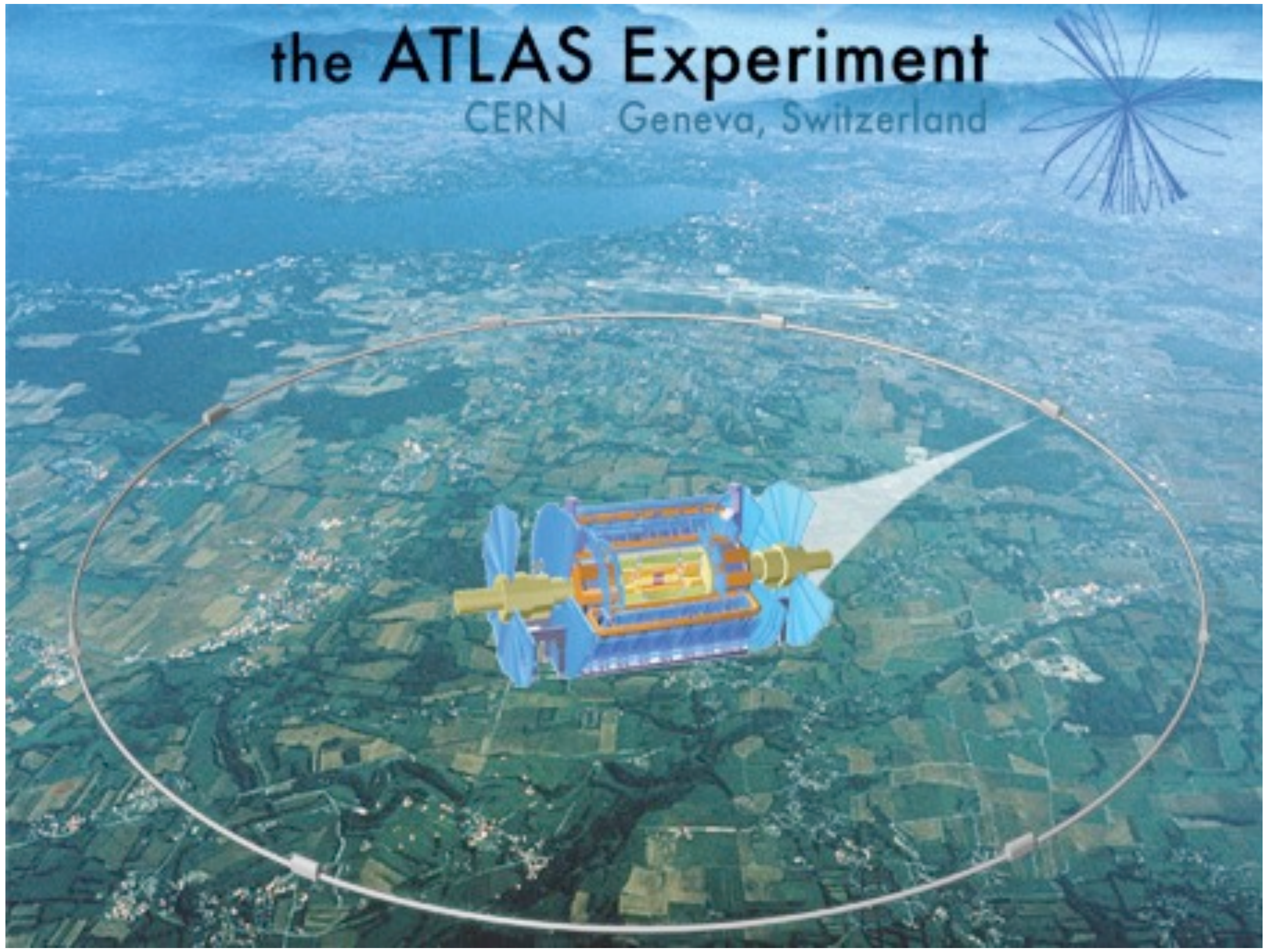
Analysis of the top quark pair production with di-leptonic final state in the ATLAS Experiment

JPS 2010 Autumn meeting@Kyushu Institute of Technology
13 Sep., 2010

Minoru Hirose, Kazunori Hanagaki
Osaka Univ.

Introduction

- **Large Hadron Collider(LHC)**
  - The world's largest and most powerful collider.
    - ➡Proton-Proton collisions
    - ➡3.5 TeV beam energy.
    - ➡$\sqrt{s}$ = 7TeV !!

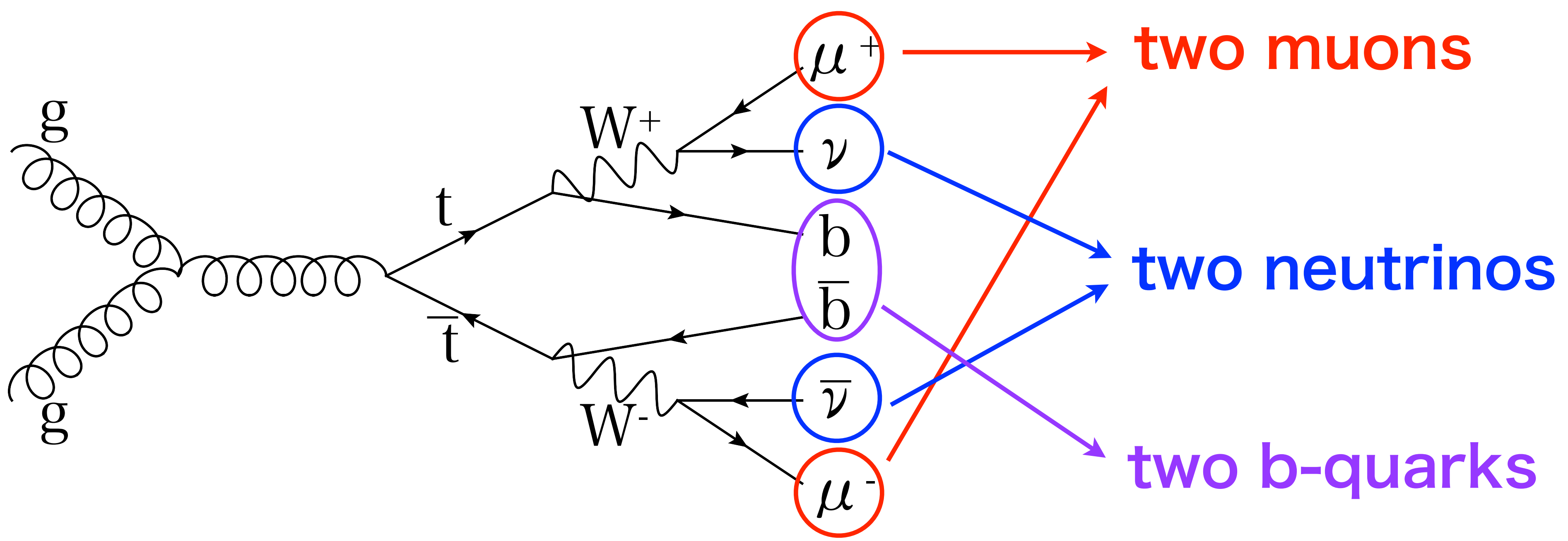


- **the ATLAS Experiment**
  - General purpose detector.
    - ➡Higgs hunting
    - ➡SUSY search
    - ➡Extra Dimensions
  - 3.4pb^{-1} recorded

We are taking data stably!!

top quark pair production

- di-muon final state of the top quark pair production



- Easy to distinguish from background !!

1) measure the cross section precisely
➡Validate QCD at higher energy

2) can be a good b-quark source
➡b-tagging plays important role to search for Higgs/SUSY

Event Selection for ttbar analysis(di-muon)

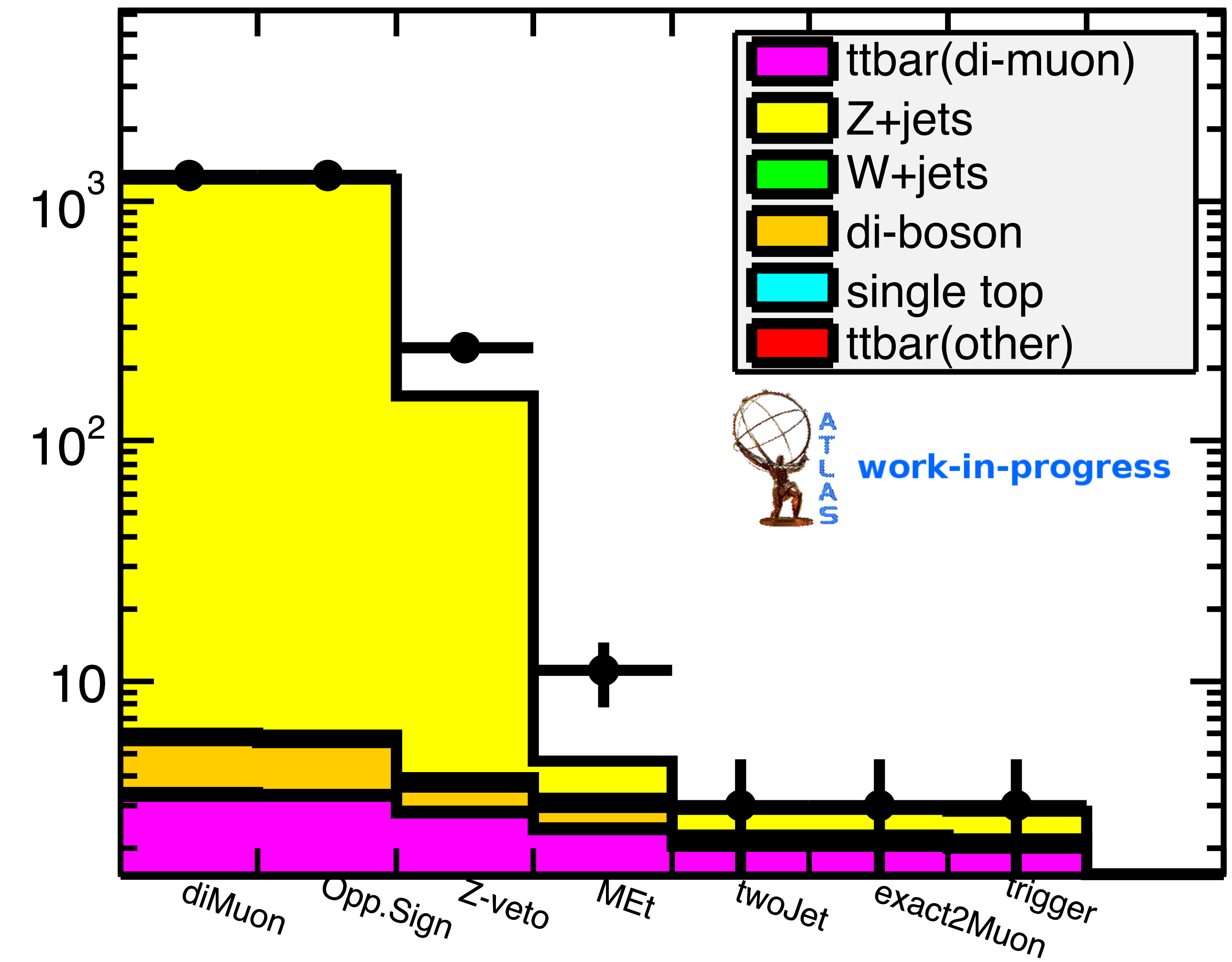
- **Object Definition**
  - Electron : Pt > 20GeV, Isolated electron
  - Muon : Pt > 20GeV, Isolated muon
  - Jet : Pt > 20GeV

- **Event Selection**
  1. #muons >=2
     ➡leading two muons have the opposite charge
  2. |Mll - Mz| > 10GeV (Z-veto)
  3. Missing Transverse Energy(MEt) > 30GeV
  4. At least two jets
  5. exact 2 muons with no selected electron
  6. muon trigger requirement

Real Data Analysis(Data-MC comparison)

- using 3.106pb^{-1} (Currently ~3.4pb^{-1} recorded)
  - After all selection...
    - ➡expected events : 2.834+/-0.077 (signal=1.992, BG=0.841)
    - ➡observed events : 3

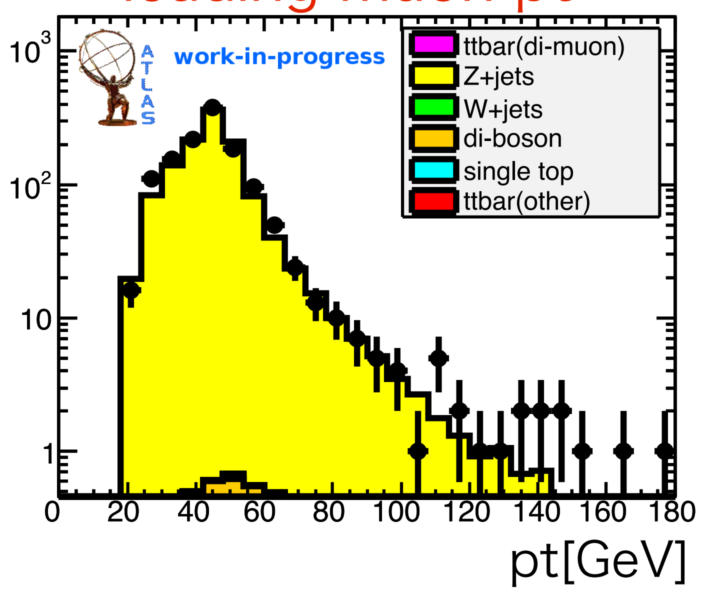
some bins are inconsistent???



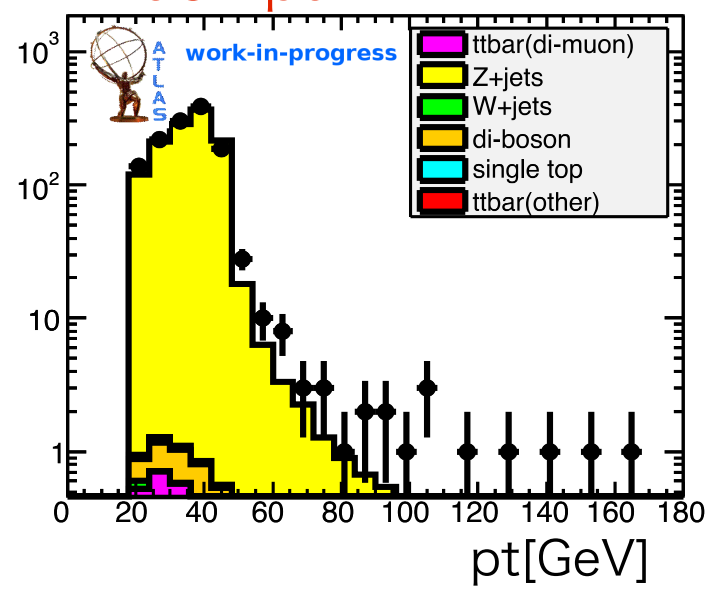
Real Data Analysis for di-muon events

- Muon kinematics, MEt, Σ|Pt| distributions
  - 1294 di-muon events observed

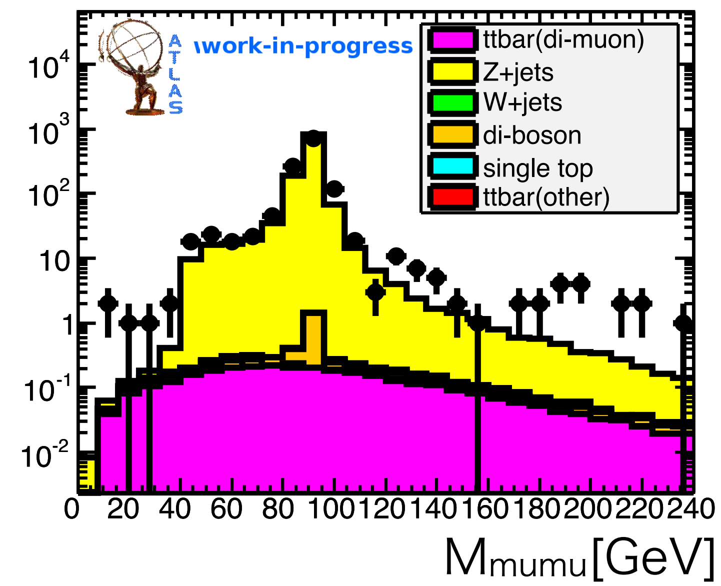
leading muon pt



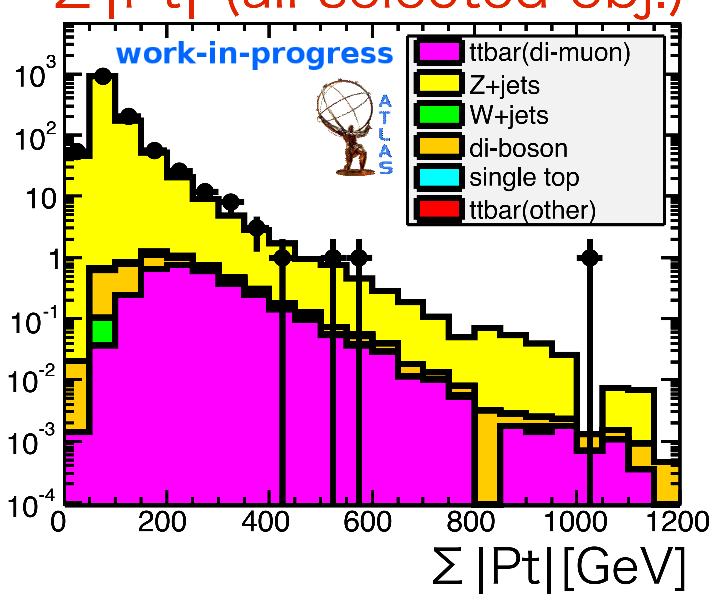
second leading muon pt



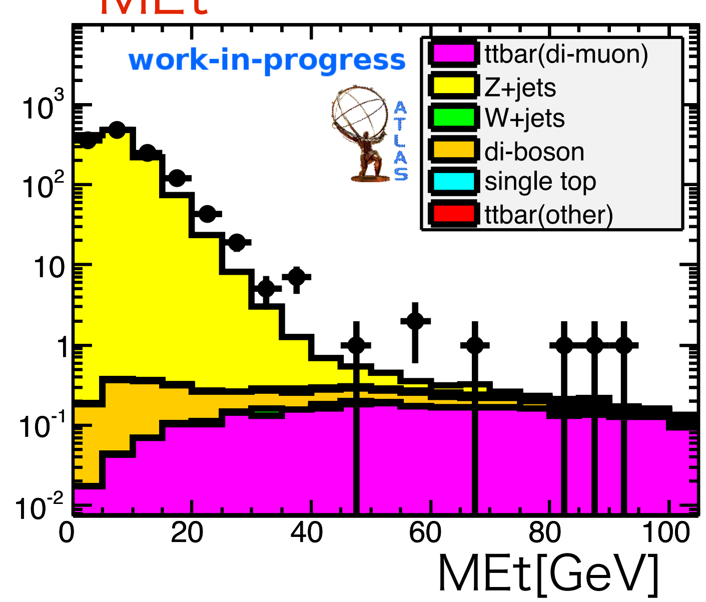
di-muon mass



Σ|Pt| (all selected obj.)



MEt



Need to investigate.

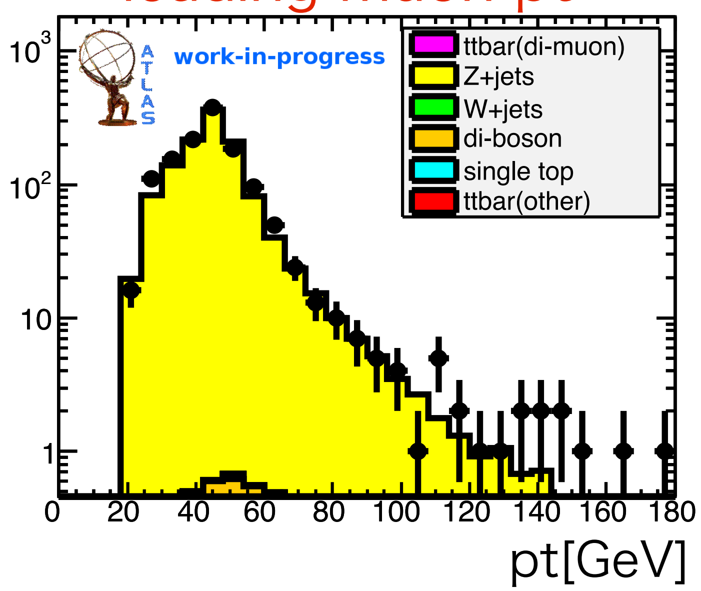
→smeared Z-mass

→higher MEt

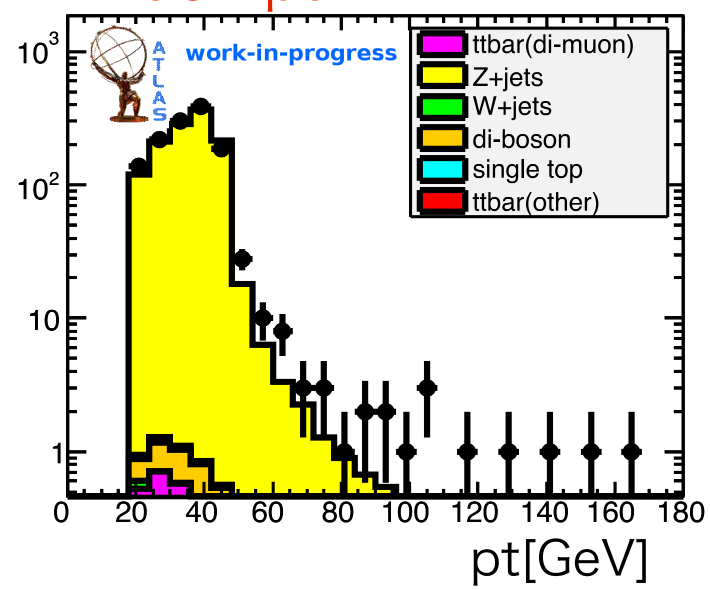
Real Data Analysis for di-muon events

- Muon kinematics, MEt, Σ|Pt| distributions
  - 1294 di-muon events observed

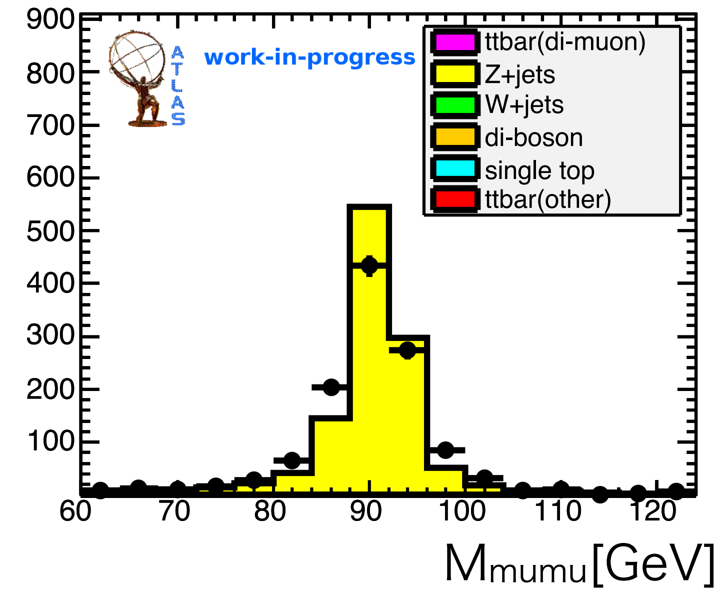
leading muon pt



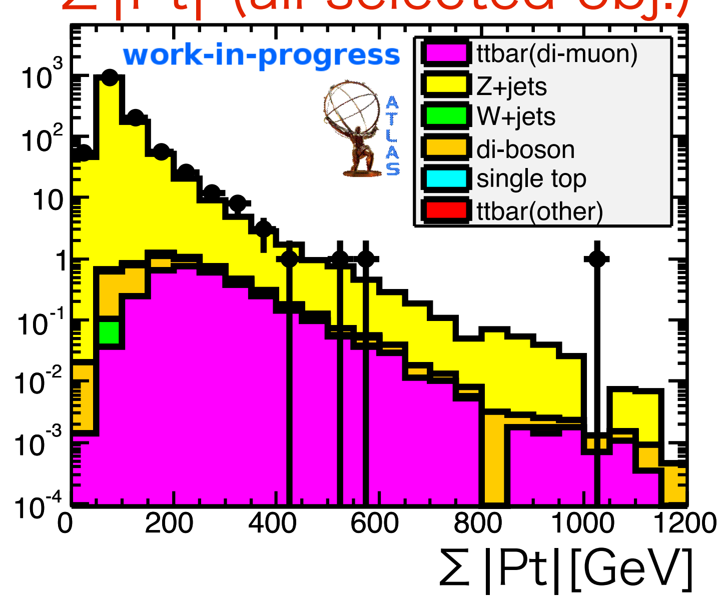
second leading muon pt



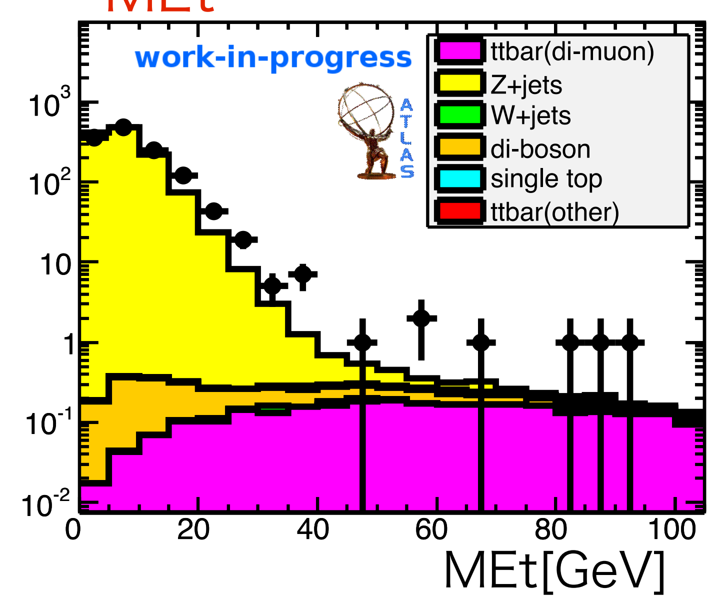
di-muon mass



Σ|Pt| (all selected obj.)



MEt



Need to investigate.

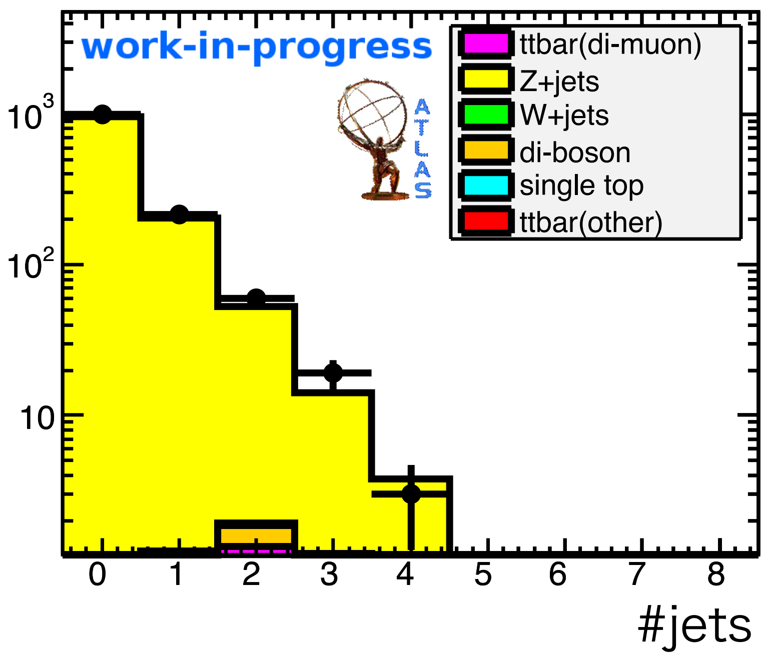
→smeared Z-mass

→higher MEt

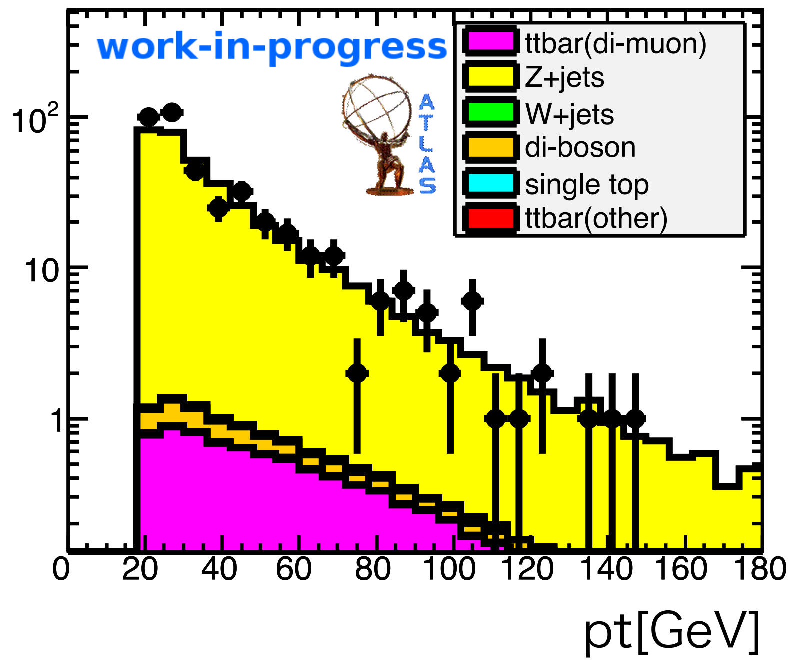
Jets in di-muon events

- Muon kinematics, MEt, Σ|Pt| distributions
  - 1294 di-muon events observed

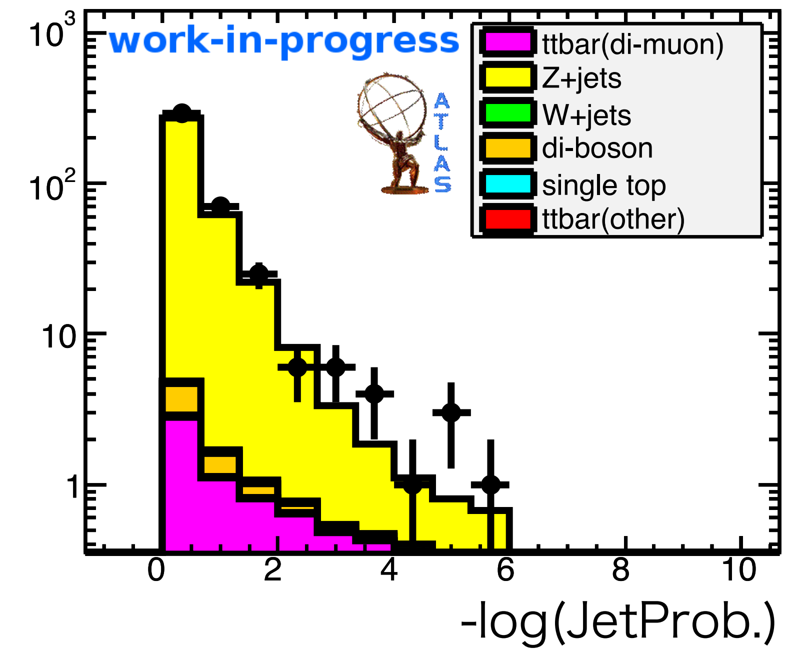
#jets



jet pt



Jet Probability
(btagging discriminant)



Consistent with MC !!

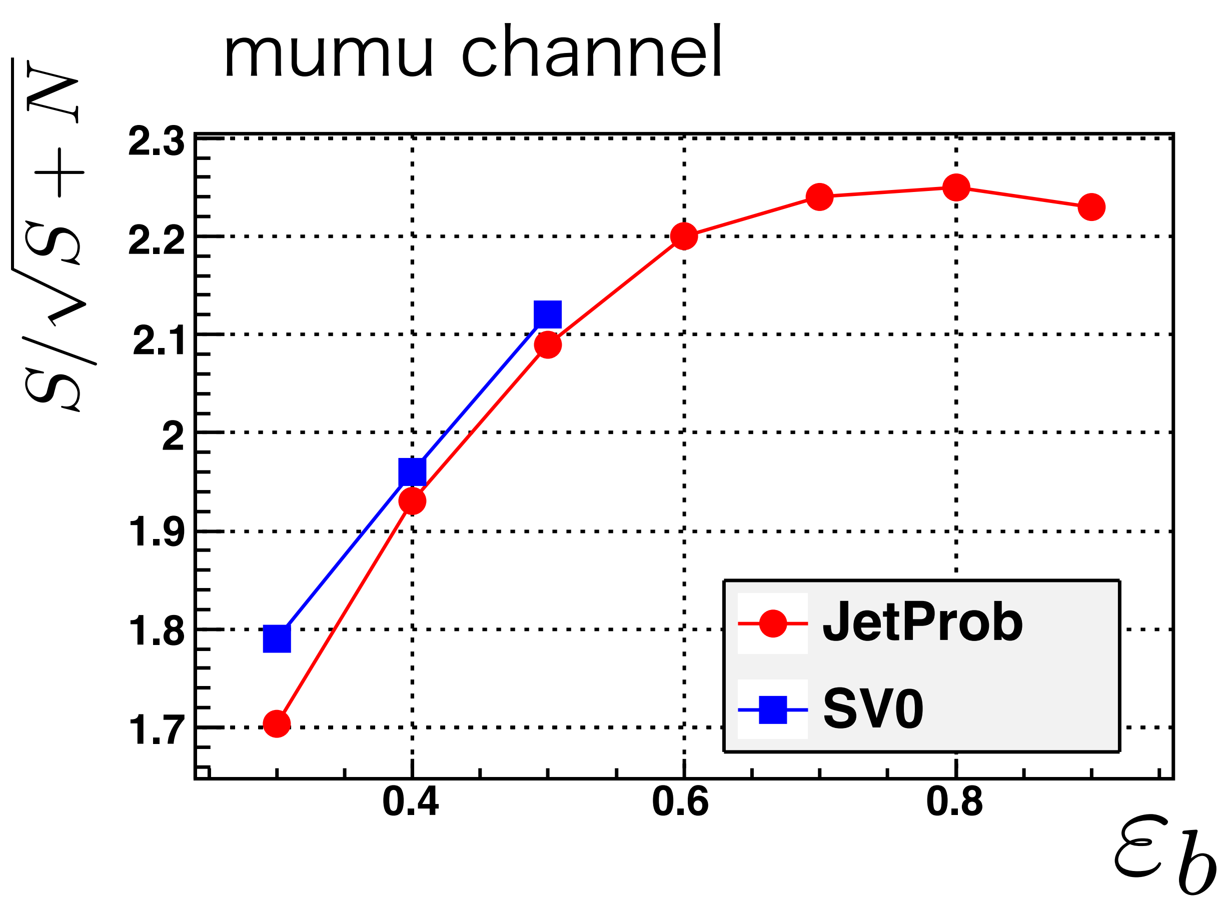
analysis of $t\bar{t}$ with b-tagging

- two b-quarks in final state
  - Requiring at least one b-tagged jet
    - ➡does not lose so many signals
    - ➡reject most of background events
    - ➡reduce systematic uncertainty from b-tagging efficiency
      - $\sigma_{P_{\mathrm{AtLeast}}} = 2(1-\varepsilon_b)\sigma_{\varepsilon_b}$

- Question
  1. Which b-tagging algorithm is the best one.
  2. Which b-tagging operation point works well.
  3. How much "S/√S+N" and "S/N" we can achieve.

b-tagging optimization(Answer of 1 & 2)

- Significance($S/\sqrt{S+N}$) as a function of b-tagging efficiency
  - For different tagging algorithms
  - require at least one b-tagged jet after the event selection of the analysis without b-tagging.



→Higher ε_b looks good.

→No big difference between taggers except SV0. (SV0 cannot reach $\varepsilon_b > 60\%$)

#Signals and #BGs (Answer of 3)

- S/N improved very well! (by factor ~3.5)
- Main BG : $Z \to \mu\mu$ (real di-muon in final state)
  Single Top(Wt) (real di-muon and real b-quark)

mumu channel : ε_b=60%

Assumed Stat. = 10 pb^{-1}

	w/o b-tag	**with b-tag**	**(with btag) / (w/o btag)**
W+jets	0	0	-
Z+jets	1.98	0.57	0.29
Di-Boson(WW,WZ,ZZ)	0.13	0.03	0.23
single top(Wt,t/s-chan)	0.23	0.16	0.70
ttbar(other final state)	0.01	0.01	1.00
BG total	2.36 +/- 0.35	0.55 +/- 0.08	0.23
signal	6.52 +/- 0.17	5.35 +/- 0.16	0.82
S/N	**2.76 +/- 0.42**	**9.58 +/- 1.40**	**3.47**
S/√S+N	2.19 +/- 0.06	2.20 +/- 0.05	1.00

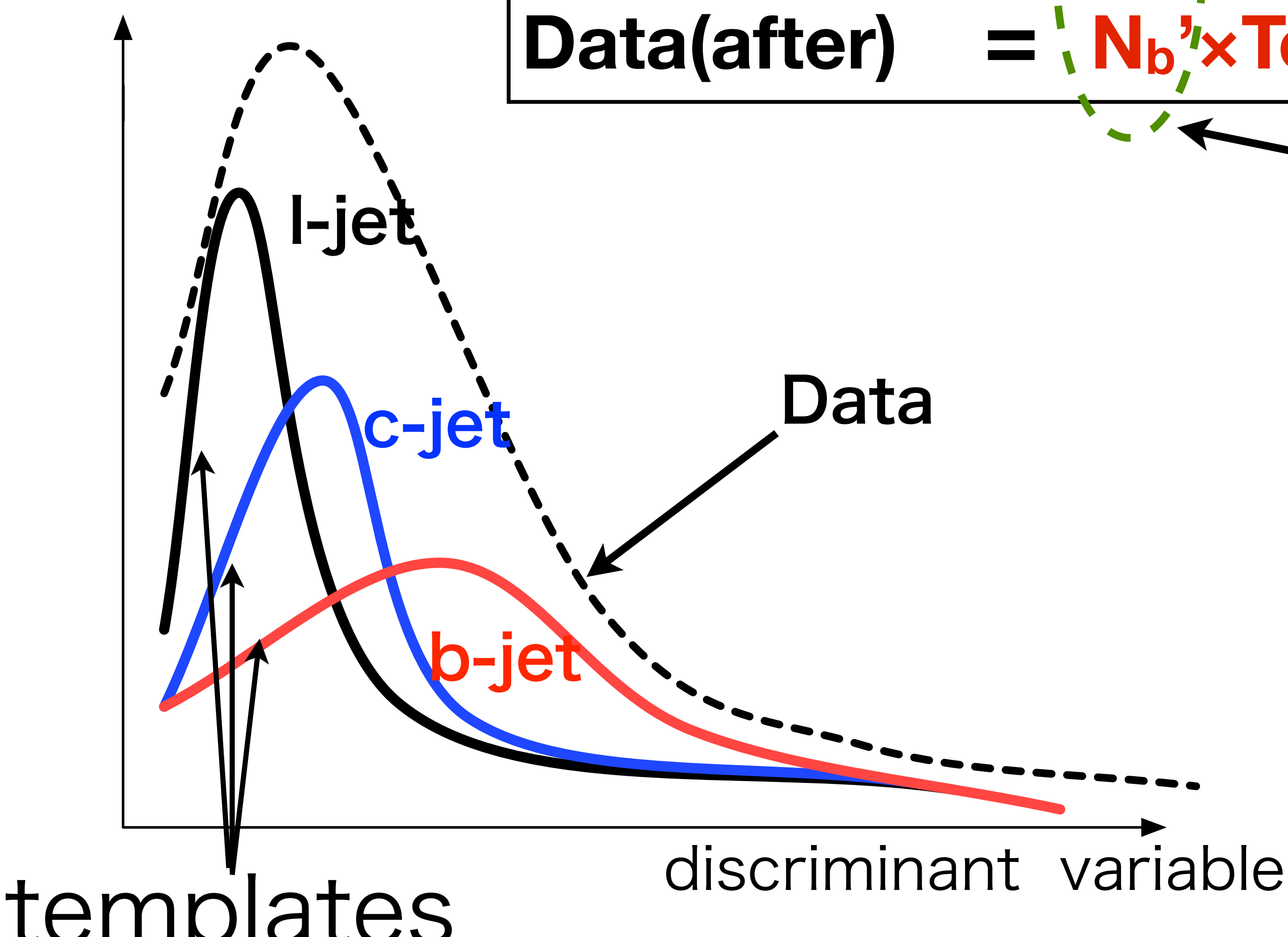
Measurement of b-tag performance

- To measure a b-tag efficiency and a fake rate,
  - Template fitting method
    ➡template : discriminant which isn't used for b-tag algorithm

Data(before) = N_b×Temp.(b) + N_c×Temp.(c) + N_l×Temp.(l)

Data(after) = N_b'×Temp.(b)+ N_c'×Temp.(c)+ N_l'×Temp.(l)

$f_{b,c,l}$: fitting parameter



$$\varepsilon_{b,c,l} = \frac{N'_{b,c,l}}{N_{b,c,l}}$$

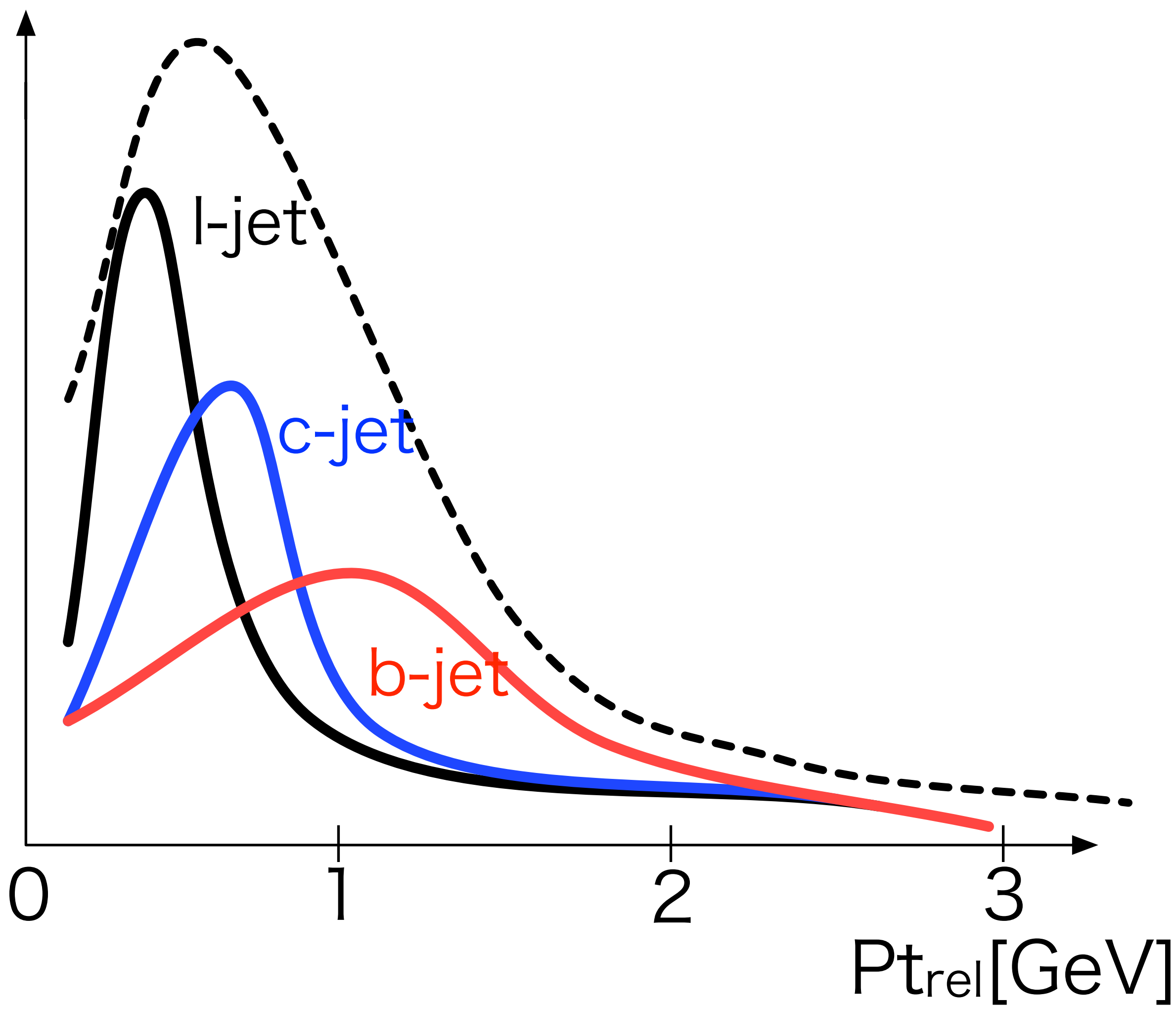
Pt_{rel} as a discriminant

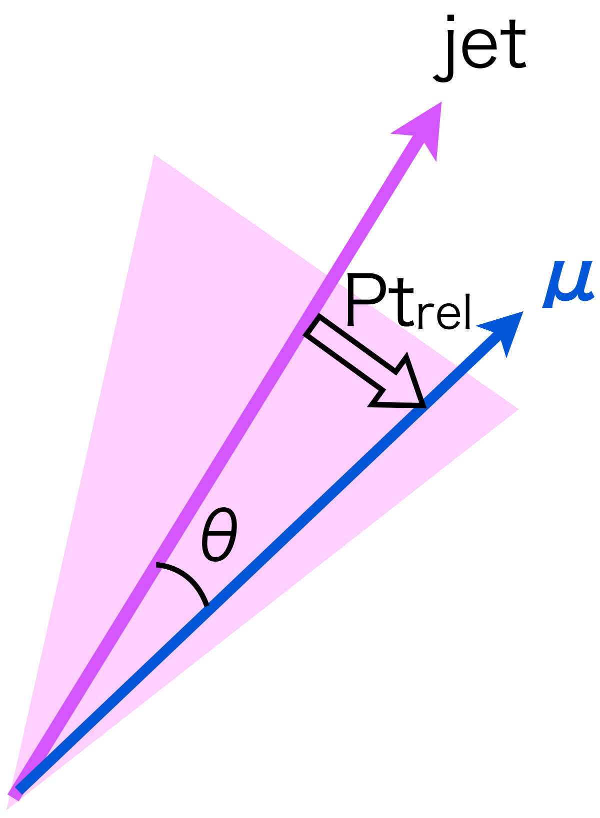
- Pt_{rel} : Transverse Pt of muon in jet.

  $Pt_{rel} = Pt(muon)_{\perp \text{ w.r.t.JetAxis}}$

- real b-jet : Pt_{rel} reaches up to ~2.5GeV
  (because typical b-hadron mass is ~5GeV)

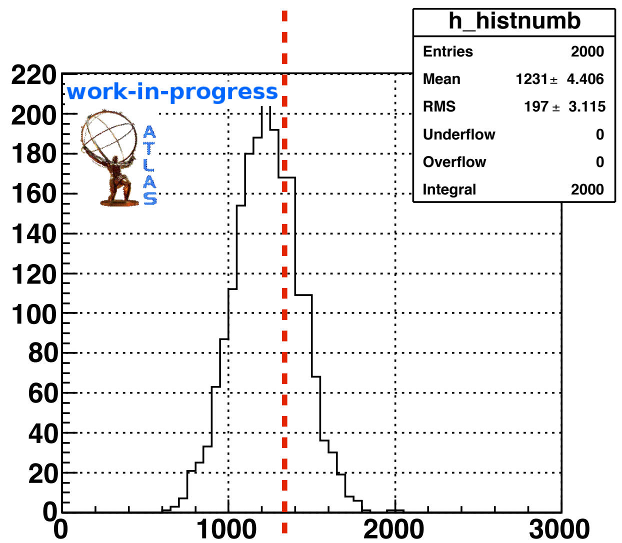
- Pt_{rel} can be a good discriminant.





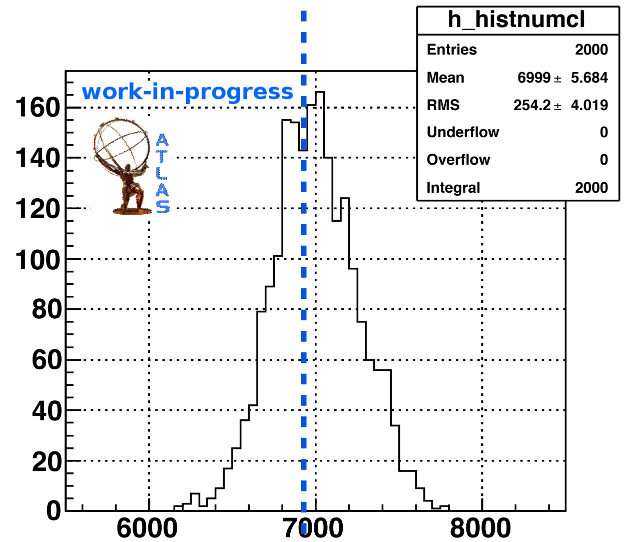
Toy MC to validate method

estimated #b



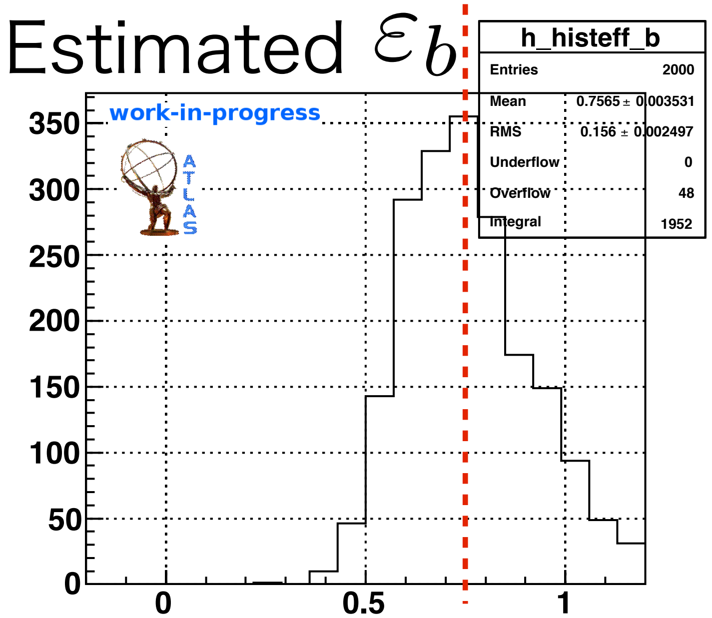
input #b

estimated #c



input #c+l

Estimated ε_b

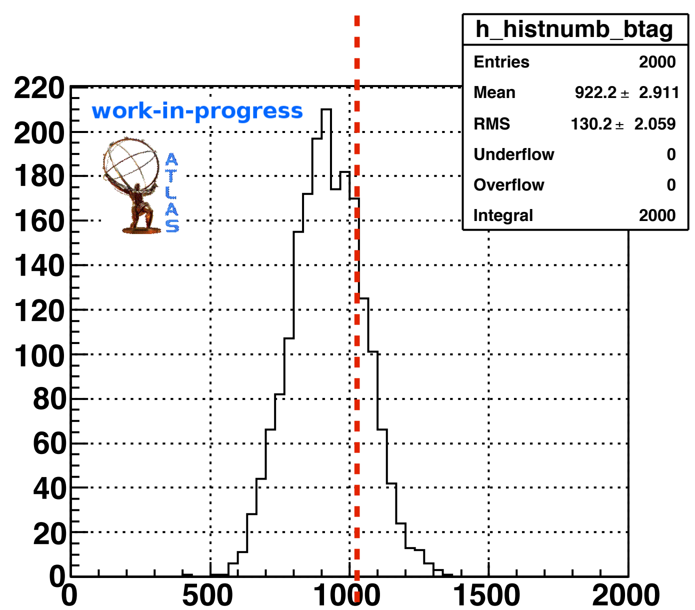


input ε_b

before btag

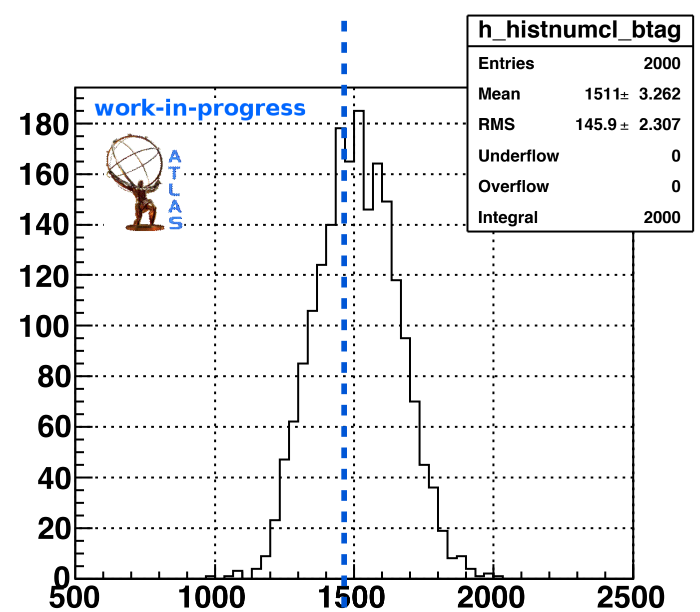
after btag

estimated #b



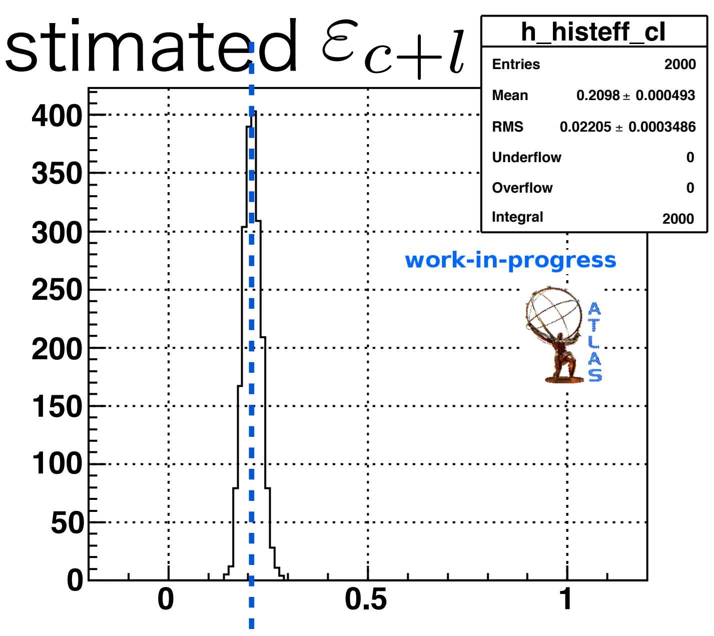
input #b

estimated #c+l



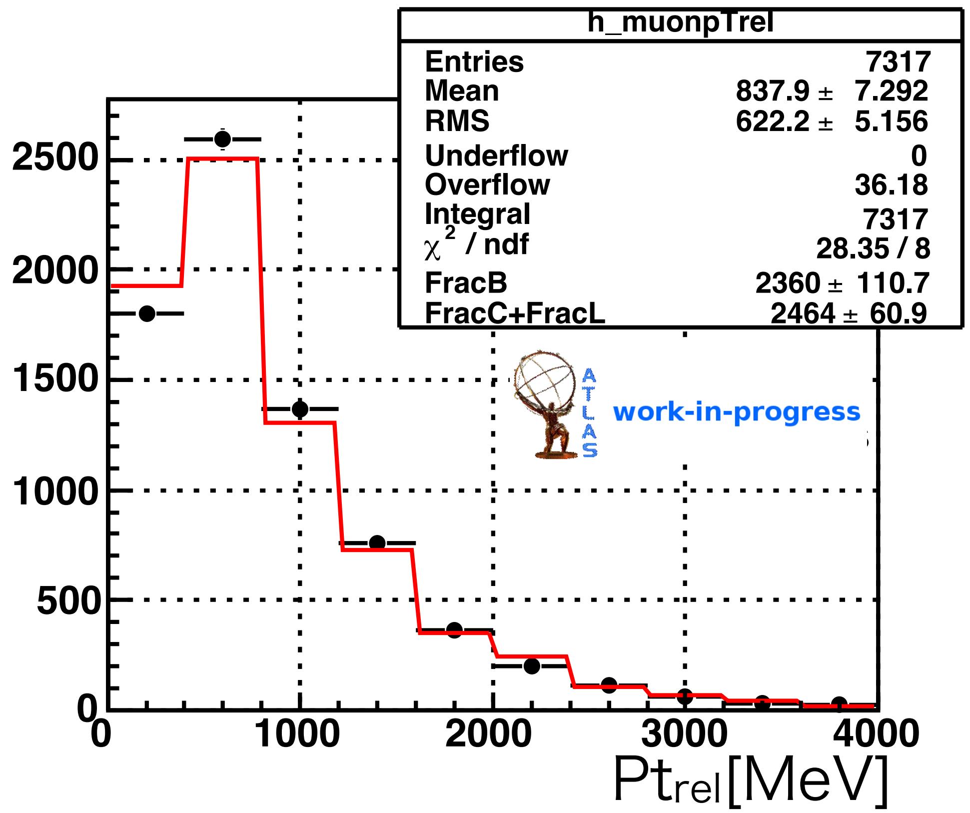
input #c+l

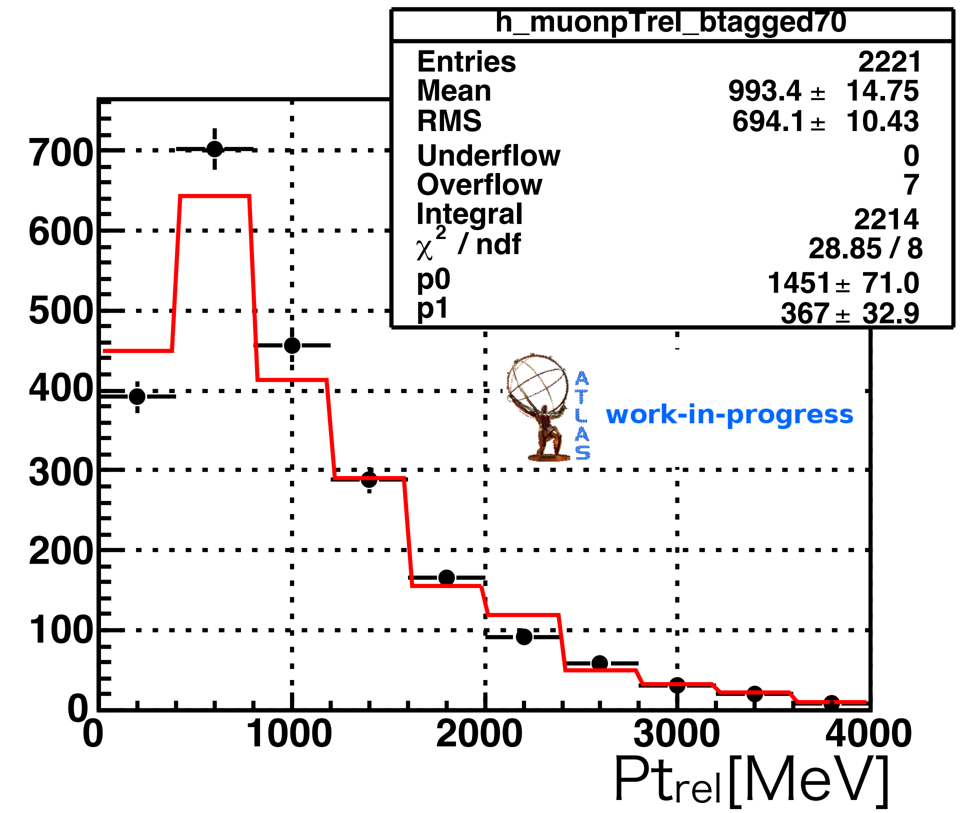
Estimated ε_{c+l}



input ε_{c+l}

Applying this method to real data

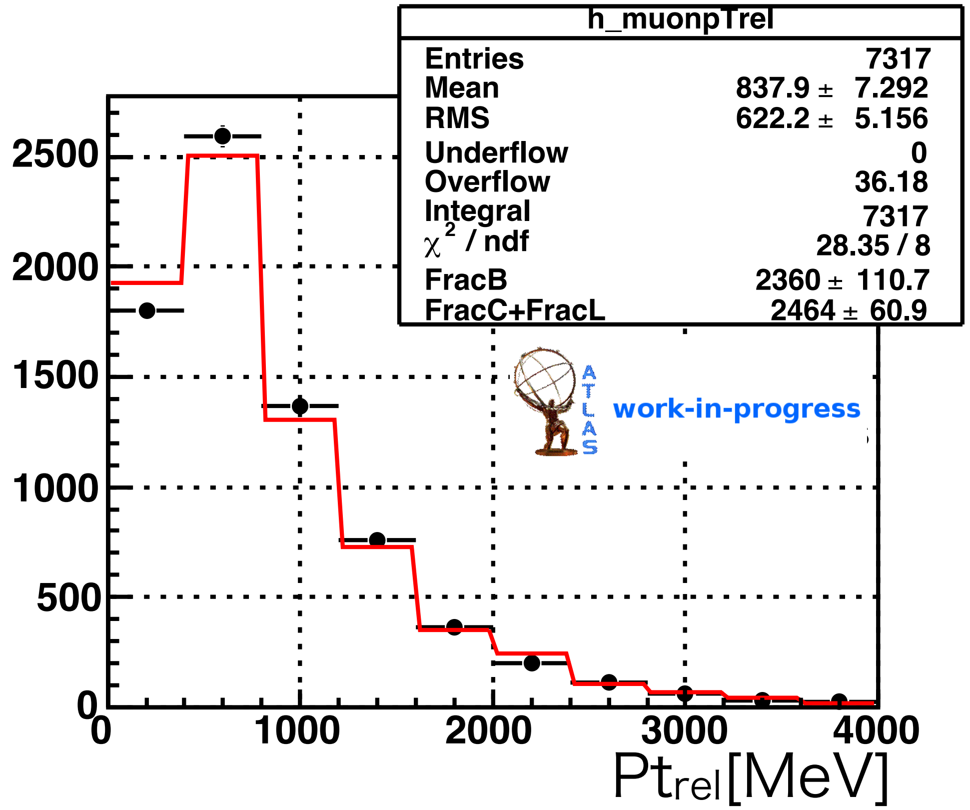


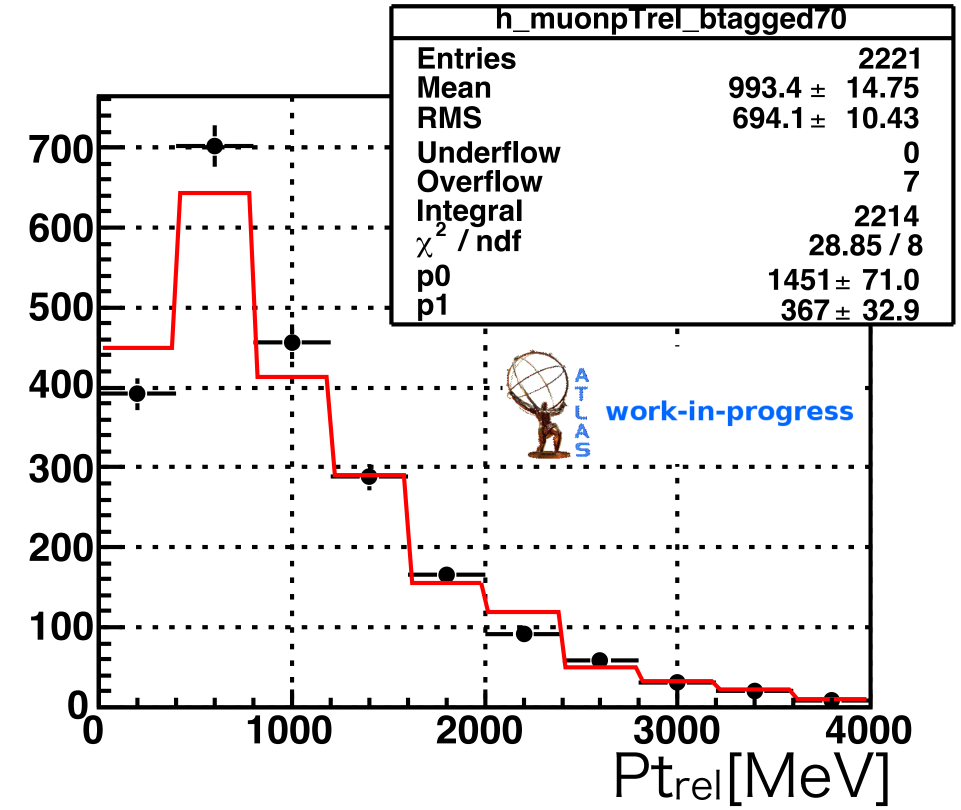


Estimated ε_b = 0.61 +/- 0.04

Estimated ε_{c+l} = 0.15 +/- 0.01

Applying this method to real data





Estimated ε_b = 0.61 +/- 0.04

Estimated ε_{c+l} = 0.15 +/- 0.01

Slightly lower efficiency than MC

Conclusions

- ATLAS Experiment started in March 2010!!
- Analysis of $t\bar{t}$ production in di-muon final state
  - Currently 3 events observed(expected 2.834 event)
  - Distributions of di-muon event is almost consistent with MC.
    - ➡Need some investigation.
- With b-tagging, S/N ratio will improve by factor ~3.5.
  - S/N ~ 9.5
- b-tagging efficiency measurement
  - using pT_{rel} fitting method
    - ➡method is validated by using MC.
    - ➡For data, we see a slightly lower b-tagging efficiency.

Backup

less b-tagging systematic uncertainty

- requiring **"at least one b-tagged jet"**
  - we can reduce a systematic uncertainty from the b-tagging efficiency by a factor $(1-\varepsilon_b)$.
  - For the event with two real bjets(e.g. ttbar)

    ➡"at least one b-tagged jet" :

$$P_{\mathrm{AtLeast}} = \varepsilon_b^2 + 2\varepsilon_b(1-\varepsilon_b)$$
$$= \varepsilon_b(2-\varepsilon_b)$$
$$\Rightarrow \sigma_{P_{\mathrm{AtLeast}}} = 2(1-\varepsilon_b)\sigma_{\varepsilon_b}$$

⇒We'll get one more good thing
if we apply a loose b-tag requirement!!

#Signals and #BGs (Detail)

mumu channel : ε_b=70%

	w/o b-tag	with b-tag	(with btag) / (w/o btag)
W→eν	0	0	-
W→μν	0	0	-
W→τν	0	0	-
Z→ee	0	0	-
Z→μμ	1.57	0.44	0.28
Z→ττ	0.41	0.13	0.32
Di-Boson(WW,WZ,ZZ)	0.13	0.03	0.23
single top(Wt,t/s-chan)	0.23	0.16	0.70
ttbar(other final state)	0.01	0.01	1.00
BG total	2.36 +/- 0.35	0.55 +/- 0.08	0.23
signal	6.52 +/- 0.17	5.35 +/- 0.16	0.82
S/N	**2.76 +/- 0.42**	**9.58 +/- 1.40**	**3.47**
S/√S+N	2.19 +/- 0.06	2.20 +/- 0.05	1.00

Assumed Stat. = 10 pb^{-1}