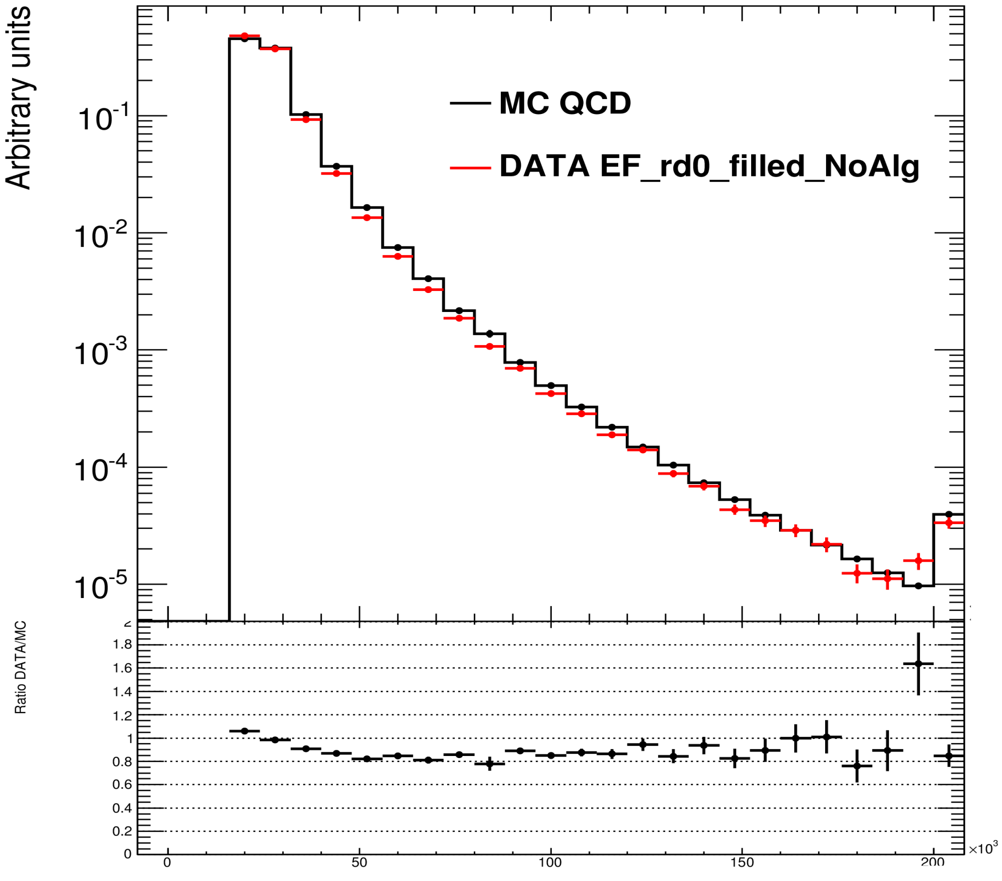
- Remove event based on
  - LarError, tileError, TileTripReader, GRL
- At least one PV with at least two tracks associated
- DATA: EF_rd0_filled_NoAlg and EF_j110_a4tchad
- At least one offline jet
  - p_T > 20 GeV and $|\eta|$ < 3.2
- Veto on events with jets with |timing| > 10 ns
- Isolation requirement (only for isolated jets study) : offline jets separated by a distance $\Delta R < 0.6$
  - Veto on event with BadLoose or Ugly jet

Object ID

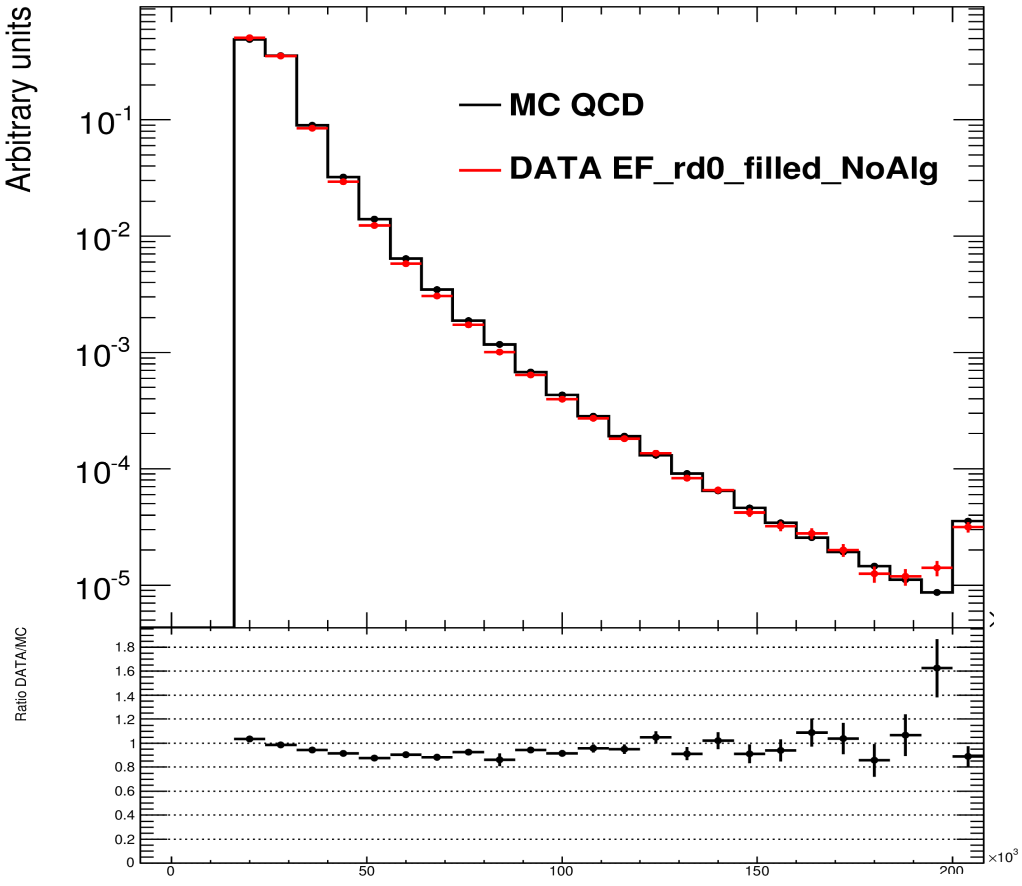
- L1 online jet:
  - Et = et8x8
- L1.5 online jet:
  - InputType == “NONE”
  - OutputType == “A4TT”
- EF online jets:
  - AntiKt4_topo_calib_EMJES
- Offline jets:
  - antikt4topoemjets

Comparison DATA/MC

- Just a validation of the QCD MC sample and his ability to describe Min Bias triggered data
  - Considering only offline jets with p_T > 20 GeV and $|\eta|$ < 3.2
  - Different QCD MC samples are normalized to the relative xsec the overall normalization for the plots shown below comes from imposing same number of events in data and MC



Leading jet p_T [MeV]



All jet p_T [MeV]

Isolated jets

Methodology of the work

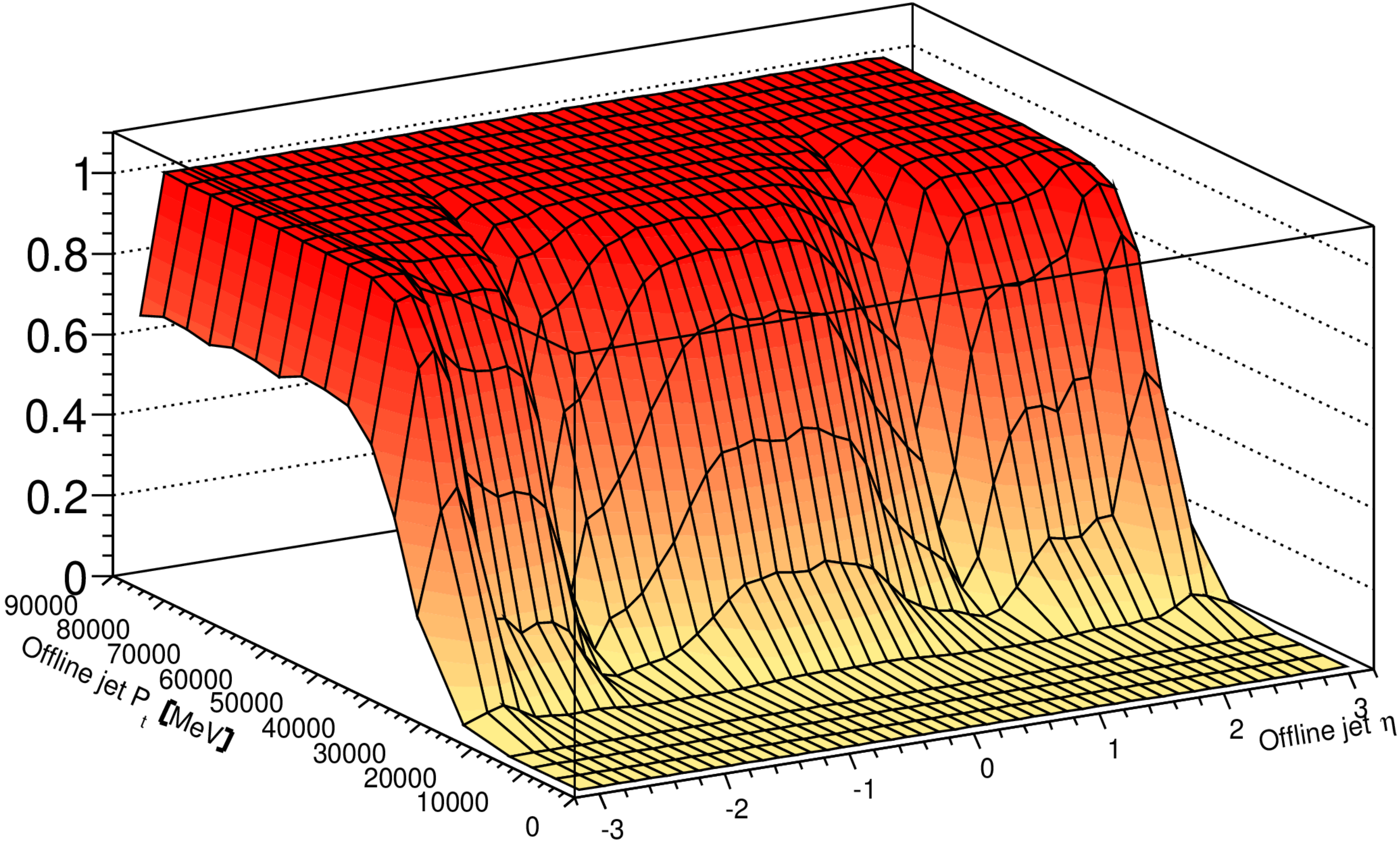
- A way to account for these differences is to introduce a Scale Factor (SF), but that is not trivial: need to find event observables that are able to be used as a parametrization of the trigger efficiency
  - In this study we are considering a parametrization w.r.t. the properties of the offline jets in the event: number of jets, η , p_T and isolation
    - Building a single-jet efficiency parametrization (turn-on curve)
    - Interpreting this as the probability of a single jet to fire a Jet trigger chain L1-L2-EF
    - Combining the probabilities of all the jets in the event to obtain a prediction of the number of jets that fire the trigger in the event
- First task is to prove that this procedure is sufficient to estimate the multi-jet trigger efficiency in any physics sample

Isolated single jet turn on

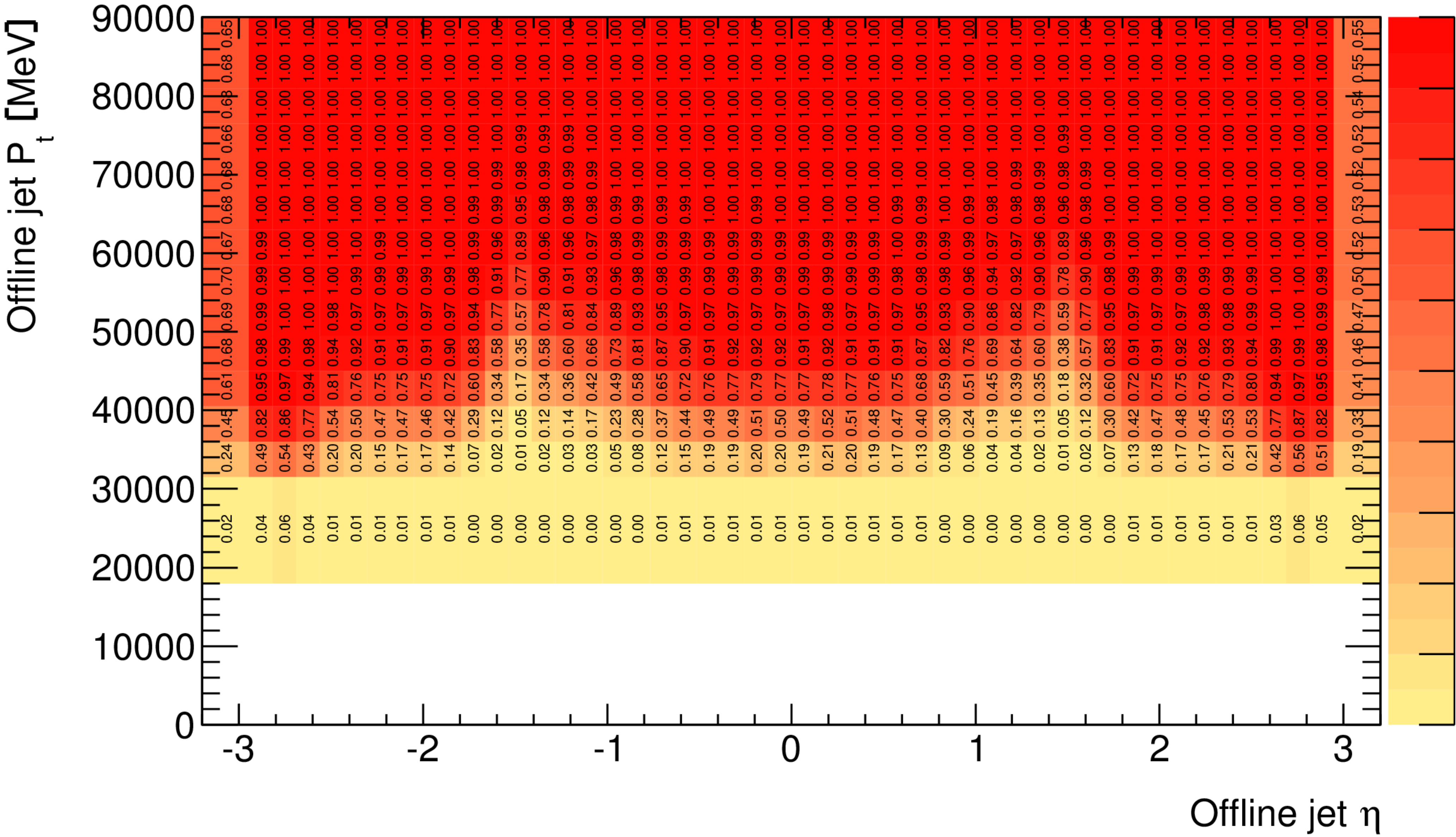
$$\epsilon(P_t,\eta)=\frac{N(P_t,\eta)}{N_{Tot}(P_t,\eta)}$$

- **Denominator N_{Tot}** is the total number of offline jets, in bins of p_T and η
- **Numerator N** is the number of offline jets, in bins of p_T and η, that are matched to online jets that pass the trigger threshold
  - Thresholds used are:
    - 15 GeV at L1
    - 15 GeV at L1.5
    - 30 GeV at EF
  - **Matching** is done requesting $\Delta R < 0.4$ between the two jets
    - If more than one online jet has $\Delta R < 0.4$ to the same offline jets, the closest is considered as matched

Single jet 2D turn on for QCD MC



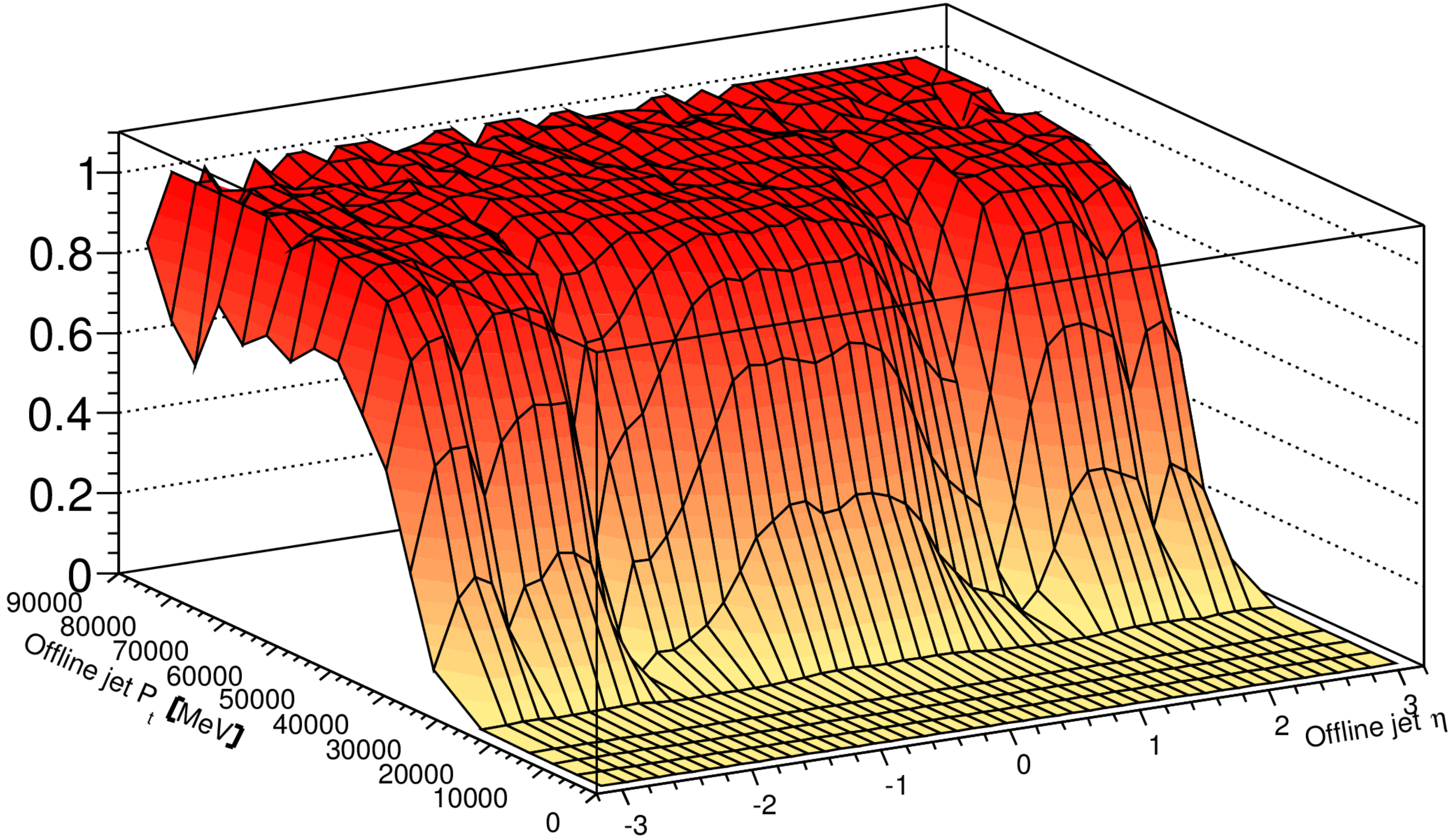
Single jet 2D turn on for QCD MC



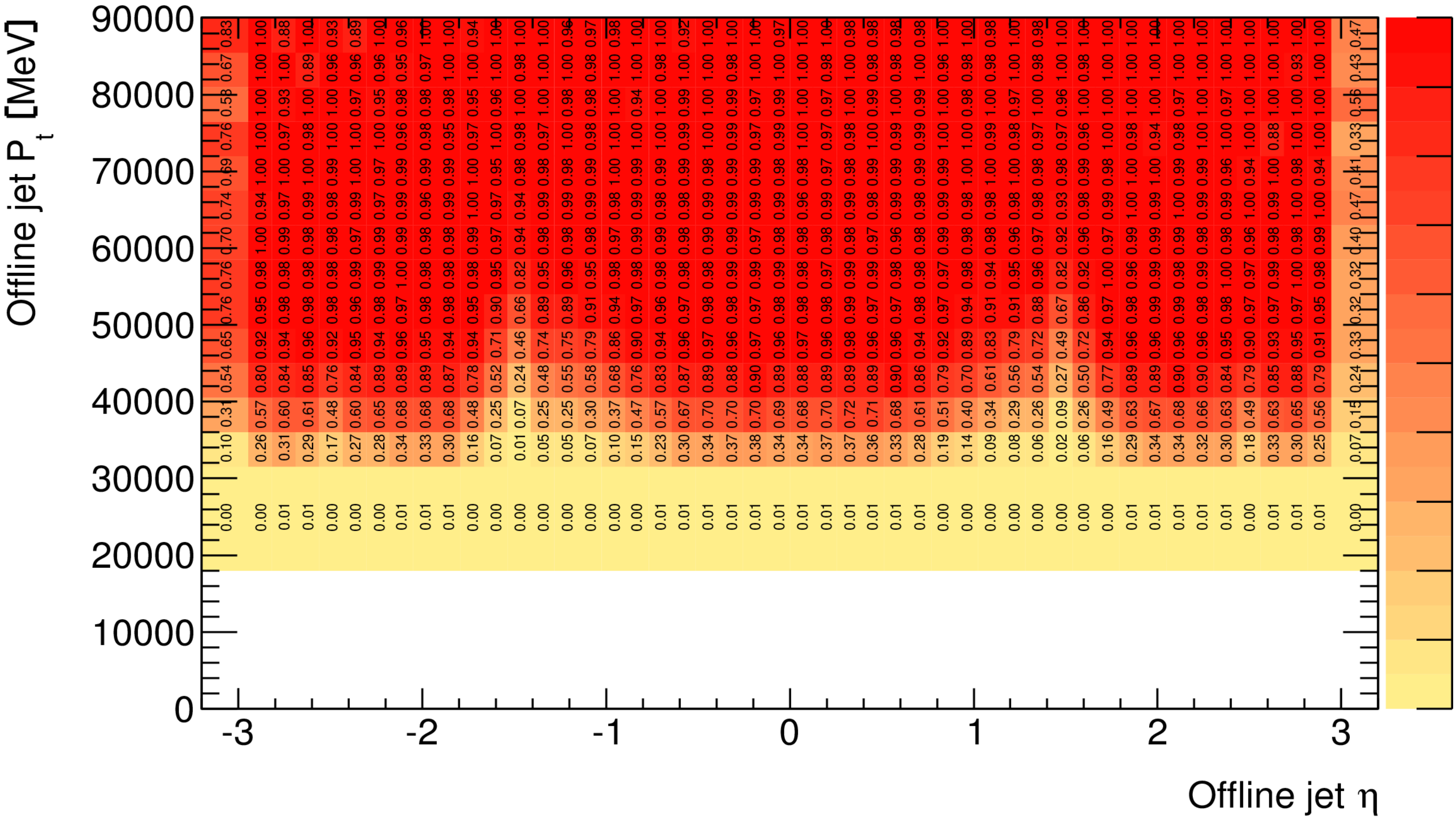
For this study we focus on events having *n* offline jets with

p_T > 45 GeV where *n* is the multiplicity of the multi-jet trigger

Single jet 2D turn on for minimum bias triggered DATA



Single jet 2D turn on for minimum bias triggered DATA



Validation of the 2D parametrization

- Derive the probability that an event fires the n = (0,1,2,3,≥4) multi jet trigger from the single-jet trigger probability ε

$$P_0 = \prod_{i=1}^{N\ jets} \left(1-\epsilon(i)\right) \qquad P_1 = \sum_{i=1}^{N.\ jets} \epsilon(i) \prod_{k\neq i} \left(1-\epsilon(k)\right)$$

$$P_2 = \sum_{i=1}^{N.\ jets} \sum_{j=i+1}^{N.\ jets} \epsilon(i)\epsilon(j) \prod_{k\neq i;k\neq j} \left(1-\epsilon(k)\right)$$

$$P_3 = \sum_{i=1}^{N.\ jets} \sum_{j=i+1}^{N.\ jets} \sum_{l=j+1}^{N.\ jets} \epsilon(i)\epsilon(j)\epsilon(l) \prod_{k\neq i;k\neq j;k\neq l} \left(1-\epsilon(k)\right)$$

$$P_{n\geq 4} = 1 - P_3 - P_2 - P_1 - P_0 \qquad \epsilon(i) = \epsilon(\eta_i, p_{Ti})$$

Validation parametrization on the same sample

- Considering events having at least NJ offline jet with $p_T \geq 45$ GeV
- With "Triggered events" are designed the number of events having NJ L1_J15, L2_j15, EF_ j30.
- Prediction is estimated from ε_J (p_T, η) where J are all isolated jets with $p_T > 20$ GeV and $|\eta| < 3.2$

Divided in two sub-samples, one for efficiency calculation and one for validation

MC QCD	Triggered events	Prediction
J==1	558349	558831
J==2	170157	169643
J==3	11685	11608
J>=1	887406	877472
J>=2	198439	197927
J>=3	14731	14687
J>=4	1571	1565

DATA	Triggered events	Prediction
J==1	24456	25434
J==2	8210	8444
J==3	443	462
J>=1	40762	41931
J>=2	9450	9696
J>=3	559	578
J>=4	52	51

L1	$E_T > 15$ GeV	L1.5	$E_T > 15$ GeV	EF	$p_T > 30$ GeV

Principle for the SF

- In a similar way as described in the b-tagging ATLAS note ATL-COM-PHYS-2010-331 a weight is defined to account for the different trigger efficiency in DATA and MC

- The event weight ***W*** is defined as: $$W = \prod_{jets} w_{jet}$$

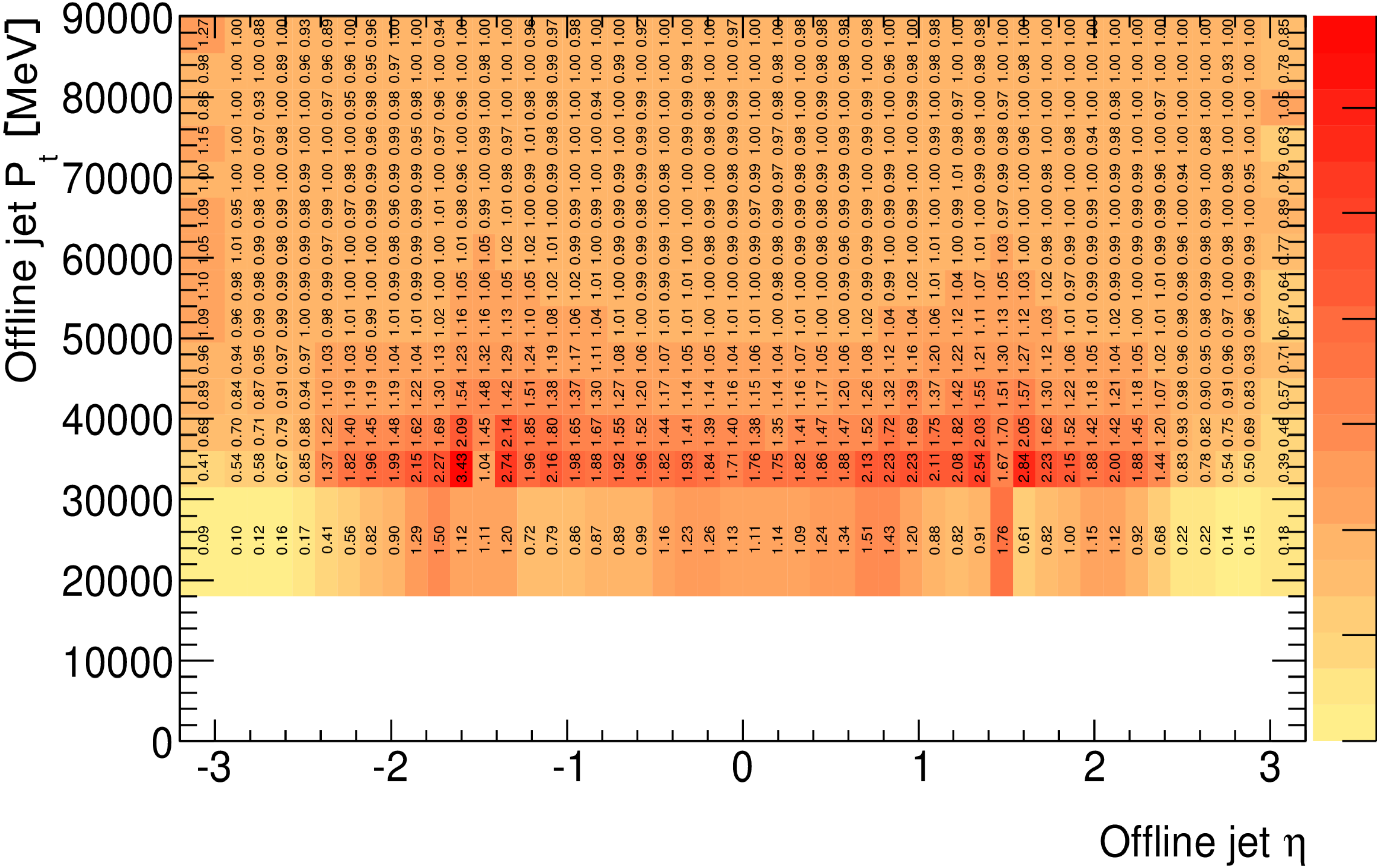
- The jet weight $\boldsymbol{w_{jet}}$ is different, depending if the jet is triggered (i.e. matched to a complete trigger chain) or not:

$$w_{triggered\ jet} = SF(\eta, Pt)$$

$$\boxed{SF(\eta, Pt) = \frac{\epsilon^{Data}(\eta, Pt)}{\epsilon^{MC}(\eta, Pt)}}$$

$$w_{untriggered\ jet} = \frac{1 - \epsilon^{Data}(\eta, Pt)}{1 - \epsilon^{MC}(\eta, Pt)} = \frac{1 - SF(\eta, Pt)\,\epsilon^{MC}(\eta, Pt)}{1 - \epsilon^{MC}(\eta, Pt)}$$

Ratio Min Bias triggered DATA and MC QCD



Application of the SF on MC QCD

- Look at the trigger chains in the MC sample
- Compare with the prediction made using the efficiency in DATA which, as shown, describe the trigger behaviour in DATA
- Weighting the trigger simulation in MC using the SF we obtain a behaviour close to the one in DATA

MC QCD	Triggered events	Prediction using DATA turn-on	After applying DATA / MC SF
J==1	558349	544663	544355
J==2	170157	170525	170787
J==3	11685	11496	11526
J>=1	887406	899795	909642
J>=2	198439	202441	202585
J>=3	14731	15007	14967
J>=4	1571	1603	1618

L1	E_T > 15 GeV	L1.5	E_T > 15 GeV	EF	p_T > 30 GeV

Non-Isolated jets

Non-Isolated jets

- For events with isolated jets we made one to one link between offline and online jets to be able to describe the trigger behaviour

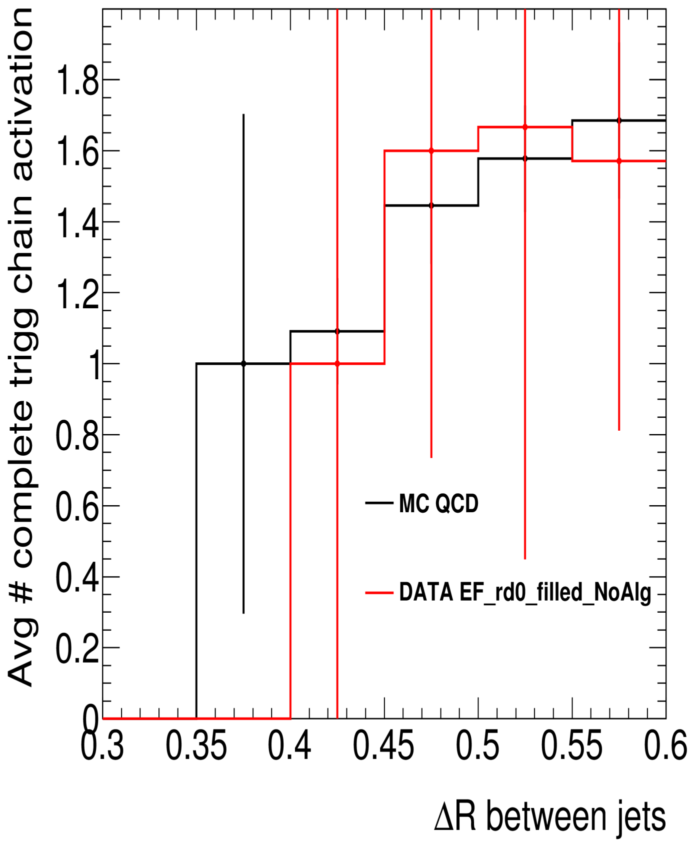
- For non-isolated jets this is not possible, because there can be non trivial behaviour. I.e. :
  - Two offline jets are matched to the same online jet
    - If the two offline jets are at $\Delta R < 0.4$ from the same online jet it is not possible to link this object exclusively to one of the two offline
  - The jets are matched to a partial chain
    - There are at least three online objects that can build a trigger chain, but they are not matched to the same offline jet

Non-isolated jet events : presence of close-jets

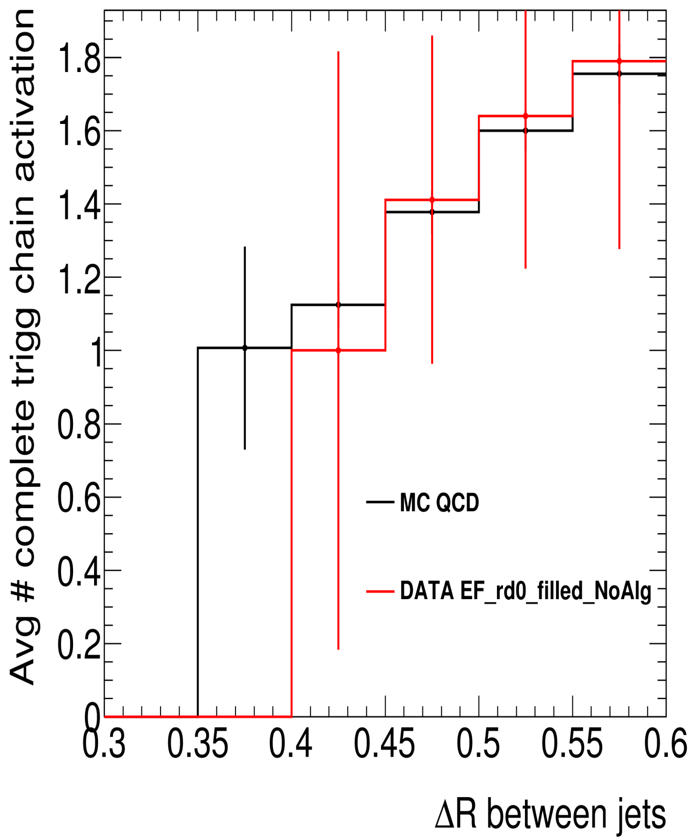
- Trigger efficiency parametrization for non-isolated jets:
  - In this study we are considering a parametrization w.r.t. the properties of the offline jets in the event: p_T of the close-jets, ΔR between close-jets, number of close-jets in a $\Delta R < 0.6$
  - Need to build a trigger firing probability for the activation of the multi-jet trigger in an environment where there are multiple offline jets
    - This is presented using as an example L1_nJ15-L2_nj15-EF_nj30 (n<5)
    - For the isolated jets this trigger chain is fully efficient at 55 GeV offline jet p_T we will use it for jet having at least 45 GeV
- Proceed to prove that this procedure is sufficient for the description of the multi-jet trigger

Close-jets trigger chain activation

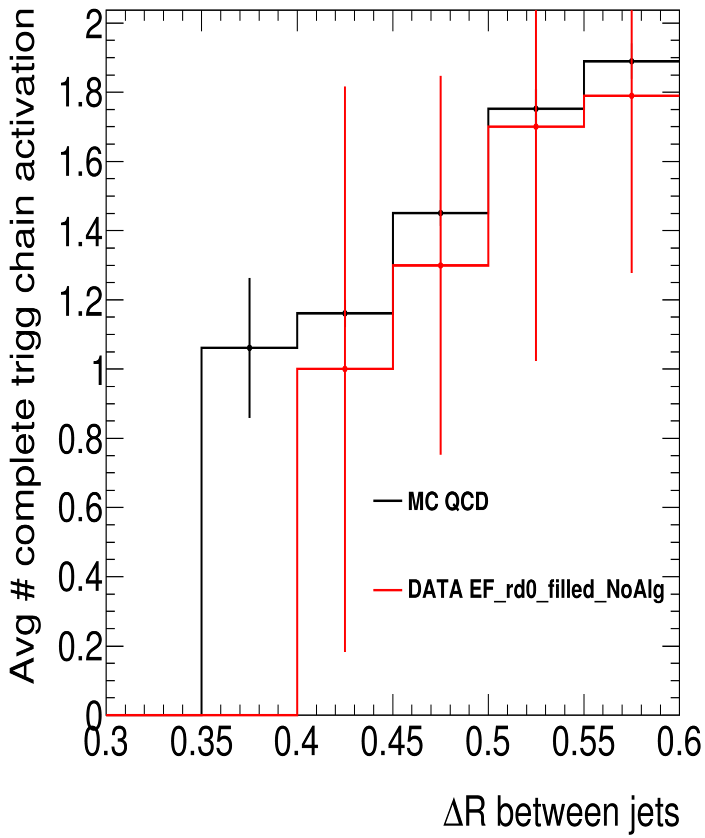
- Considering only offline jets with p_T > 45 GeV
- Looking at average completed trigger jet activation as a function of ΔR in bins of offline jet p_T
- Is evident the lack of statistics in minimum bias triggered DATA



0 jet with p_T > 55 GeV



1 jet with p_T > 55 GeV



2 jet with p_T > 55 GeV

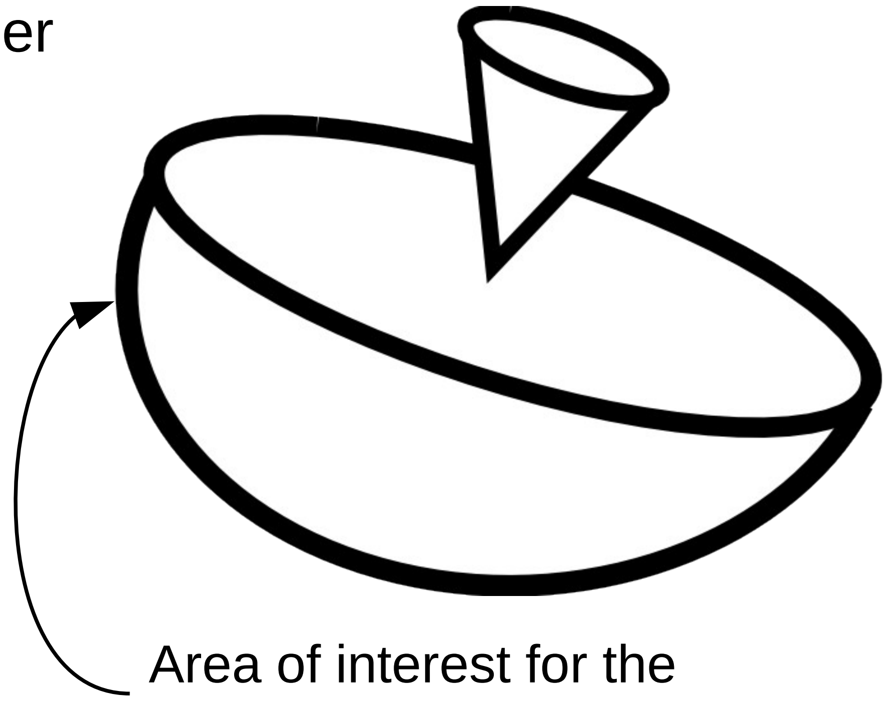
New event selection based on single jet trigger

- In order to increase statistics of close-jets need to look at multi-jet events
- look at event selected by a single jet trigger, and perform the study using the jets far from the one that has fired the trigger
- Select half of the detector in the (η, ϕ) space using ΔR

$$\pi r^2 = \frac{6.4 \times 2\pi}{2} \Rightarrow r = \sqrt{6.4}$$

Procedure:

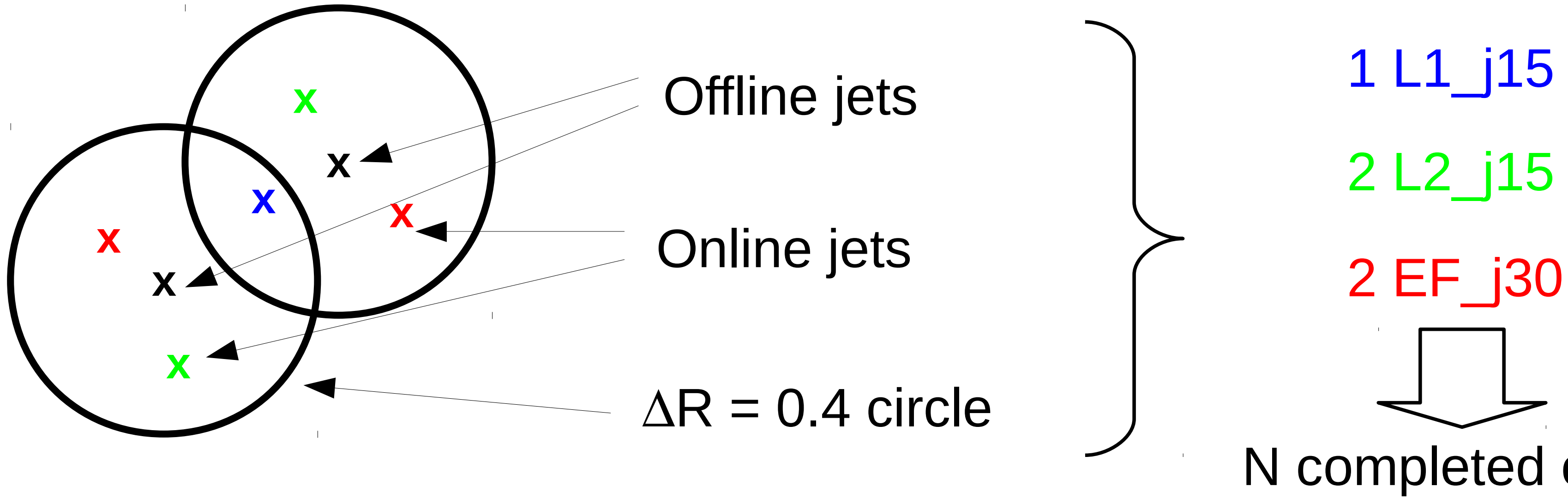
- Requesting event passing a high p_T jet trigger
- Veto on event with # of EF jet with p_T > Thr. greater than 1
- Find the offline jet that matches the high p_T trigger jet
- Request $\Delta R > r$ for every jet used for the analysis



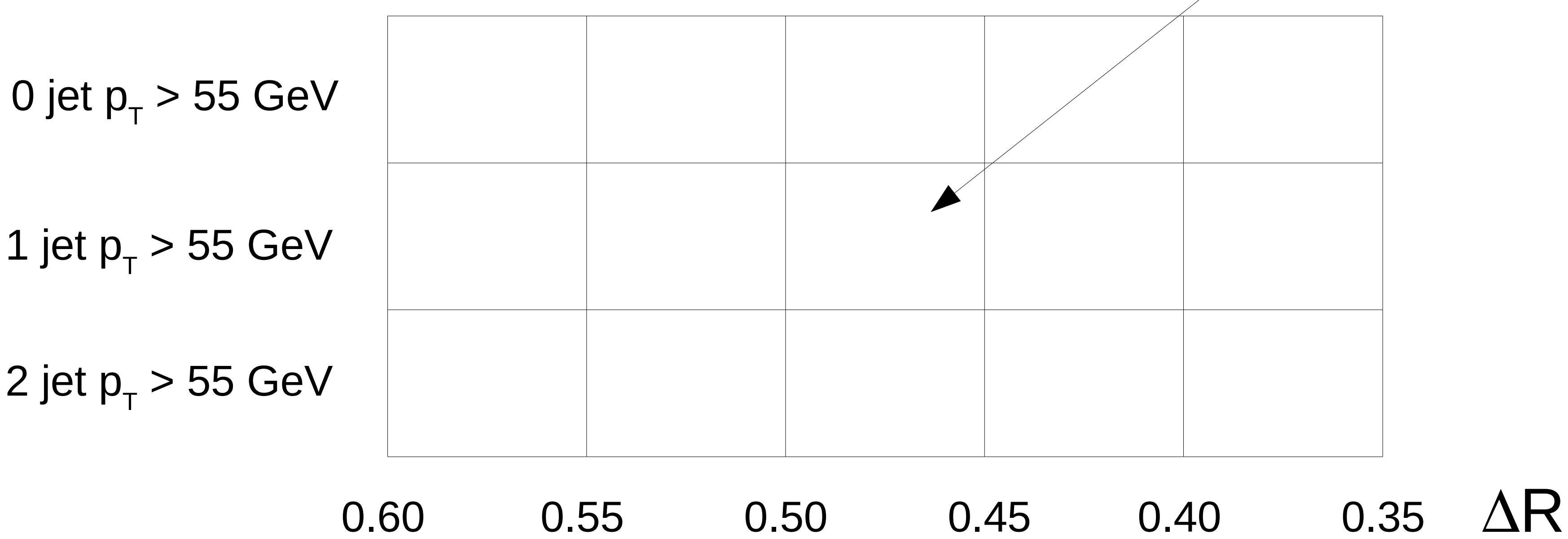
Trigger for close-jets

- For each pair of non-isolated jets we can have up to two chain activated
  - Not possible to build an efficiency curve as the one described for isolated jets
- Looking at chain multiplicity in close-jet environment
  - Not considering pairs of jets close to other jets(i.e. more than 2 close-by jets)
- 3 bins depending on p_T
  - 0 jet with p_T > 55 GeV ; 1 jet with p_T > 55 GeV ; 2 jet with p_T > 55 GeV
- 5 bins depending on ΔR between jets
  - [.35,.40] ; [.40,.45] ; [.45,.50] ; [.50,.55] ; [.55,.60]

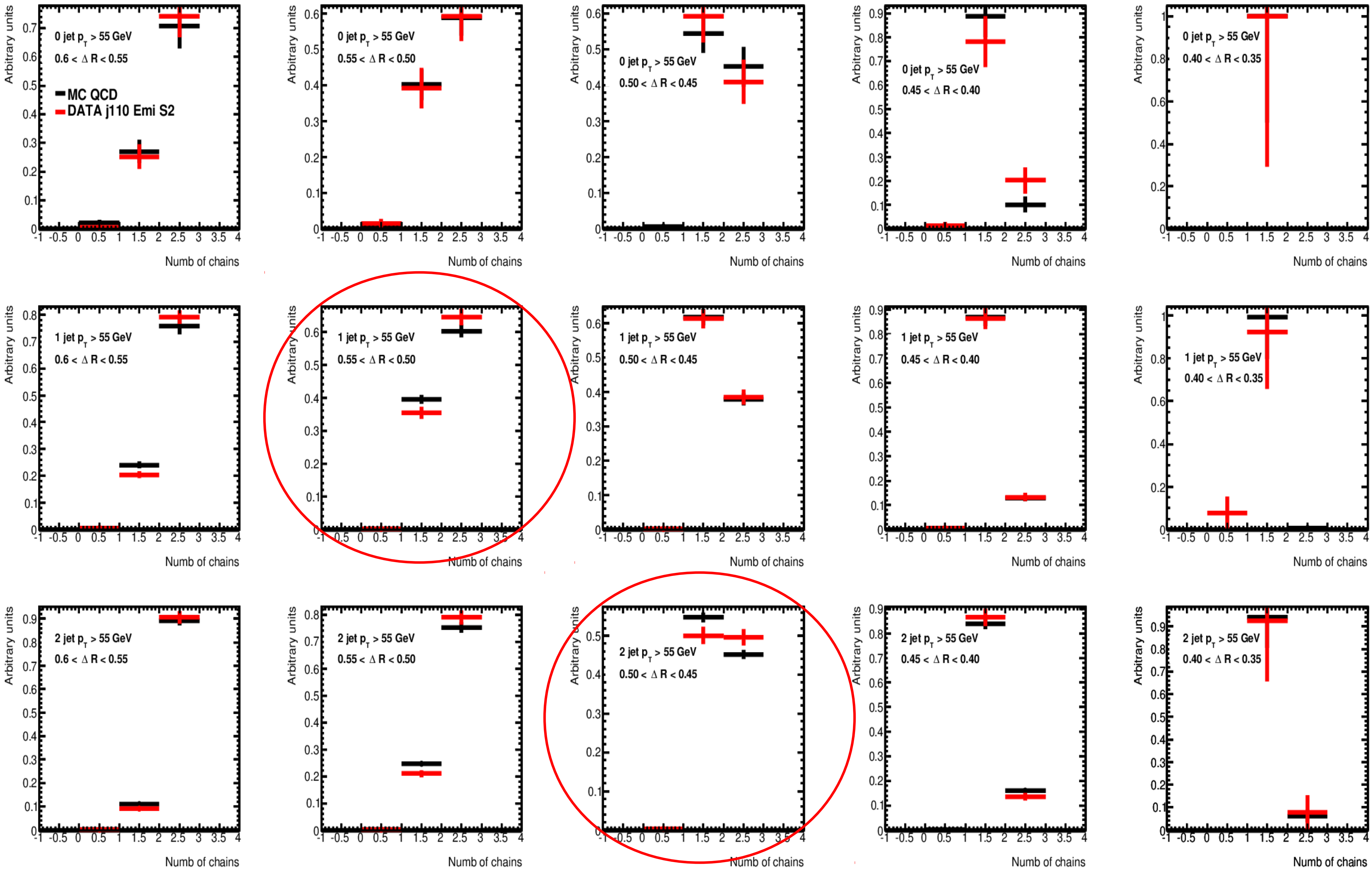
Validation using a topology Matrix



In this example 1 chain is completed



Chain multiplicity within the topology Matrix



Validation

- NO request on jet multiplicity and p_T
- Using only pairs of jets where both p_T > 45 GeV

Divided in two sub-samples, one for curve extraction and one for prediction

DATA	Trigger	Prediction using matrix
J==1	3203	3132
J==2	4935	5016
J==3	3	3
J>=1	8144	8154
J>=2	4941	5022
J>=3	6	6
J>=4	3	3

Inverting the two samples

DATA	Trigger	Prediction using matrix
J==1	2147	2168
J==2	3484	3455
J==3	3	2
J>=1	5635	5627
J>=2	3488	3459
J>=3	4	4
J>=4	1	2

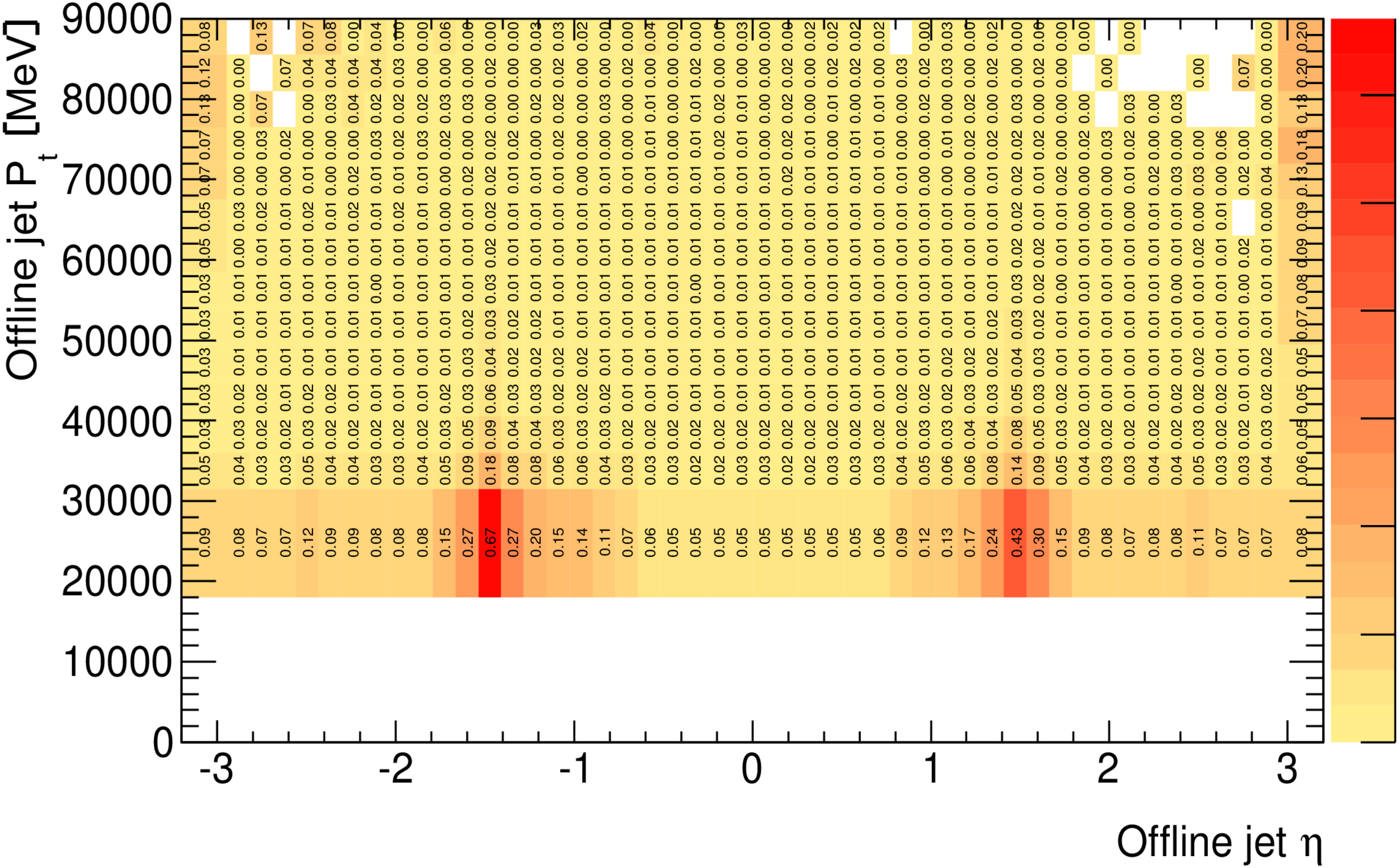
Validation by interpreting matrix as a probability

- Need to validate the assumption that the matrix is able to predict the trigger behaviour
- Looking at MC QCD events with close-jets
  - Validating prediction using differently derived topology matrix

MC QCD	Trigger	Prediction Using matrix derived in DATA	Prediction Using matrix derived in DATA MB	Prediction Using matrix derived in MC QCD	Prediction Using matrix derived in MC TTBAR
J==1	614	585	656	620	603
J==2	840	870	790	836	854
J==3	6.59278	6.62724	6.14235	6.5993	6.697
J>=1	1465	1467	1457	1467	1468
J>=2	852	881	801	847	865
J>=3	11.2093	11.4057	10.6316	11.0516	11.29
J>=4	4.61653	4.77844	4.48928	4.45227	4.59

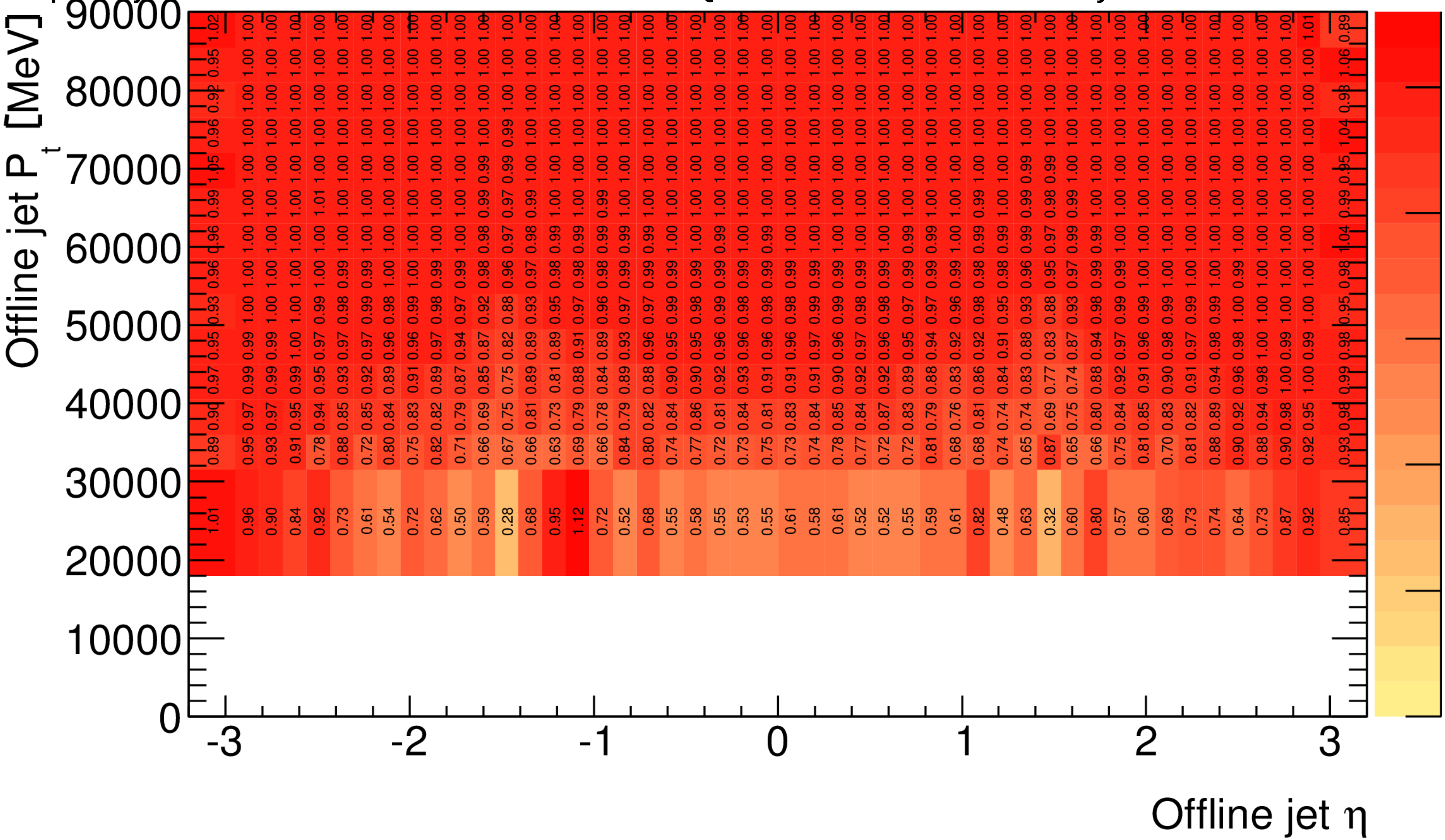
Using only pairs of jets where both p_T > 45 GeV

Statistical error on the SF

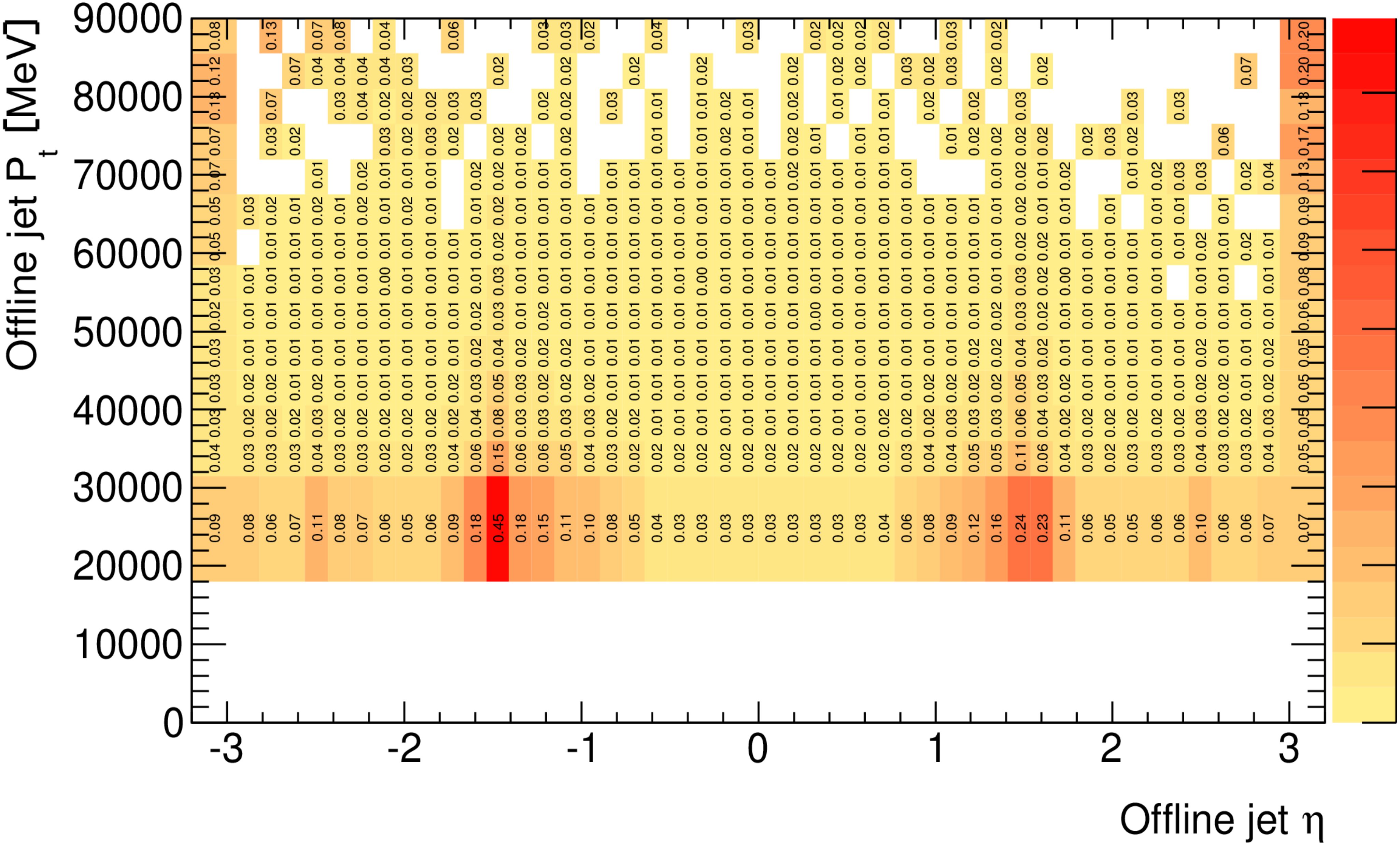


Systematic study : sample dependence

We introduce a systematic error due to physics difference between gluon-jets and quark-jet, this is estimated from the ratio of QCD over TTBAR efficiency



Relative statistical error minimum bias triggered DATA



Relative statistical error MC QCD