Background Rejection in $H \rightarrow \gamma\gamma$ with the ATLAS Detector

Henso ABREU

Journees Jeunes Chercheurs (29/11/2009 – 05/12/2009)

Relais du Moulin Neuf, Barbaste (Lot et Garonne)

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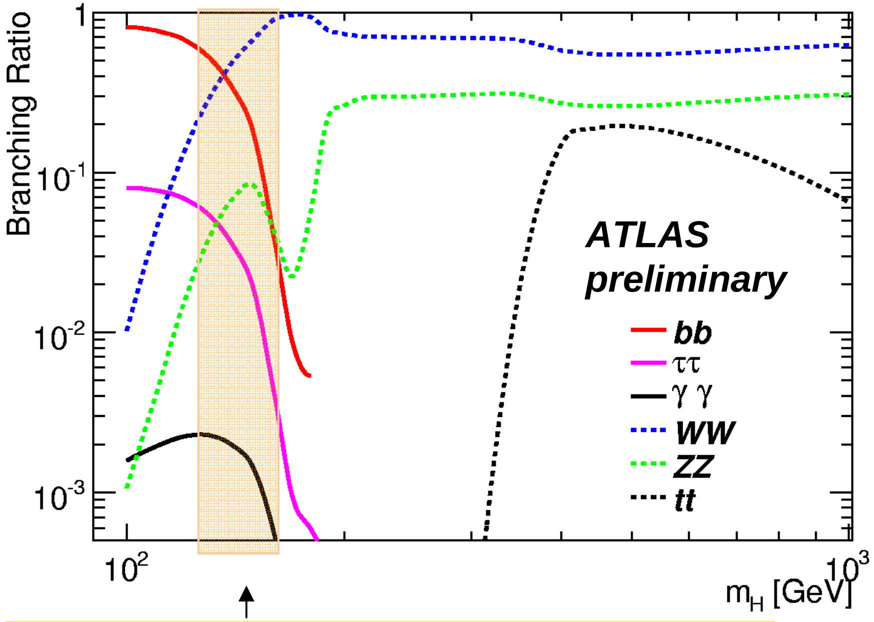
LABORATOIRE
DE L'ACCÉLÉRATEUR
LINÉAIRE

MOTIVATION

- The search for the Higgs Boson in the $\gamma\gamma$ channel is amongst the most important analysis in the low mass range $(114 < m_H < 150 GeV/c^2)$



about 3σ for 14 TeV in this window of mass

- Low branching ratio $(\approx 2.2\cdot 10^{-3}$ for $m_H = 120 GeV/c^2)$

BUT

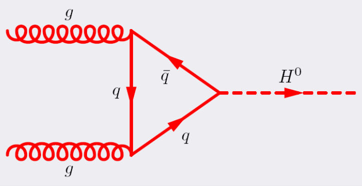
- Simple signature
- Good mass resolution $(\approx 1.5 GeV/c^2)$

→ Need a good photon reconstruction and identification.
→ Good manipulation of Conversions
→ Good measurement of photon direction
→ Good background rejection

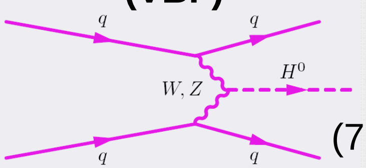
Signal and Background

Higgs Boson Production

- *gg* fusion (75%)

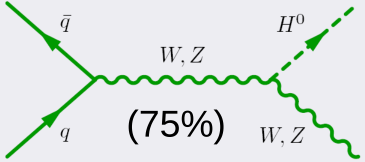


- Vector Boson Fusion (17%) (VBF)

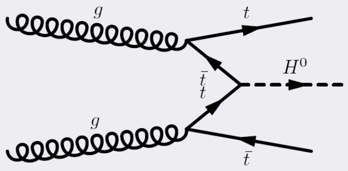


(75%)

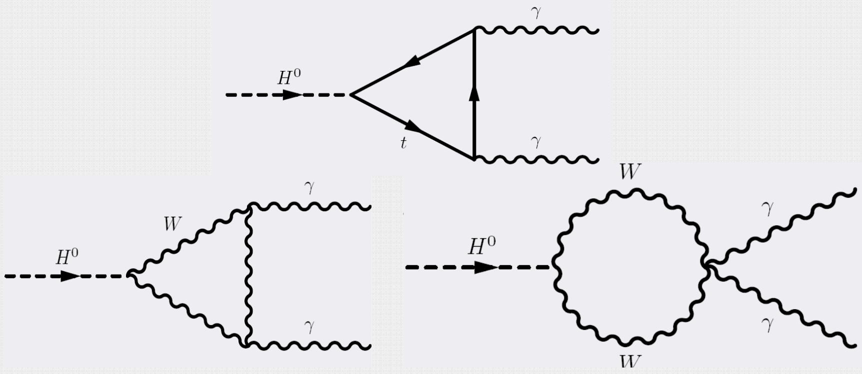
- Associated Production with *W,Z* (7%) or tt_{bar} (2%)

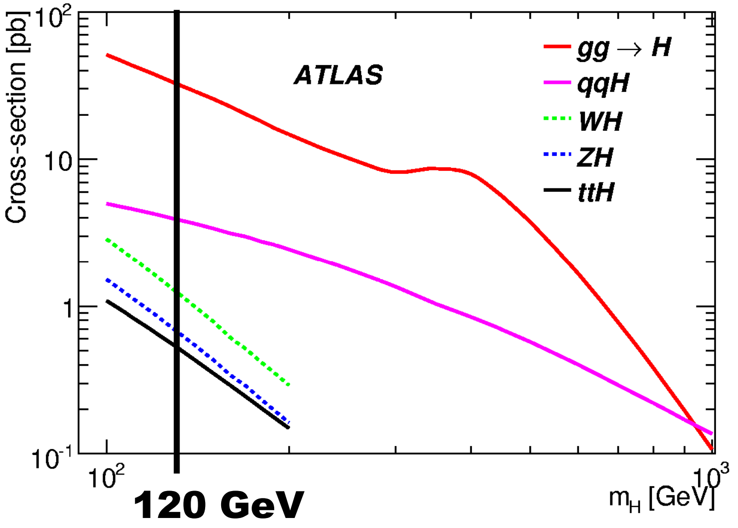


(75%)



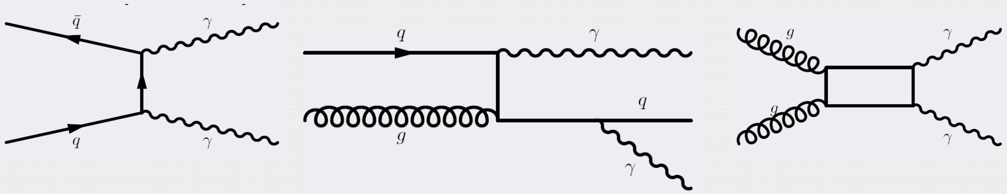
Signal



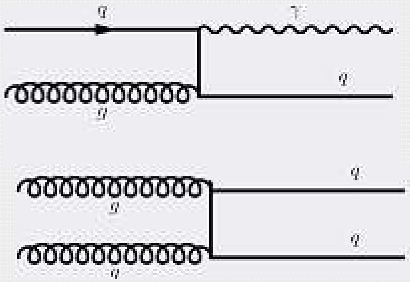


Background

- Irreducible : γγ (+jet) (Born, fragmentation process, box)

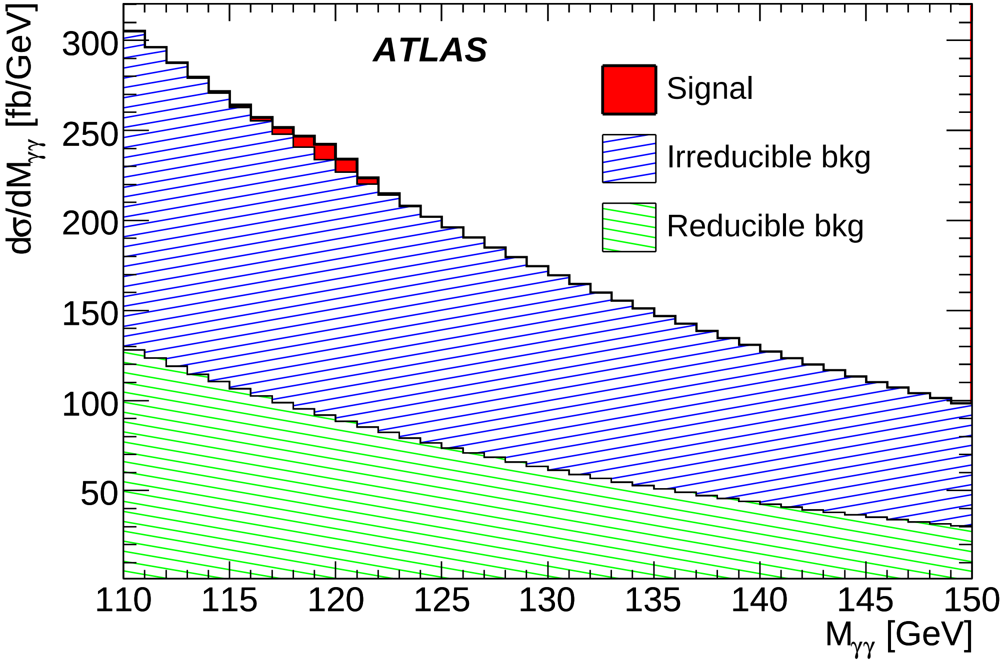


- Reducible : γ/jet(s) , jet(s)/jet(s)



Inclusive Analysis

- $0 < |\eta| < 1.37$, $1.52 < |\eta| < 2.37$ (motivated by identification offline of photon)
- $p_T^{\gamma_1} > 40GeV$, $p_T^{\gamma_2} > 25GeV$ (given by optimization studies)



Expected Cross-Section

σ_{signal}	25.4 fb
$\sigma_{\text{background}}$	947 fb

inside a window of mass $m_{\gamma\gamma} \pm 1.4\sigma$

S/B = 0.02

√S = 14 TeV arXiv:0901.0512 [hep-ex]
Expected Performance of the ATLAS Experiment - Detector, Trigger and Physics

K-factor applied for reducible background *(dominated by* γj*)* : $K_{\gamma j} = 2.1$ *and* $K_{jj} = 1.3$

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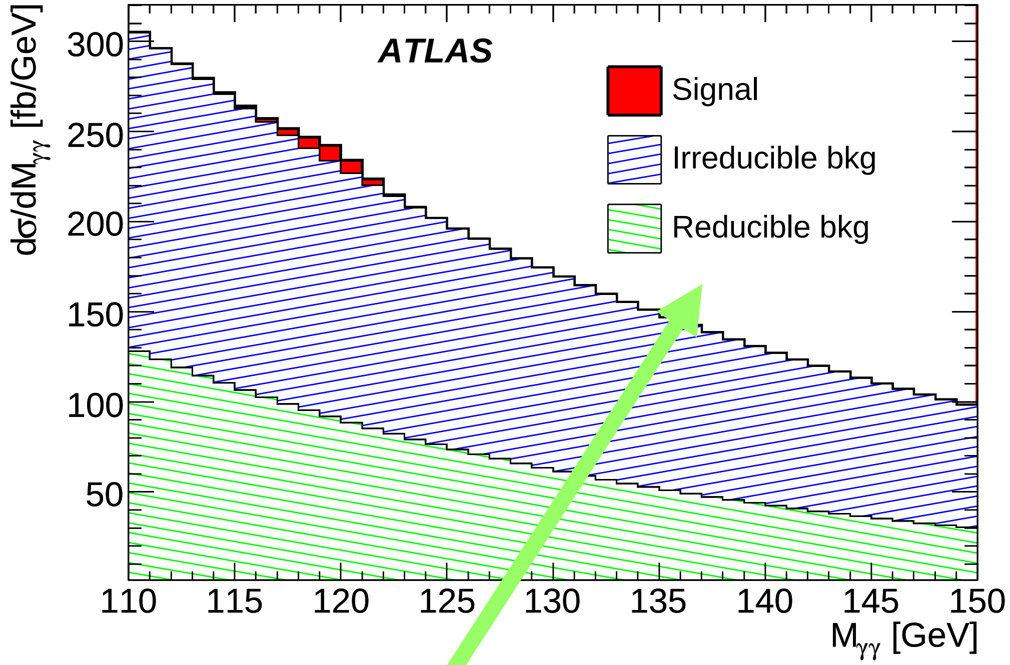

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Large uncertainty on the reducible background. It has been computed with Pythia. It is much larger with Herwig (see later)

$\sqrt{S}$ = 14 TeV **arXiv:0901.0512** [hep-ex]
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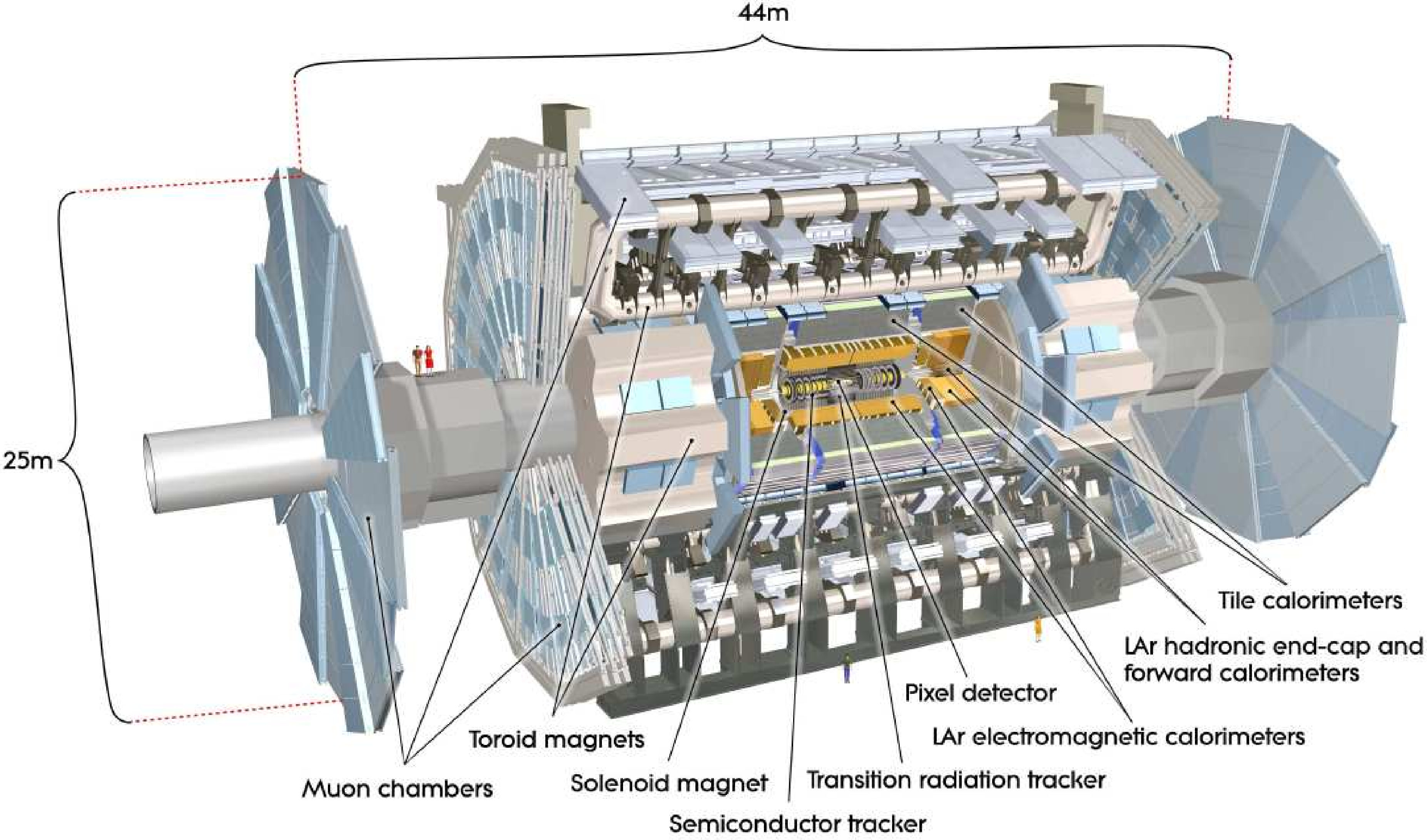
The ATLAS Detector



Selenoide (2T)
Toroidal System (0.5 T in central and 1T in end-caps)

EM ATLAS Calorimeter

- EM Calo design optimized to the study of the $H \rightarrow \gamma\gamma$ channel : **Energy resolution (and angular)** need a good and precise invariant mass reconstruction

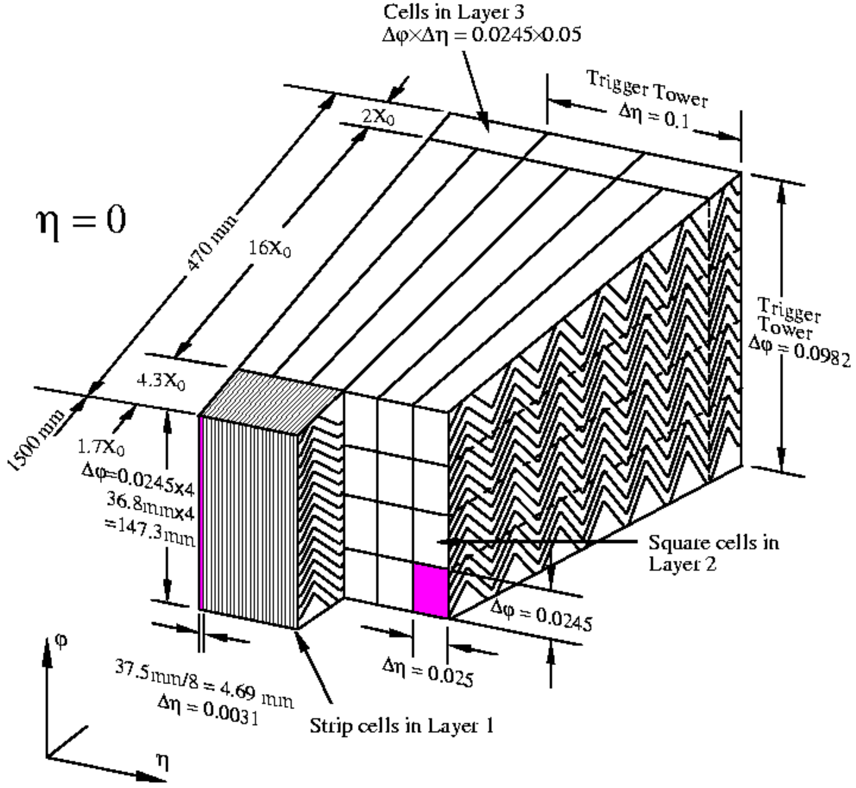
$$M_{\gamma_1\gamma_2} = \sqrt{2E_{\gamma_1}E_{\gamma_2}(1-\cos\theta_{\gamma_1\gamma_2})}$$

$$\frac{\sigma_E}{E} \approx \frac{10\%}{\sqrt{E}} \oplus 0.7\%$$

Structured in four compartments:

pre-sampler(measure shower energy upstream of calo.)

strip (fine granularity)
→ early EM shower
middle
→ measure big energy fraction of EM shower
back
→ shower tail (EM vs Had)



Photon identification and track isolation

- To reduce jet background below the irreducible background.
- Identification cuts (EM shower shapes)

  → Second compartment and hadronic calorimeter: Jet rejection by large shower

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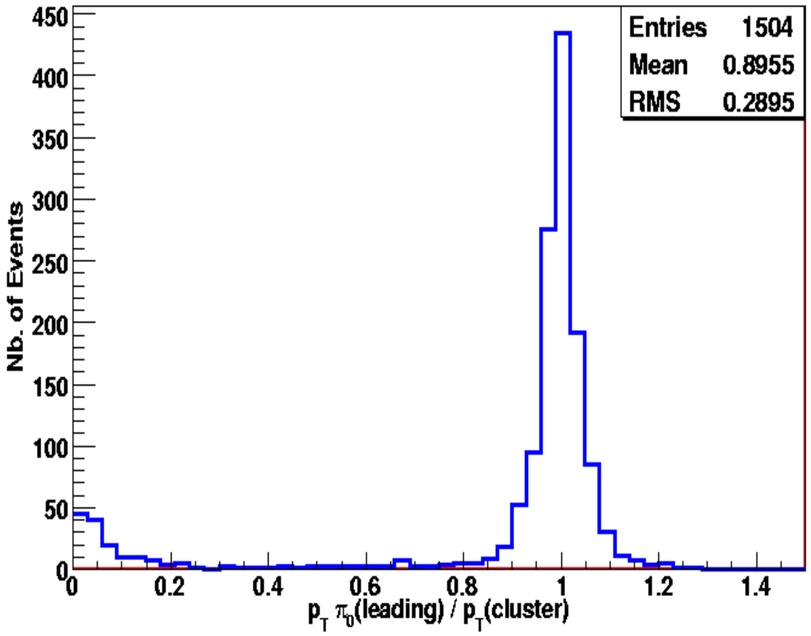

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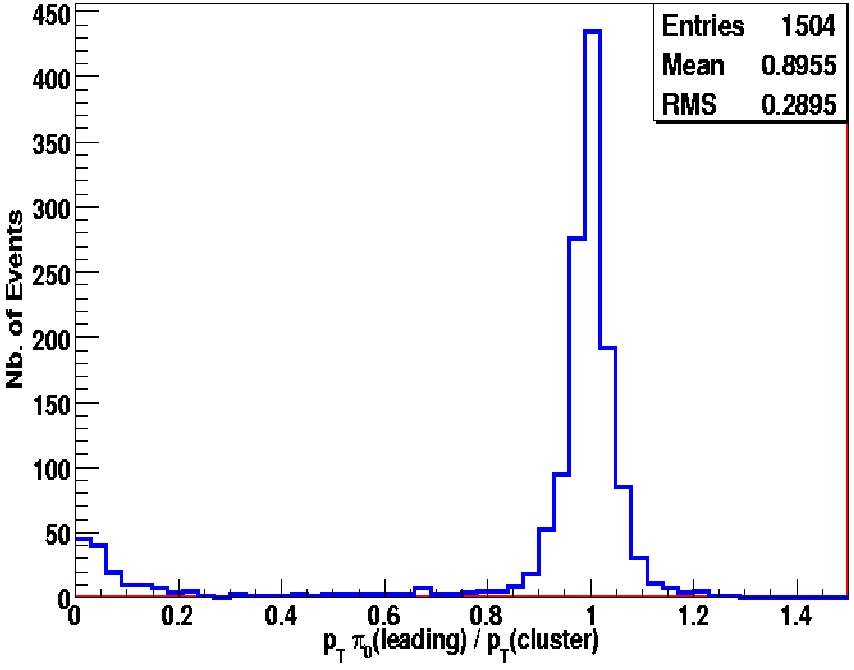
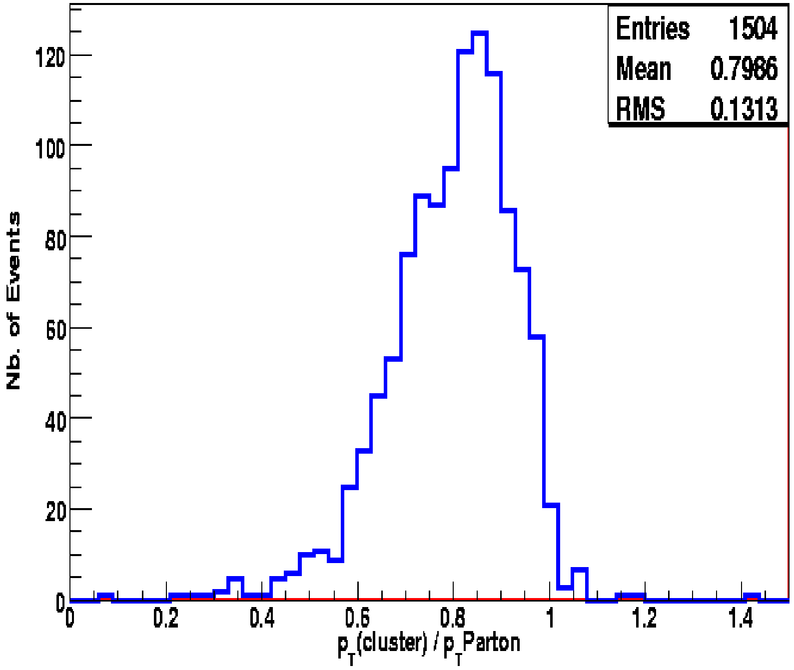
- Track Isolation





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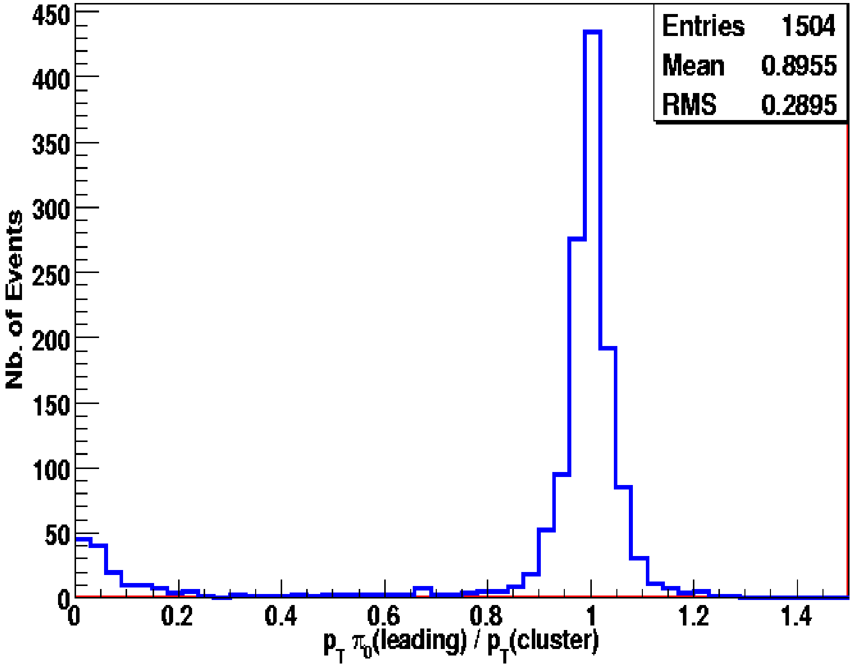

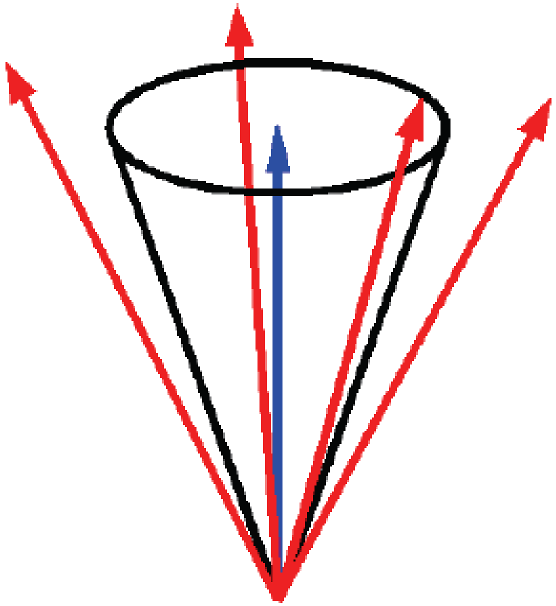

$$\text{ptcone}(R_0) = \sum_{\substack{tracks \\ \Delta R < R_0}} p_T$$

Photon identification and track isolation

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Jet Rejection

	All	quark-jet	gluon-jet
Rejection (before isolation)	4922 ± 88	1617±36	15676 ± 463
Rejection (after isolation)	7764±159	2489±62	37796 ± 1628

Table1. Jet rejection expected for the inclusive jet sample for E_T>25GeV. The results are shown before and after track isolation cuts for all jets and separately for quark and gluon jets. The erros are statistical only

Photon identification and track isolation

- To reduce jet background below the irreducible background.
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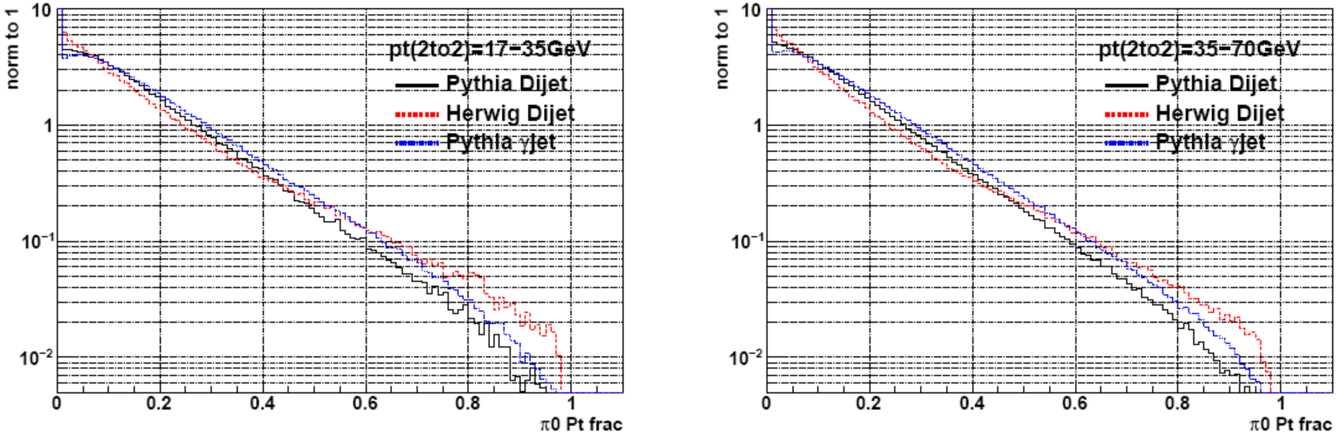
Jet Rejection (Pythia vs Herwig)

		All	quark-jet	gluon-jet
Pythia	Rejection (before isolation)	4922 ± 88	1617±36	15676 ± 463
	Rejection (after isolation)	7764±159	2489±62	37796 ± 1628
Herwig	Rejection (before isolation)	2445 ± 59	707 ± 21	10043 ± 487
	Rejection (after isolation)	3341 ± 90	939 ± 31	15739 ± 940

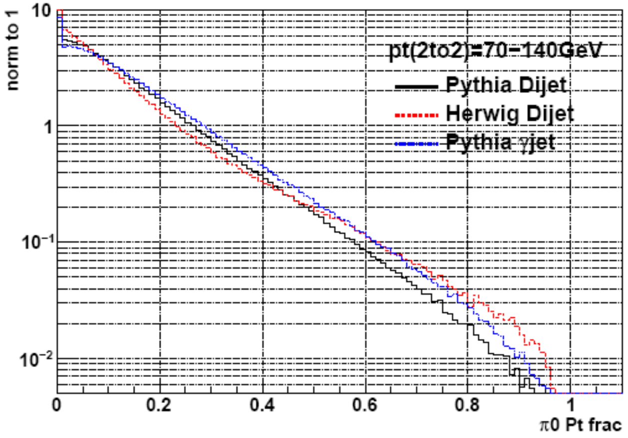
Table 2. Jet rejection expected for the inclusive jet sample for E_T>*25GeV*. The results are shown before and after track isolation cuts for all jets and separately for quark and gluon jets. The erros are statistical only. Pythia vs Herwig Comparison

Pythia – Herwig differences



(a) 17< p_T <35 GeV (b) 35< p_T <70 GeV

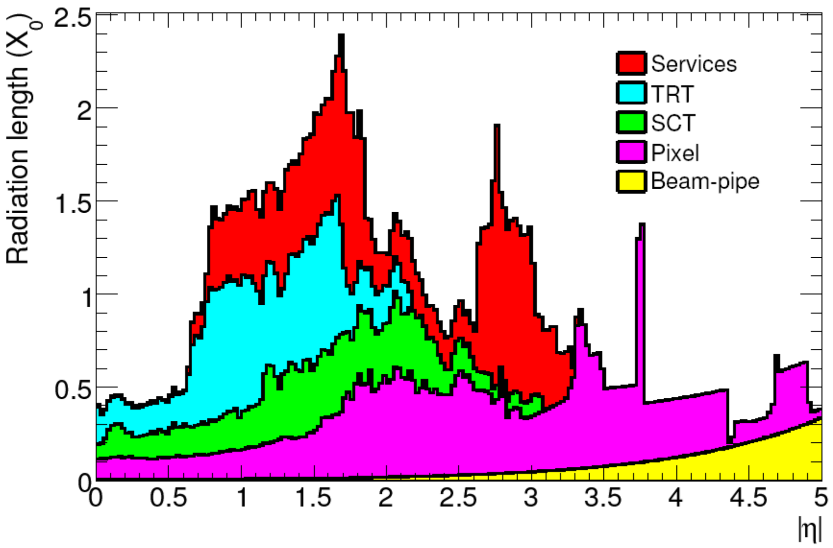
(c) 70< p_T <140 GeV



taken from
ATL-COM-PHYS-2009-420
(Junichi Tanaka)

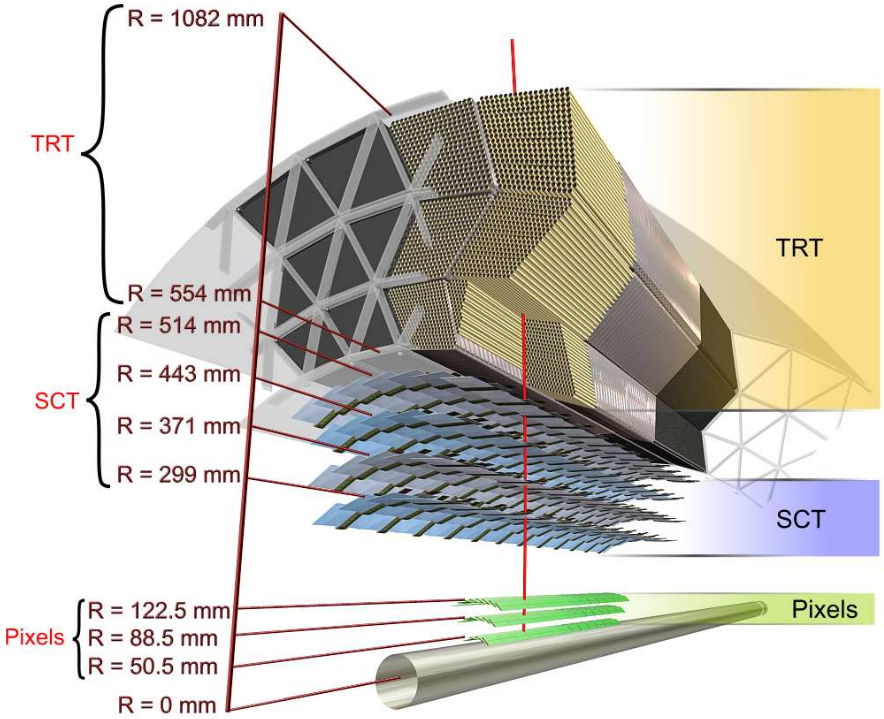
Figure 6: A p_T fraction of a π^0 with respect to a quark. A solid black histogram shows Pythia QCD dijet, a dashed red histogram shows Herwig dijet and a dotted blue histogram shows Pythia γjet.

Converted Photon Reconstruction Performance



Material in the inner detector as a function of $|\eta|$.

taken from CSC-Book



ATLAS inner detector

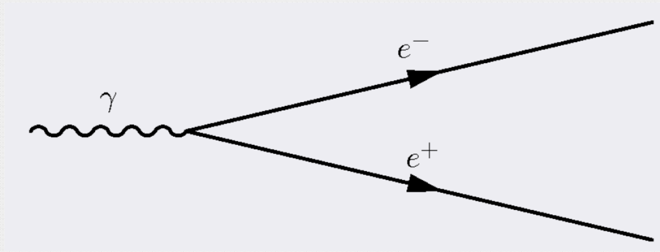
- Monte Carlo Studies:

→ 57% of the photons in $H\rightarrow\gamma\gamma$ with ≥ 1 conversion with $R_{conv} < 800mm$ (which correspond ≈ the last point where we can to hope reconstruct one track)

→ 35% of the photons in $H\rightarrow\gamma\gamma$ with ≥ 1 conversion with $R_{conv} < 350mm$ (can be reconstructed with the software version used for **arXiv:0901.0512** [hep-ex] and in the current software this part is dominated by double track conversions)

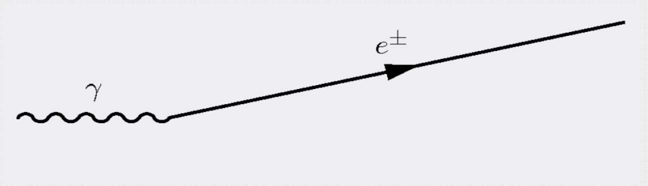
Converted Photon Reconstruction Performance

- 2 types of converted photons are used:



Two track conversions

→ Reconstructed by a vertexing algorithm using 2 tracks with opposite charges
→ Dominates at small radius

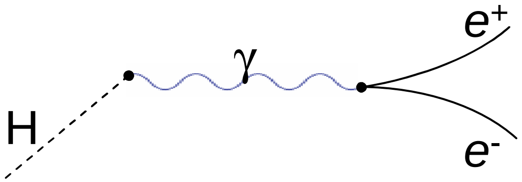


One track conversions

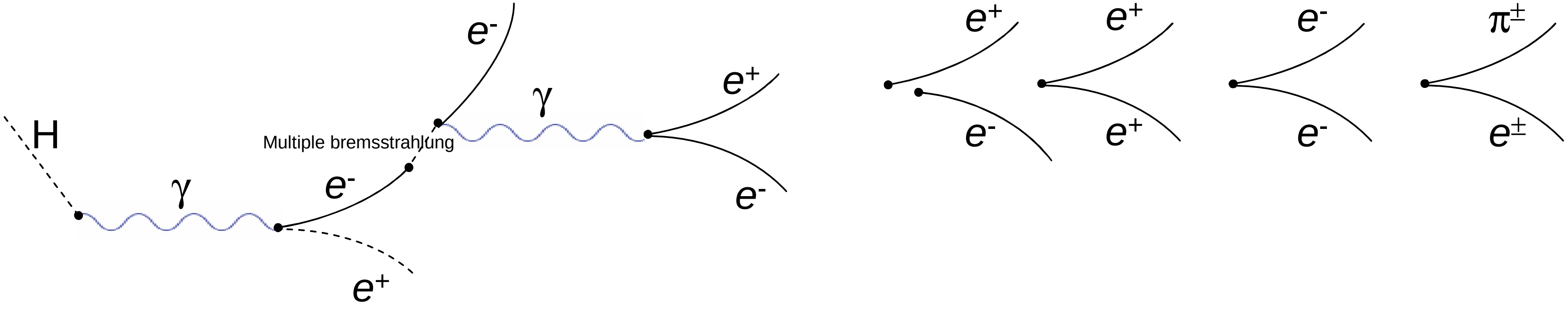
→ One of the 2 tracks not reconstructed by the detector or could not do vertexing
→ Primary electron separation / electron of conversion from signal with a hit in the first pixel layer (b-layer)
→ Dominates at large radius (mainly TRT tracks called TRT stand alone)

Converted Photon Reconstruction Performance (Purity Conv. Photons)

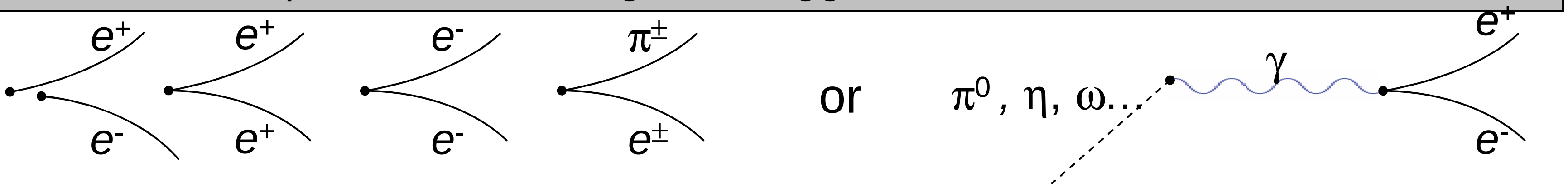
"Signal" = Converted photon with true conversion coming from H



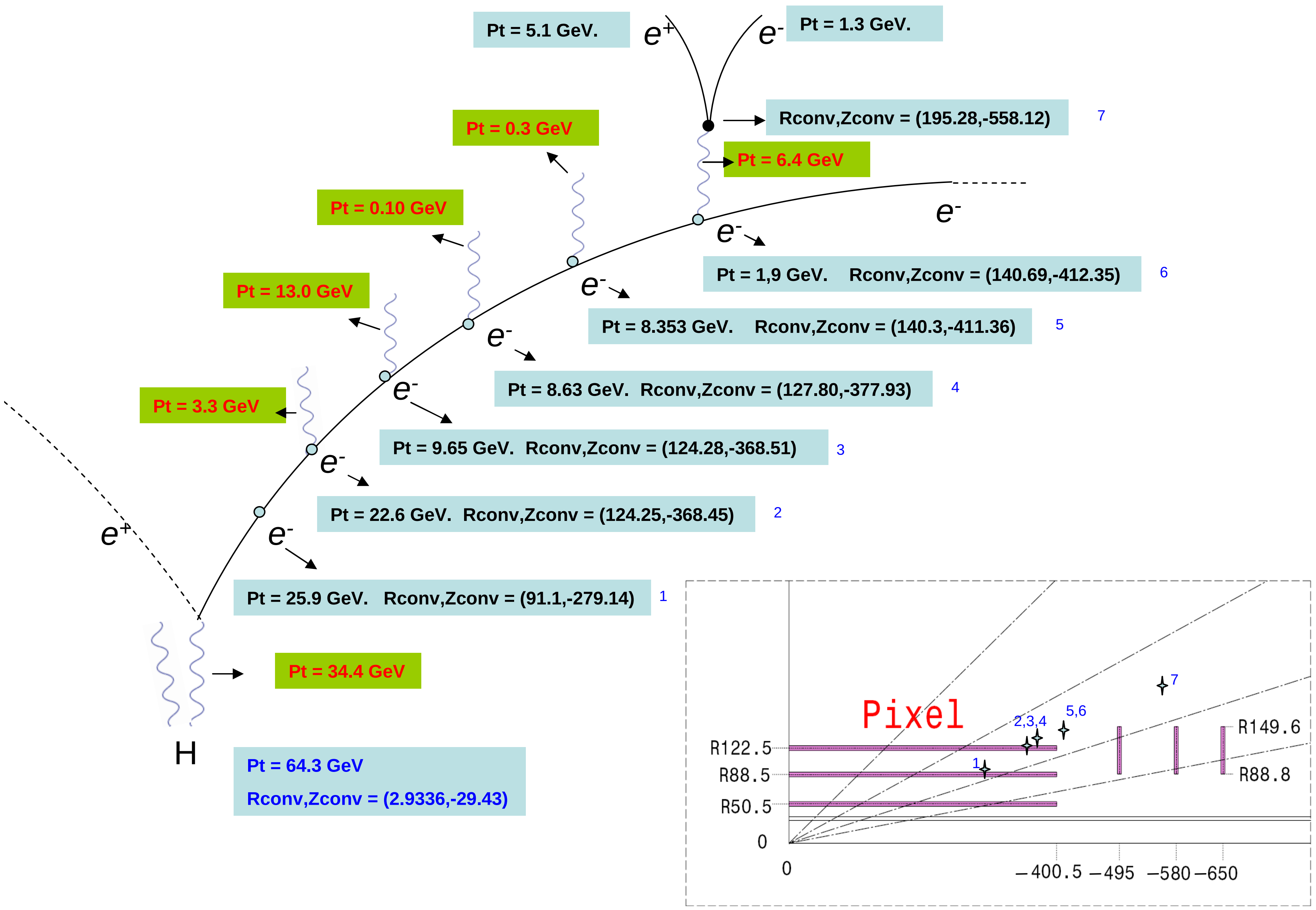
"Secondary" = True converted photon coming from Higgs (after bremsstrahlung)
Or False conversion but at least one of the track is coming from Higgs



"Fakes" = True converted photon not coming from Higgs OR false converted photon not coming from Higgs



Example of secondary converted photon from Higgs



Pt = 5.1 GeV. e^+ e^- Pt = 1.3 GeV.

Rconv,Zconv = (195.28,-558.12) 7

Pt = 0.3 GeV

Pt = 6.4 GeV

Pt = 0.10 GeV

e^-

e^- Pt = 1,9 GeV. Rconv,Zconv = (140.69,-412.35) 6

Pt = 13.0 GeV

e^- Pt = 8.353 GeV. Rconv,Zconv = (140.3,-411.36) 5

e^- Pt = 8.63 GeV. Rconv,Zconv = (127.80,-377.93) 4

Pt = 3.3 GeV

e^- Pt = 9.65 GeV. Rconv,Zconv = (124.28,-368.51) 3

e^- Pt = 22.6 GeV. Rconv,Zconv = (124.25,-368.45) 2

e^+

e^- Pt = 25.9 GeV. Rconv,Zconv = (91.1,-279.14) 1

Pt = 34.4 GeV

H

Pt = 64.3 GeV

Rconv,Zconv = (2.9336,-29.43)

Converted Photon Reconstruction Performance (Purity Conv. Photons)

Higgs Converted Photon Purity		No Isolation	Isolation
Double track conversions	**Signal**	**91.86 %**	**91.93 %**
	Secondary	**8.01 %**	**7.98 %**
	Fakes	**0.13 %**	**0.09 %**

Summary of the purity's computation for single track converted Higgs photons

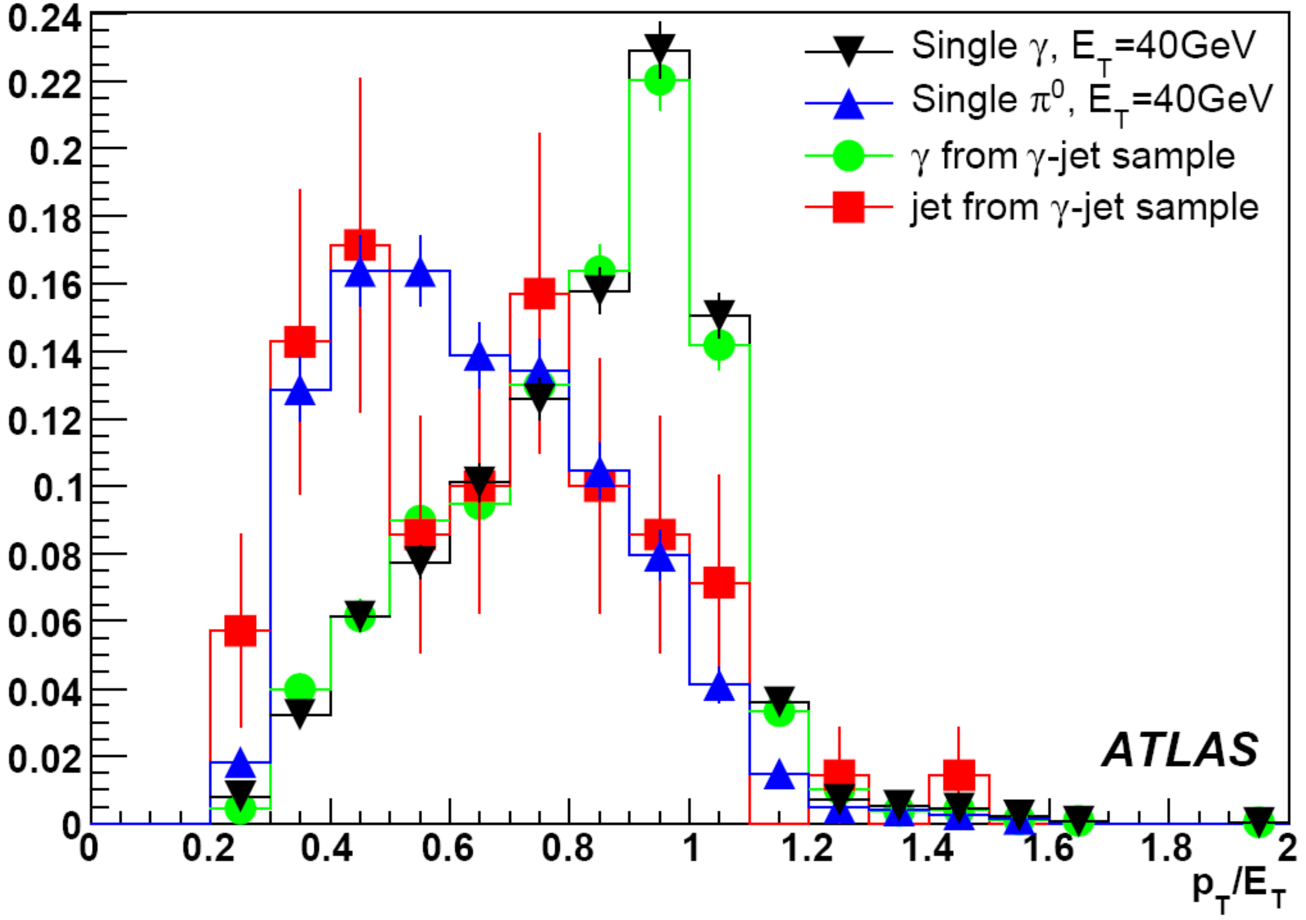
Higgs Converted Photon Purity		No Isolation	Isolation
Single track conversions	**Signal**	**96.01 %**	**96.08 %**
	Secondary	**1.59 %**	**1.56 %**
	Fakes	**2.40 %**	**2.36 %**

Summary of the purity's computation for double track converted Higgs photons

Cuts

- **$p_T\gamma$(leader) *>40 GeV* and $p_T\gamma$(Subleader) > *25GeV***
- **Identification cuts**
- ***$0 < |\eta| < 1.37$, $1.52 < |\eta| < 2.37$***

Purity Conv. Photons (γ-jet sample)



We can evaluate the jet contribution to the total background based on the analysis of converted photons. Also, use this as discrimination variable

Conclusions

- Channel with a weak B.R, but favorite for the low mass Higgs (clean signature at LHC)

- Signal and Background estimation is done with MC.

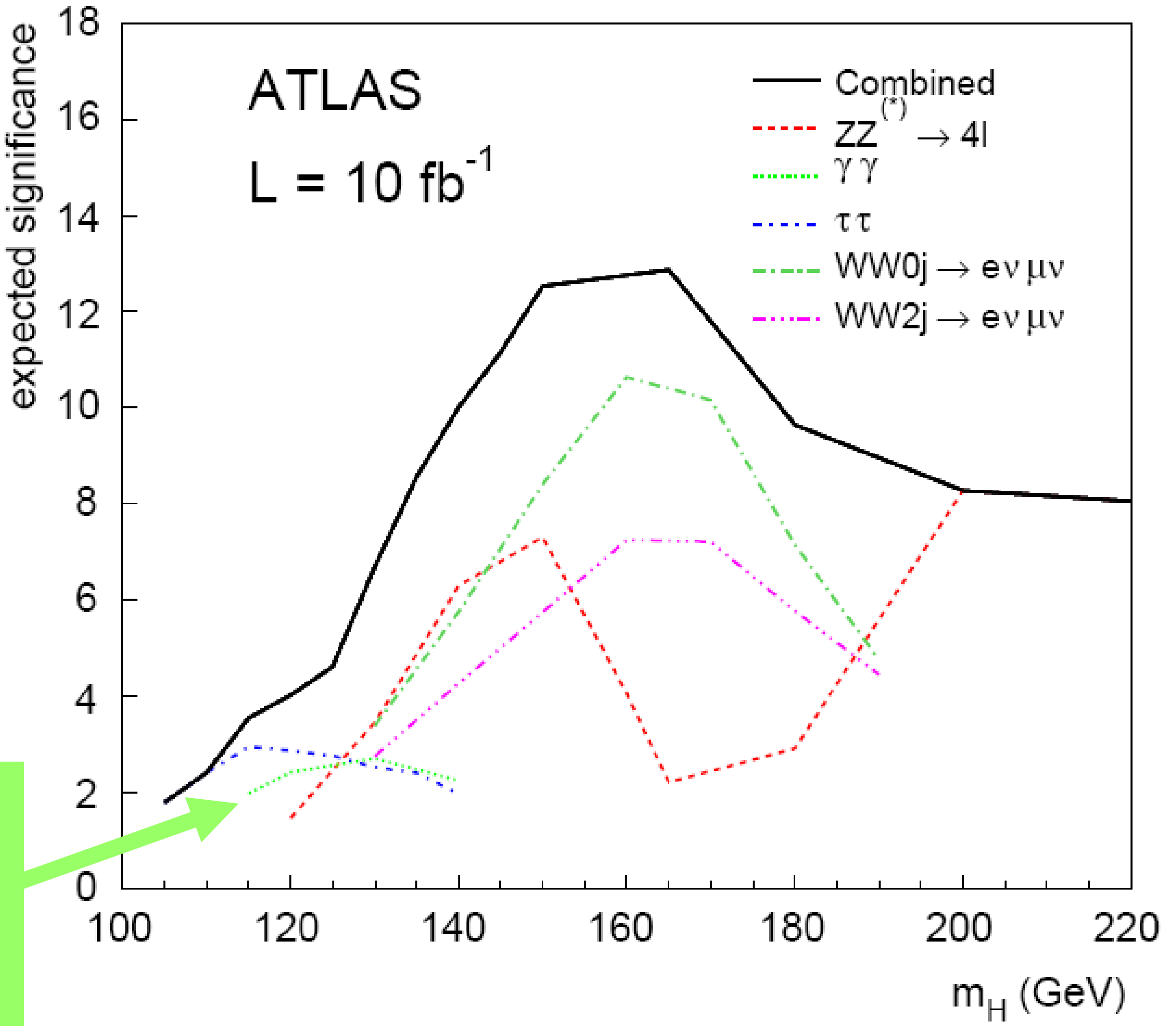
- Analysis strategy : identification cuts, discrimination variables .

- Large uncertainties to estimate reducible background
  - Pythia – Herwig differences
  - Converted Photon analysis will be use
  - More work to do!!!

- At this moment, we have good manipulation of converted photons

- Good purity values have been found for Higgs Signal

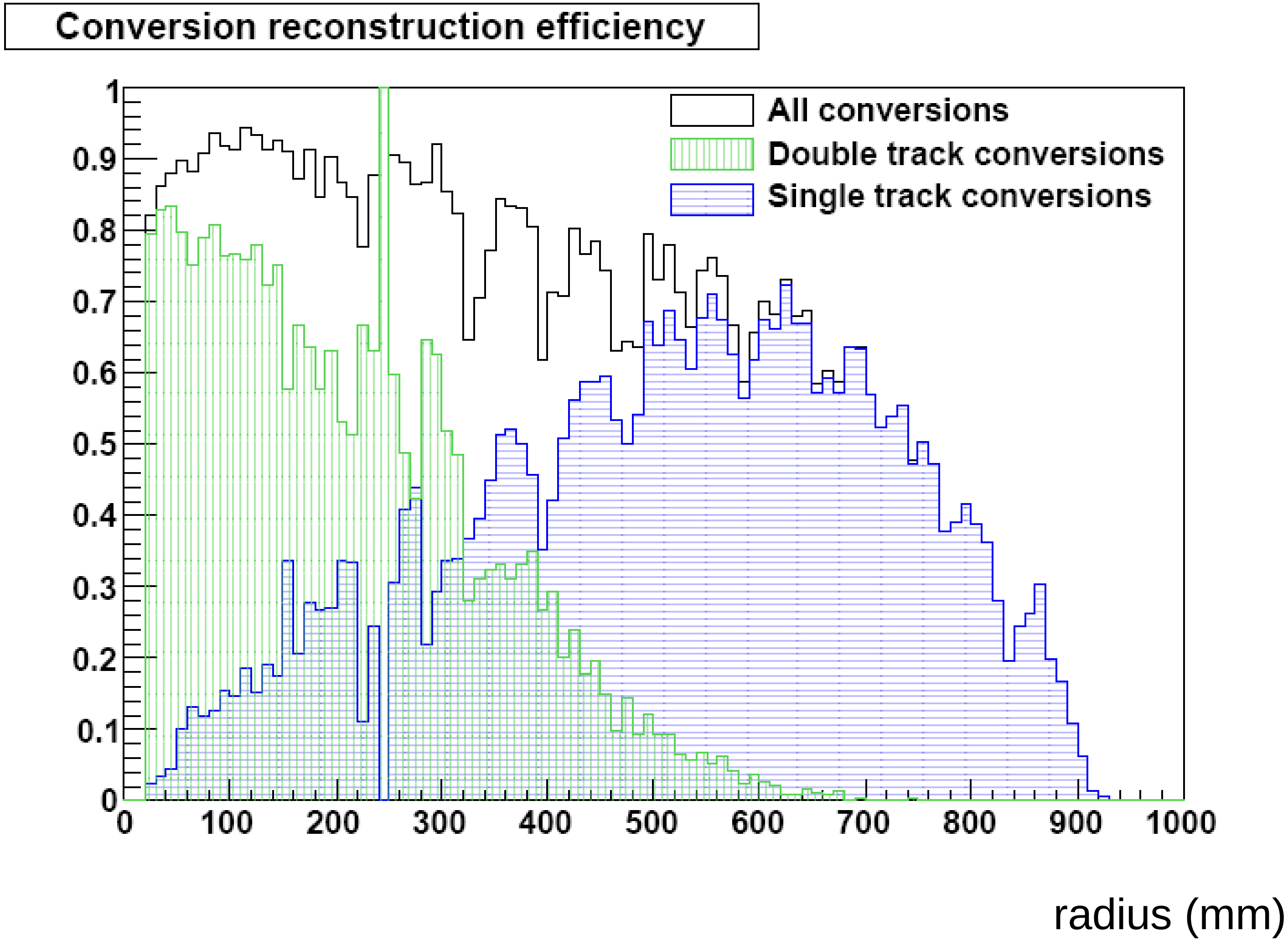
backup



very important at
low mass

Note that on this plot only the inclusive analysis is there for the H → γγ analysis

We can gain a factor 1.5 with more detailed analysis


Conversion reconstruction efficiency
All conversions
Double track conversions
Single track conversions
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
100
200
300
400
500
600
700
800
900
1000
radius (mm)

Roughly we need 2 times the statistics to get the same limit at 10 TeV than at 14 TeV . And an additional factor 2 at 7 TeV