Single top cross section, top polarization and dark matter

Jin Wang on behalf of
SDU-LPSC-LZU Collaboration

Manpower in SDU-LPSC-LZU collaboration

Exchange students :

- Jin Wang (Co-PhD SDU-LPSC graduated in 2012)
- Xiaohu Sun (SDU Master →LPSC PhD)
- Mengqing Wu (LZU Master →LPSC PhD)

Involved supervisors

- Cunfeng Feng (SDU)
- Marie-Helene Genest (LPSC)
- Annick Lleres (LPSC)
- Zhongliang Ren (LZU)
- Julien Donini (LPC Clermont-Ferrand)

Other students and senior researchers

- Benoit Clément, Thomas Delemontex, Arnaud Lucotte, Peng Ge, Caterina Monini

Analysis within the collaboration

Published papers with important contribution (2012):

- Single top t-channel cross section measurement
  - Paper: Physics Letters B 717, 300-350, 2012
- Search for FCNC single top production
  - Paper: Phys. Lett. B712 (2012) 351-369

Ongoing work

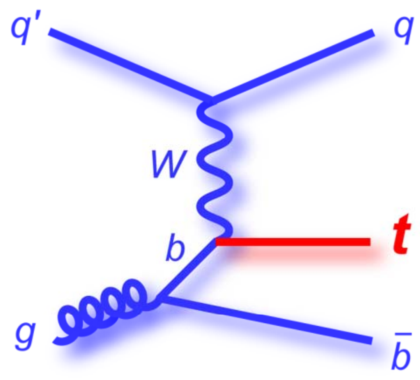
- Measurement of top-quark polarization
- Search for dark matter at the LHC

Single top t-channel cross section Measurement

Julien Donini, Cunfeng Feng, Annick Lleres, Jin Wang

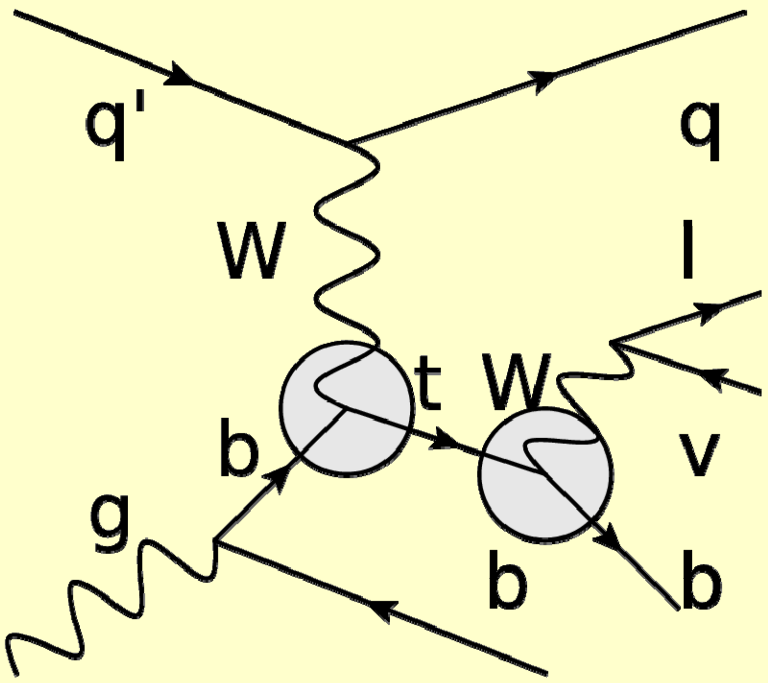
Single top production at LHC

- The production of single top is via electroweak process
  - totally different from ttbar production
  - keeping all the information from highly polarized top quarks
- Three sub-processes:
  - Exchange of a virtual W-boson in t-channel and s-channel
  - Associated production with an on-shell W-boson
  - t-channel is the dominant process: 65 pb at 7 TeV



- Single top production provides a direct probe of the standard model W-t-b coupling
  - determines the Vtb matrix element
  - polarization observables tests the left-handed nature of the charged current
- Single top production is sensitive to many models of new physics
  - anomalous t-W-b couplings
  - Non standard neutral currents changing the flavor

t-channel Signal: event topology



So we work in ***2-jet bin***
with ***1 jet btagged***

Pretag sample

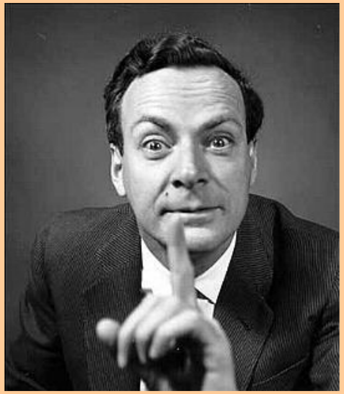
- Exact one lepton with pT > 25 GeV
- Exact two jets
  - Jet pT > 30 GeV, |eta|<4.5
  - With crack removal pT > 35 GeV at 2.75<|eta|<3.5
- Retangular cut
  - MET > 30 GeV
  - MTW > 30 GeV

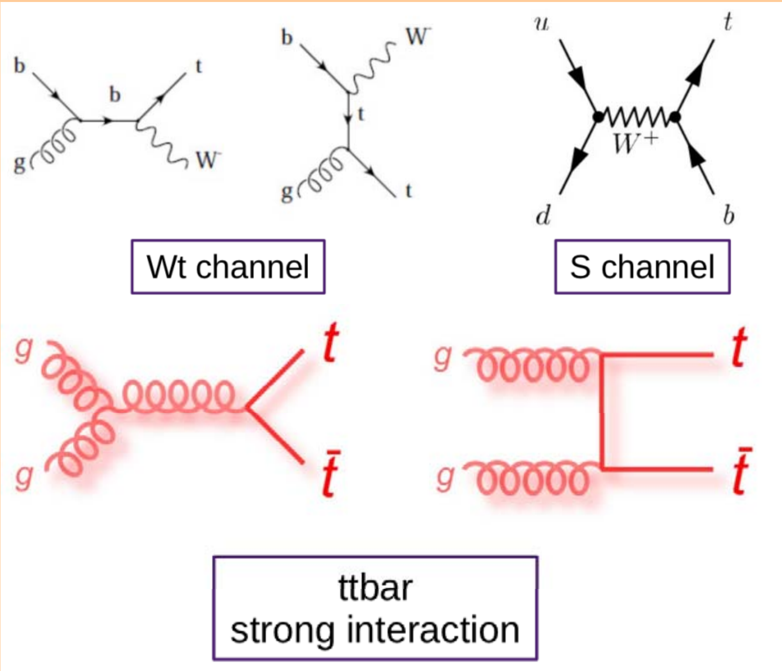
Tagged sample

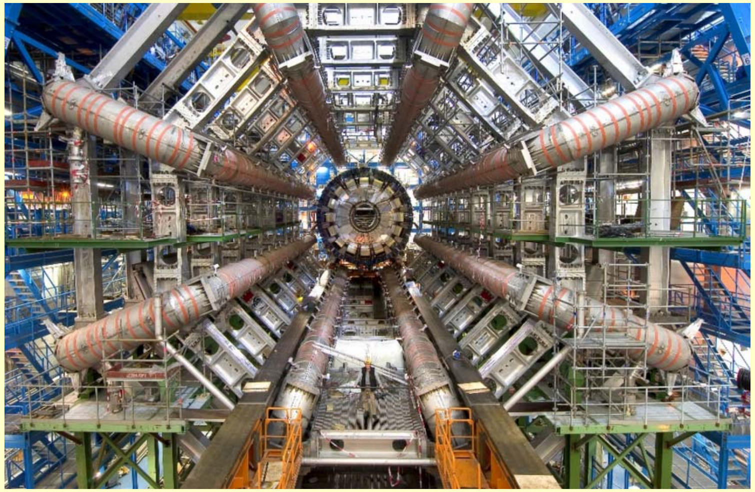
- Exact one Btagged jets among the two jets
  - Central |eta|<2.5
  - JetFitterCOMBNNc at cut of 0.98

Backgrounds: overview

- Theoretical prediction and **Monte carlo** simulation
  - s channel
  - Wt channel
  - ttbar
  - Z+jets
  - Diboson





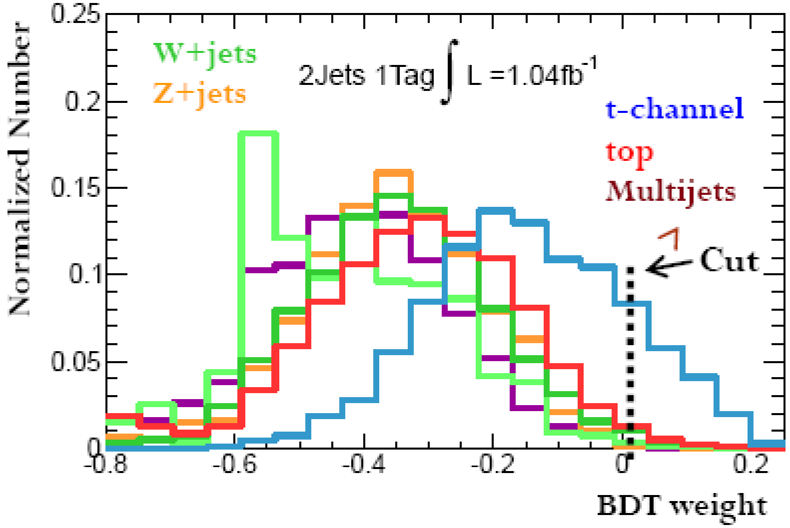


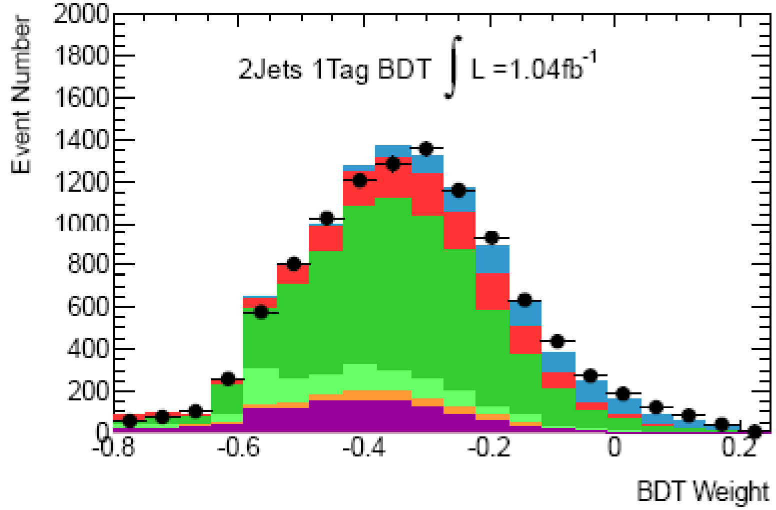
- **Data driven**
  - QCD-multijet
  - W+jets

Results

t-channel cross section measurements via Boosted Decision Tree analyses

- The most discriminating variables (signal vs backgrounds) determined from Monte Carlo simulations are used as inputs of the BDT event classifier
- Cut on the BDT output weight: value chosen to minimize statistical and systematic uncertainties on the measured σ
- Statistical analysis to extract the cross section
- Result σ=90±30 pb for an integrated luminosity of 1.04 fb^{-1}. A parallel neural network analysis gives σ=83±20 pb. (TOPQ-2011-14)





Top polarization measurement

Annick Lleres, Xiaohu Sun

Introduction

- Angular distributions help us to study top polarization

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_X} = \frac{1}{2}(1 + P\alpha_X \cos\theta_X)$$

- Spin axis is define by the direction of 4-momentum of spectator jet in top rest frame [Phys. Rev D55 7249]

- The direct measurement is P*α
- X could run over all top decay children b quark, W boson, lepton or neutrino.
- X = lepton is our case, since lepton gives the biggest spin analyzing power α.
- θ is the angle between the direction of lepton 4-momentum in top rest frame and spin axis.

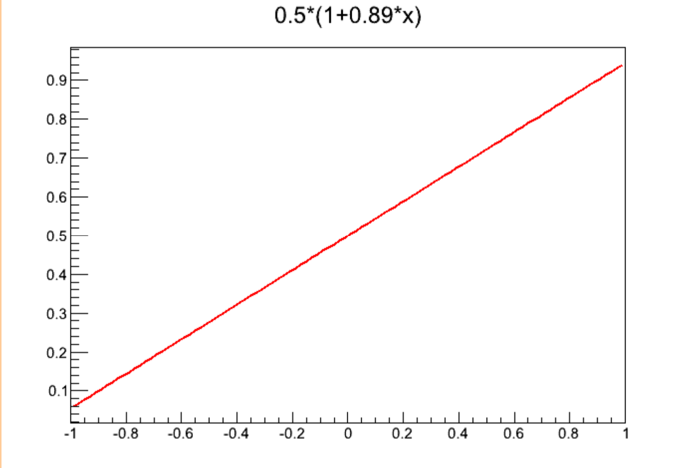
Parton level distribution

- Folding method is constructed to extract top polarization
- Theoratically we predict the distribution as

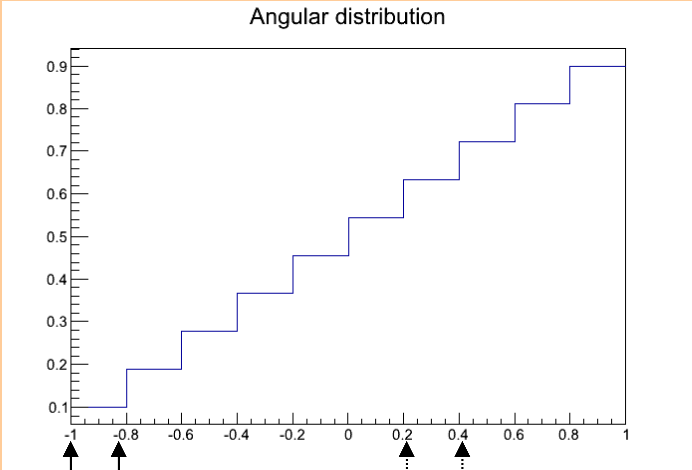
$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_X} = \frac{1}{2}(1 + P\alpha_X \cos\theta_X)$$

- Define k = P*α, integrate this distritbution bin by bin, then we get the number of evts in each bin in parton level and we could put them into a histogram (a function of k).

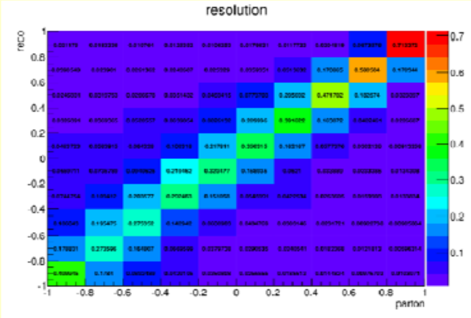
$$N_i^{parton} = \int_{a_i}^{b_i} \frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_X} d\cos\theta_X$$



BINNING



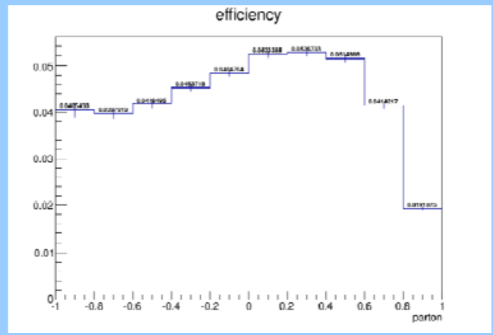
Resolution and efficiency matrices



Introduce detector
distortion and
smearing effects
by resolution matrix

Realized
by
MC Truth
TH2F
X->parton cos θ
Y->reco cos θ

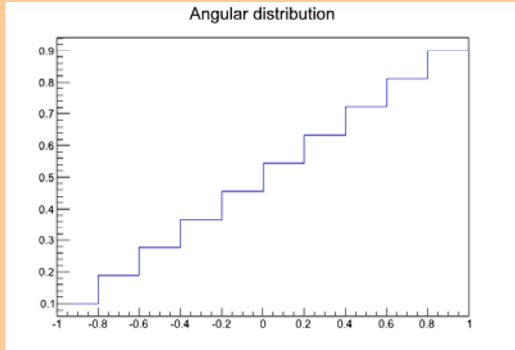
×



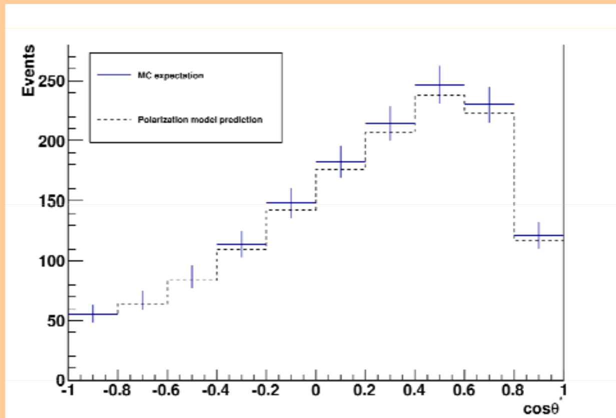
Introduce
selection
effects by
efficiency matrix

Realized
by
MC Truth
[Selected evt/all evt]
along cos θ

×



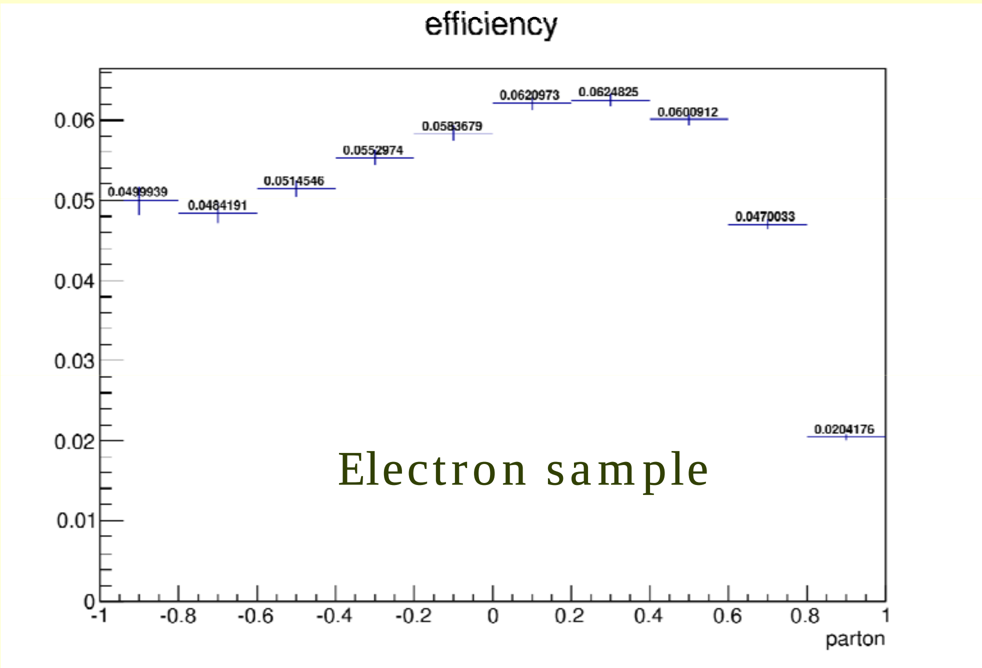
Theoretical predction
becomes distorted
after detector
and selection

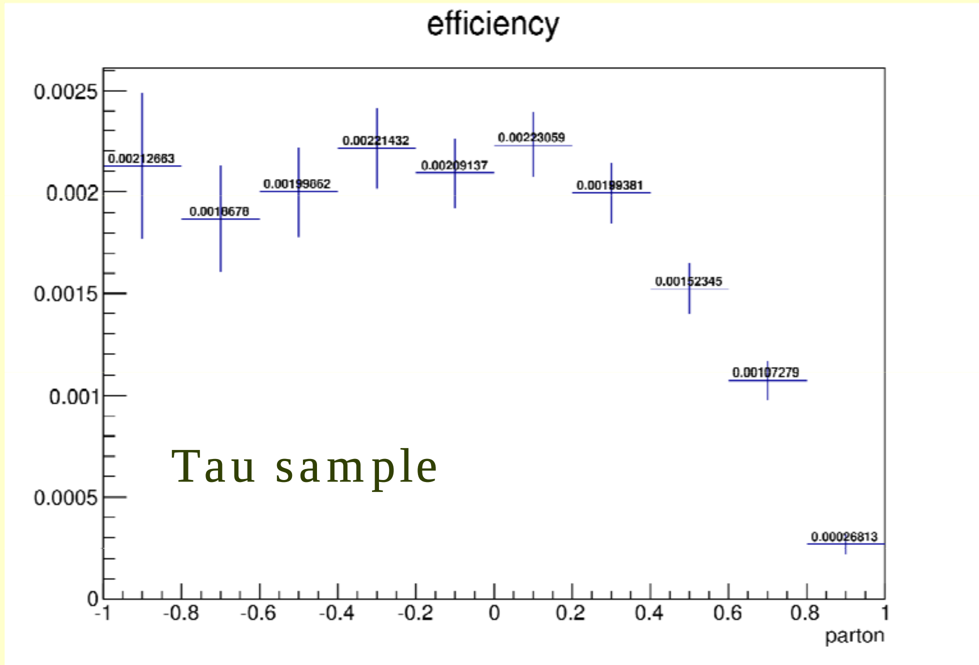


Folding - efficiency

Egamma

- Efficiency is calculated with tagged samples over parton level samples
- In egamma stream, the efficiency is dependent on the flavor of the lepton decaying from W boson
  - electron sample and tau sample are considered
  - muon sample is negiligible

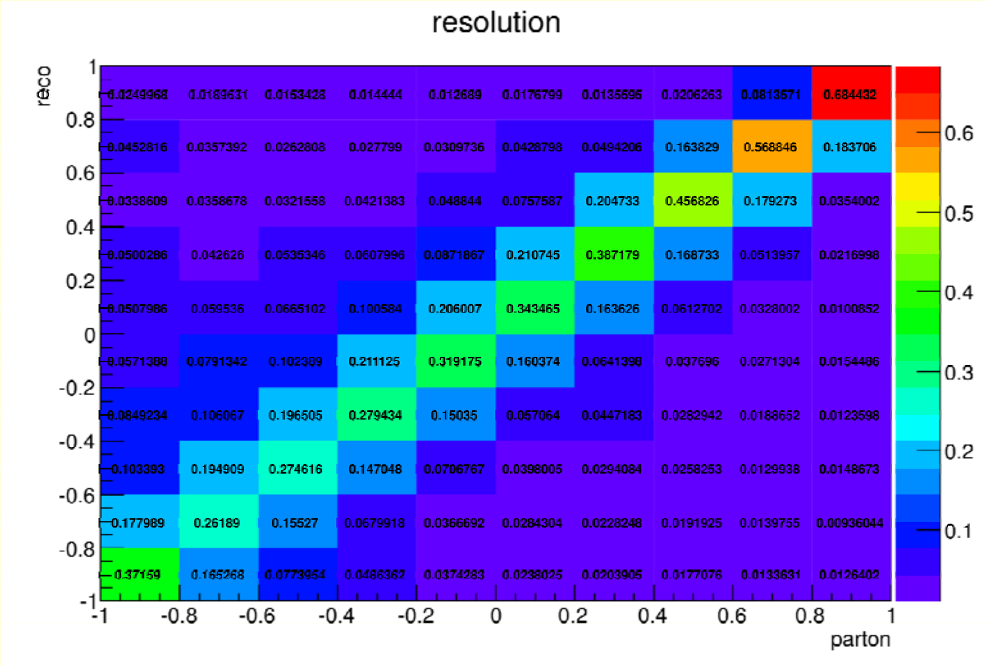




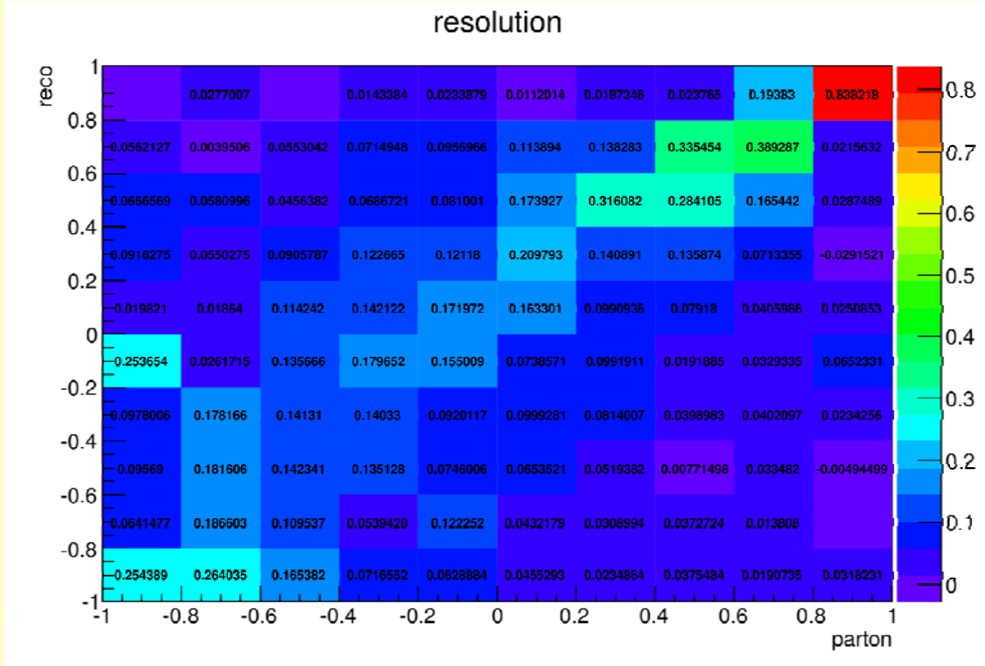
Folding - resolution

Egamma

- Resolution is calculated with tagged samples only



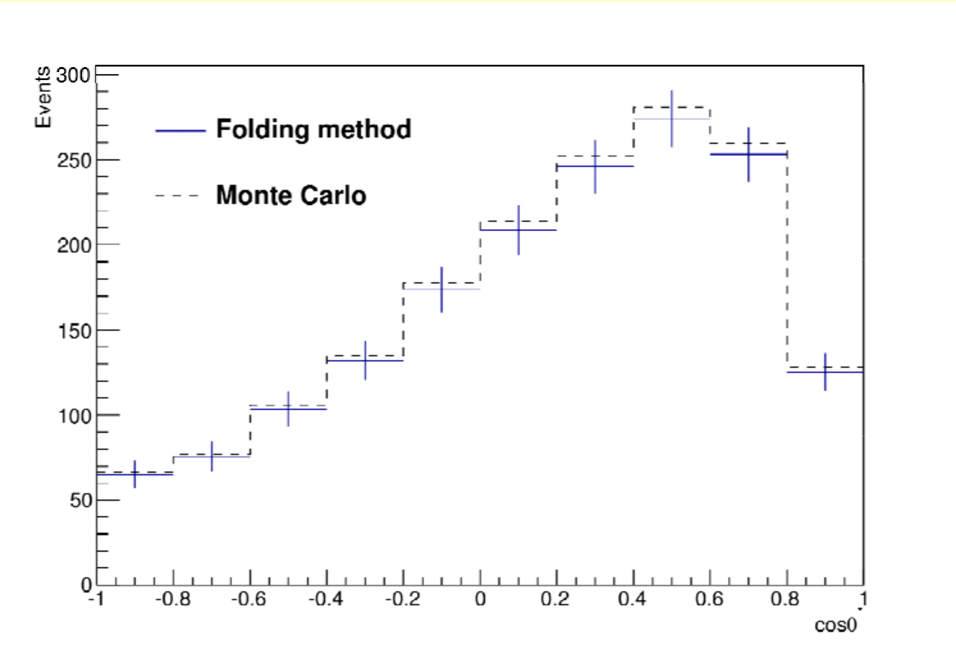
Electron sample



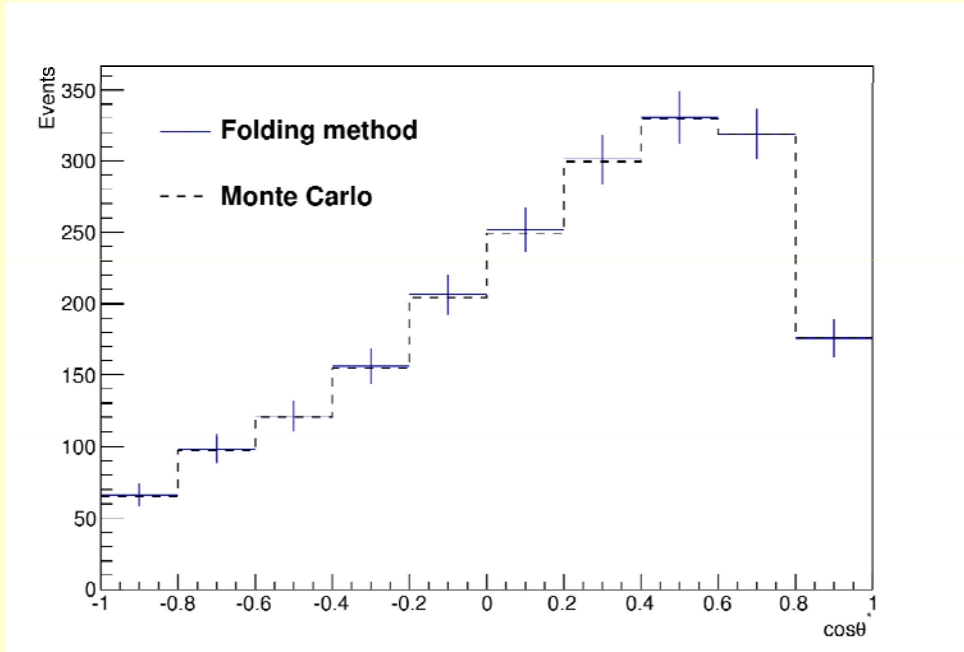
Tau sample

Folding - validation

- A comparison between folding expectation and MC expectation are shown
- The agreement is good to validate the folding method is working well.
- The P*α input (0.8947) is obtained from AcerMC parton level distribution (backup).



Egamma stream

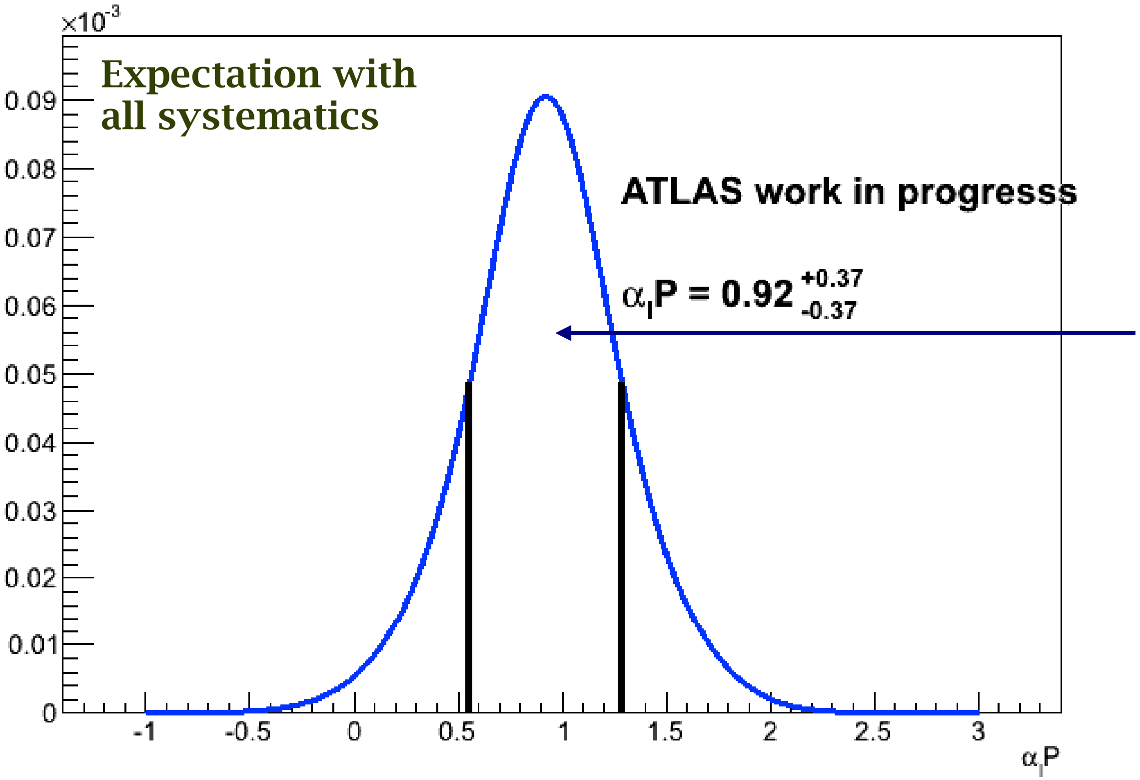


Muons stream

Binned likelihood fit

Benoit Clement

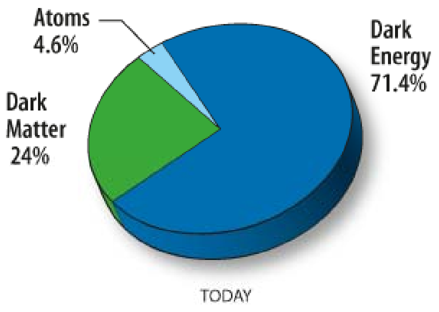
- Binned likelihood fit is implememted with Bayesian interperetation
  - The expectation value of P*α is shown below (from last year result)
- Mefisto likelihood is constructed perfectly for fraction or XS measurement, not naturally surpporting folding/unfolding method with uncertainties
  - So I am constructing a tool BOFFO (Binned likelihood fit with folding method) with both Frequentists' and Bayesian interperation to do this measurement with folding method



68.3% interval

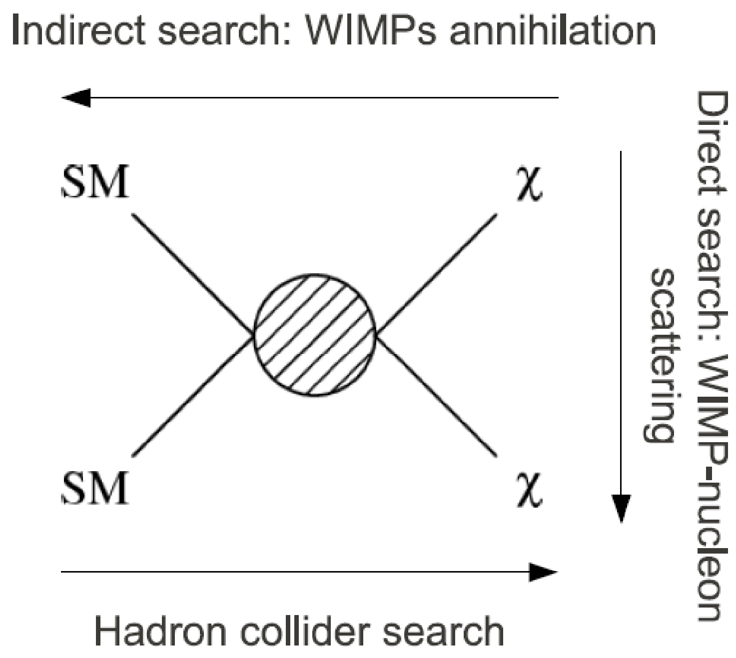
Search for Dark Matter at the LHC

Annick Lleres, Marie-Helene Genest , Mengqing Wu, Zhongliang Ren



Dark Matter at the LHC

- The presence of Cold Dark Matter in the universe has been evinced by a number of astrophysical experiments



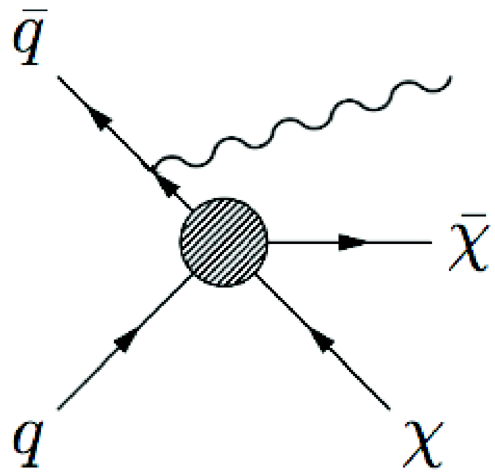
- Direct and indirect detection experiments are looking for evidences of the presence of this elusive new particle

- In a completely complementary approach, one can look for the production of such weakly interacting massive particles (WIMP) at the LHC

The monophoton analysis

Only invisible products :
- Nothing to trigger on
- Nothing with which to compute the missing transverse energy (MET)

Unless there is initial-state radiation, like a high-p_T photon



Can also probe other models of beyond the Standard Model physics :
- Supersymmetry with a compressed sparticle spectrum as the particles produced in the decay chain are too soft to be reconstructed
- Extra dimensions, a set of theories in which the Plank mass can be dramatically reduced ; the particles escaping detection could in this case be ADD gravitons

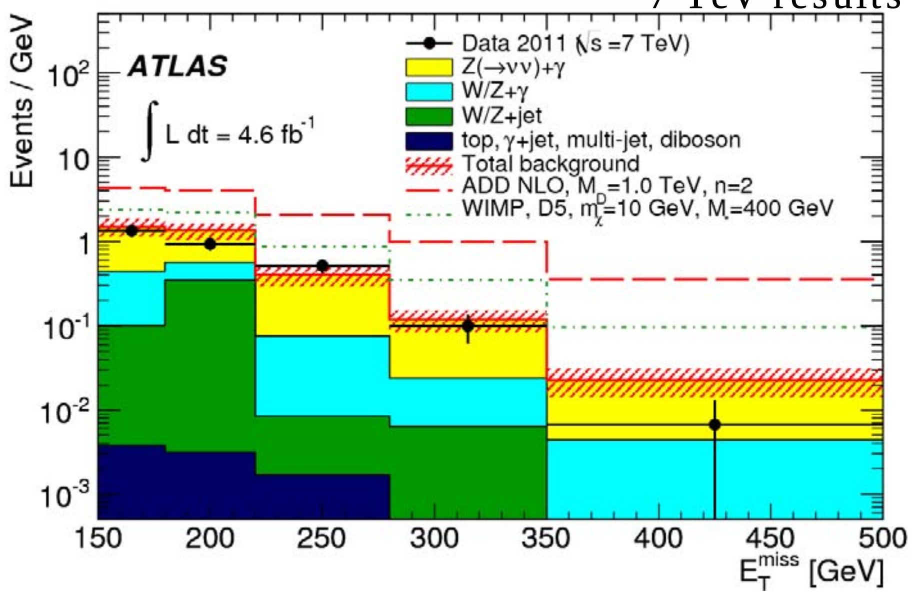
The monophoton analysis

Phys. Rev. Lett 110, 011802 (2013)

Analysis published using the 7 TeV data:

- *Leading photon with p_T > 150 GeV*
- *E_T^{miss}>150 GeV*
- *no more than 1 jet with p_T > 30 GeV*
- *Veto on electrons and muons*

7 TeV results



- The limits can be converted into limits on the Dark Matter – nucleon cross section as a function of the Dark Matter candidate mass and compared to direct searches
- The LPSC (Marie-Helene Genest and Mengqing Wu) is involved in the update of the analysis at 8 TeV, M-H Genest being the new editor of the analysis
- The focus of the LPSC group will be on the Dark Matter and the compressed SUSY interpretations

Summary and Plans

- Active and fruitfull collaboration between LPSC Grenoble, Shandong University and Lanzhou University
    - Single top t-channel cross section measurement with BDT method
    - Top polarization study
    - Search for dark matter at the LHC
- Intense communation and future collaboration are expected
    - Help to balance manpower and complete common tasks between groups

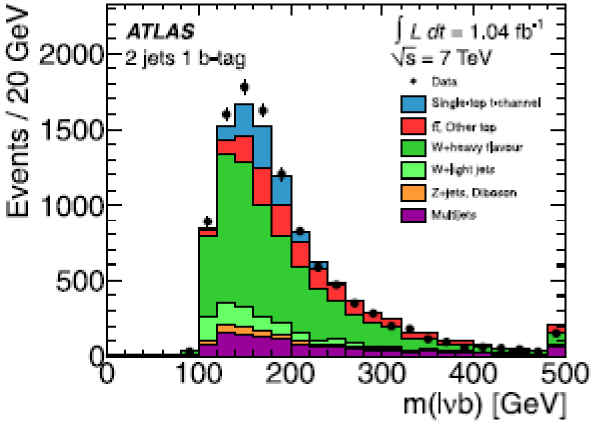
Back Up

Event yield

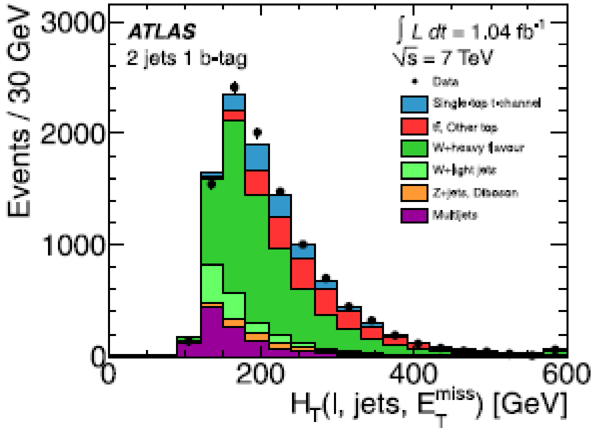
Table 1
Predicted and observed event yields, after selection, in the electron and muon 2-jet and 3-jet b-tagged samples. The multijet event yields are determined with a data-driven technique. Contributions from W + jets events are normalised to observed data in control regions as used in the cut-based analysis. The uncertainties on the multijet and the W + jets yields are also estimated from data (see Section 6). All other backgrounds and the t-channel signal expectation are normalised to theoretical cross sections. Uncertainties on these predictions are only reflecting the uncertainties on the theoretical cross section prediction and do not include experimental uncertainties (such as the jet energy scale uncertainty, etc.).

	Electron		Muon	
	2-jet	3-jet	2-jet	3-jet
Single-top t-channel	447 ± 11	297 ± 7	492 ± 12	323 ± 8
$t\bar{t}$, other top	785 ± 52	1700 ± 120	801 ± 53	1740 ± 130
W + light jets	350 ± 100	128 ± 56	510 ± 150	209 ± 91
W + heavy flavour jets	2600 ± 740	1100 ± 400	3130 ± 880	1270 ± 480
Z + jets, diboson	158 ± 63	96 ± 44	166 ± 61	80 ± 31
Multijet	710 ± 350	580 ± 290	440 ± 220	270 ± 140
Total expected	5050 ± 830	3900 ± 520	5530 ± 930	3900 ± 520
Data	5021	3592	5592	3915

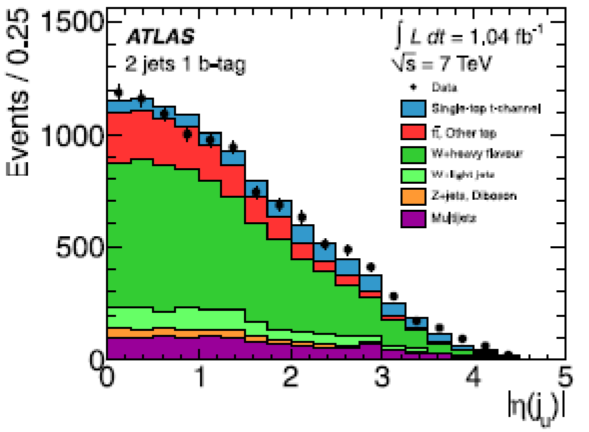
Kinematics with Tagged samples



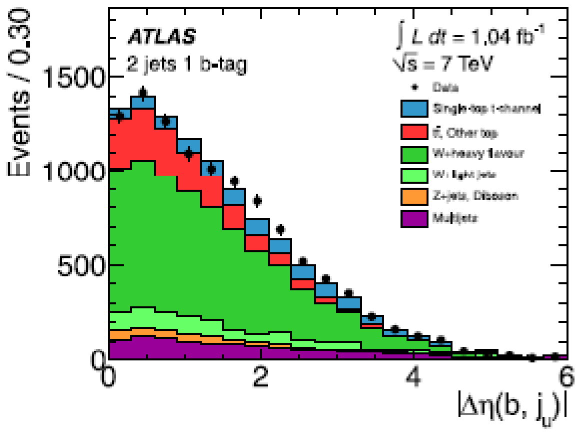
(a)



(b)

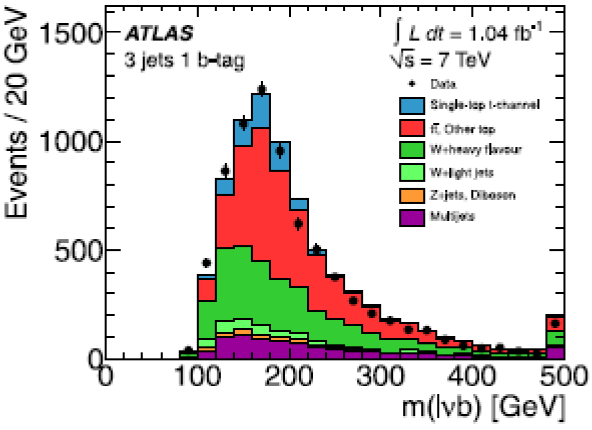


(c)

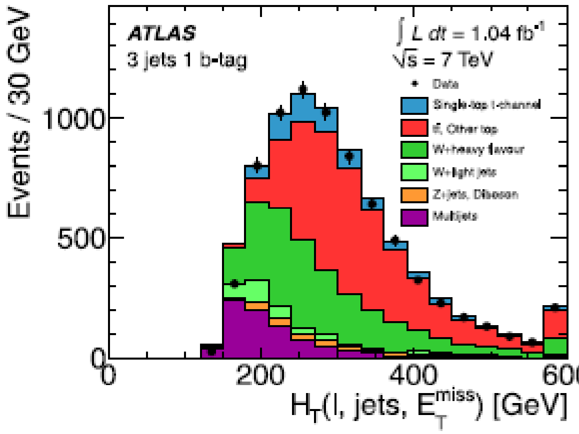


(d)

Kinematics with Tagged samples



(e)



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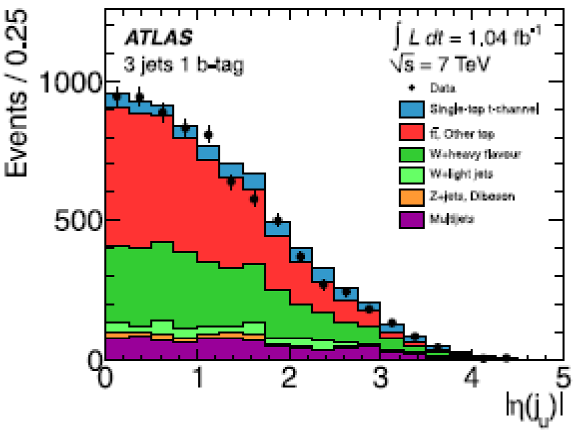

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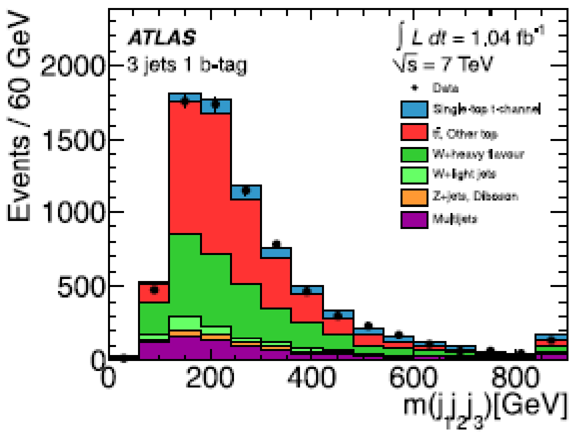

(h)