

b/tau LHC workshop

Di cosa si è parlato molto:

- CMS tracker - soprattutto Pixel
- CMS HLT e tau tagging

Di cosa si è parlato poco (o niente):

- SUSY e Higgs
- fisica del b e b-tagging
- ATLAS (2 soli talks: overviews di Higgs e SUSY fatte da “non esperti”)

www.hip.fi/btau

SUSY overview: Introduction

- Quite a few Susy final states with b's and/or τ 's
- Good b/ τ reconstruction allows
 - full or partial reconstruction of Susy events
 - determination of some sparticle masses
- Various cases (various Susy models):
 - One case will be detailed, as an example:
 - mSugra models with large $\tan\beta$ (both τ and b rec. needed)
 - Some other cases will be briefly described:
 - need either τ or b reconstruction
 - methods and ideas rather similar
 - expected results outlined
 - Some cases not shown here...
 - Some cases not even studied yet...
- Everything presented here:
 - based on Atlas simulations
 - of course valid for CMS as well...

SUSY overview: Layout

- Reconstruction (outlined)
 - Some words about τ reconstruction and b tagging
- Using τ and b reconstruction:
 - In mSugra models with large $\tan\beta$
- Using τ reconstruction:
 - Lepton flavour violation
 - GMSB with τ_1 as the NLSP
- Using b reconstruction
 - In mSugra models
 - $h^0 \rightarrow b \bar{b}$ in cascade decays
 - $\tilde{g} \rightarrow b \dots \rightarrow b l^+ l^- \dots$
- Conclusion



Described in detail



Only briefly shown

SUSY overview: Conclusions

- Many Susy models predict topologies containing b 's and/or τ 's in the final state
- These are used in many ways:
 - for selection of signal events
 - as starting point of analysis chain in cascades
 - to reconstruct sparticle masses
 - to constrain Susy models
- More possibilities than the ones presented here:
 - for example:
 - $\tilde{g} \rightarrow t \tilde{t}, b \tilde{b} \rightarrow t b \dots$
 - tau polarization studies



CMS tracker

- Pixel + SST
- $\sigma(pT) \sim 0.1 \text{ GeV}$ con +6 hits
- Pixel:
 - $4 \cdot 10^7$ pixels 150x150
 - IP res. $20 \mu\text{m}$ (10 GeV)
 - 2 anni di resistenza per il layer piu' interno (high lum.)
 - $T=-10 \text{ C}$: reverse annealing, leakage current
 - Fluido di raffreddamento: -20 C
 - 6 kW da dissipare
 - 0.1 radiation length

CMS tracker software

- 15 μm risoluzione z sul Vertice Primario in eventi uu
- 40 μm usando solo il Pixel (molto piu' veloce)

Confrontabile con i nostri risultati offline.



Track reconstruction strategy

Track reconstruction is logically divided in four phases:

- Generation of track seeds
- Building of trajectories from seeds
- Resolution of ambiguities
- Final fit (smoothing) of track

There are other ways to decompose the problem, and this decomposition does not work for some global methods (e.g. NN)

But so far it work very well in CMS

Tracks reconstruction: Choice of seeding layers

An obvious choice would be the outermost layers, since the occupancy is lowest there.

But in CMS

- Between 8% and 15% of the 1 GeV pions interact before crossing 8 layers
- The outer layers don't have stereo information
- The innermost layers are “pixel”, with very low channel occupancy and excellent 2D resolution

Therefore the pixel layers are the favored seeding layers

HLT versus offline

So far things are so general that they apply both to offline and to HLT tracking

In fact, in CMS there is no distinction between HLT and offline software:

- Both use the same framework
- Algorithms can be freely moved from one to the other

High Level Trigger time scale

- Input rate: 100 kHz
- Output rate: 100 Hz
- Average CPU time per event: order of 100 ms @ 1 GHz processor
- What can the Tracker do at this level?

CMS pixel track reconstruction

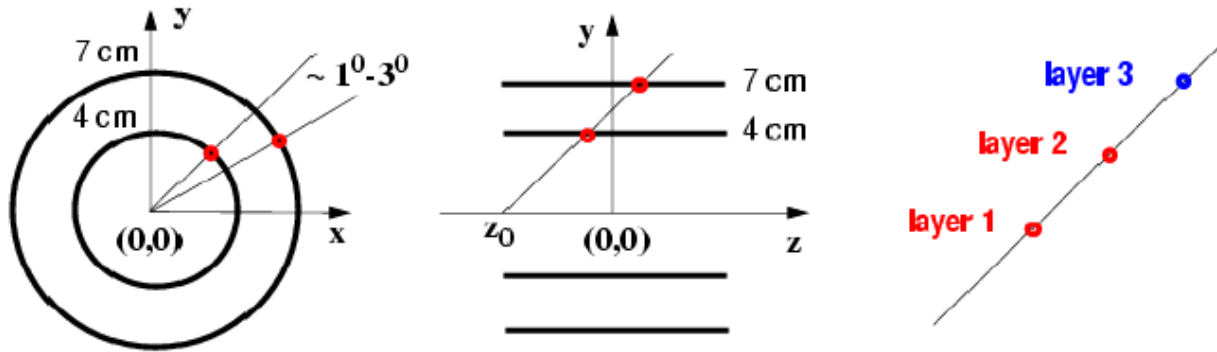
Introduction

1. In CMS standalone pixel reconstruction has been first applied for seeding by Nikita&Sasha and for B-physics channels by Andrei (see [Vertex 2001](#)).
2. Similar work has been done in ATLAS, e.g. [A.Baratella et al. Pixel2000 in Genova, NIMA 465\(2001\)190](#).

More emphasis on impact parameter tagging.
Less use of the primary vertex constraint.
3. More details can be found in :
[CMS Internal Note 2000/22](#).

Reconstruct track candidates using pixel hits

Algorithm (using 3 pixel hits per track) :

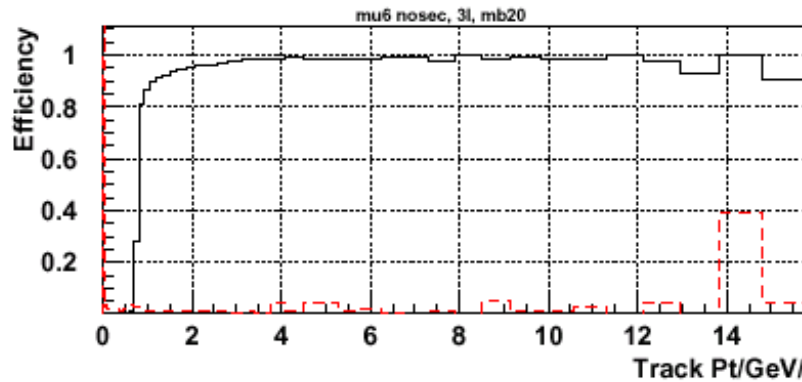


1. Match pixel hit pairs from the 1st two layers (barrel & endcaps) in $r-\Phi$ and $z-r$.
2. Valid hit pairs are matched with a hit in the 3rd layer forming track candidates.
3. Establish primary vertex candidates in z locations where at least 3 tracks cross the z axis.
4. Erase track candidates not pointing to any valid primary vertex.

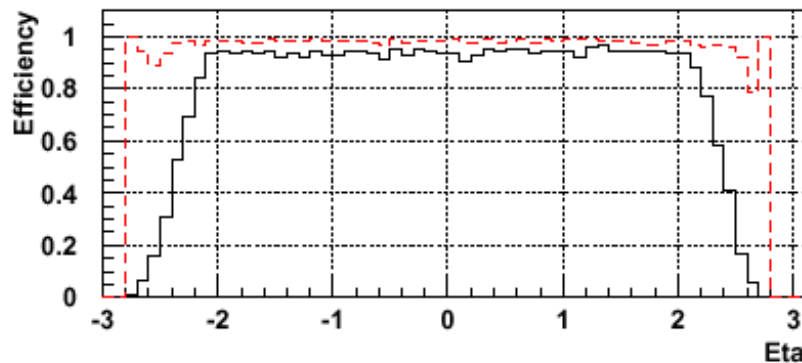
Track reconstruction efficiency

LHC high luminosity

High efficiency &
low background!



solid line – reconstruction efficiency
dashed line – ghost rate

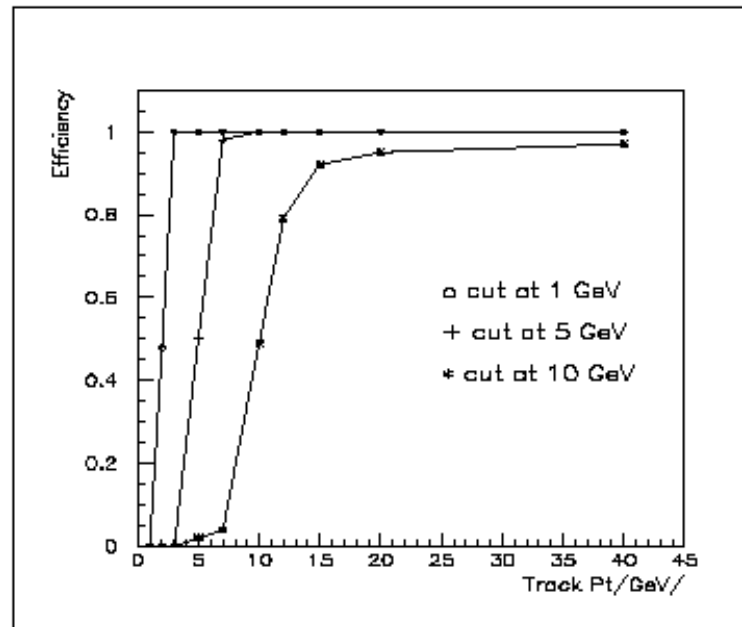


solid line – absolute efficiency
dashed line – relative (algorithmic) efficiency

Transverse momentum resolution

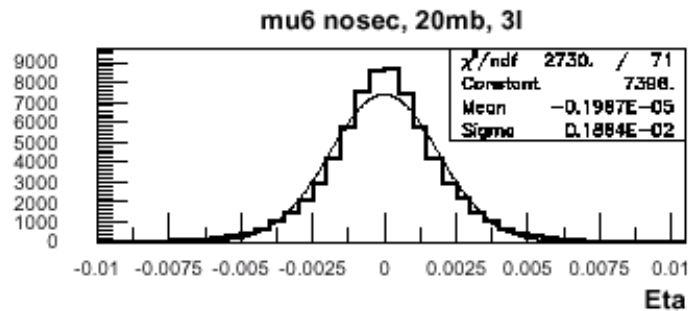
$$\Delta p_T/p_T = 0.036 + (0.017 * p_T \text{ [in GeV]}) \text{ is poor!}$$

The resolution is shown in the plot below in form of the effectiveness of a p_T cut.

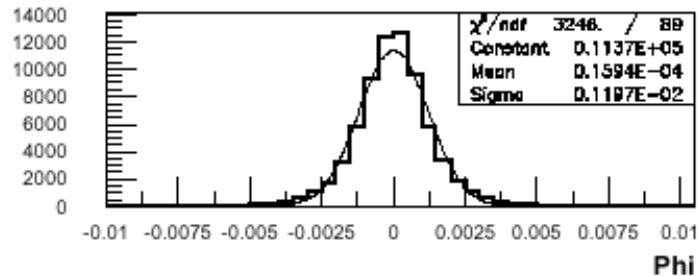


Unfortunately this means that the impact parameter resolution is also very poor!

Track direction resolution



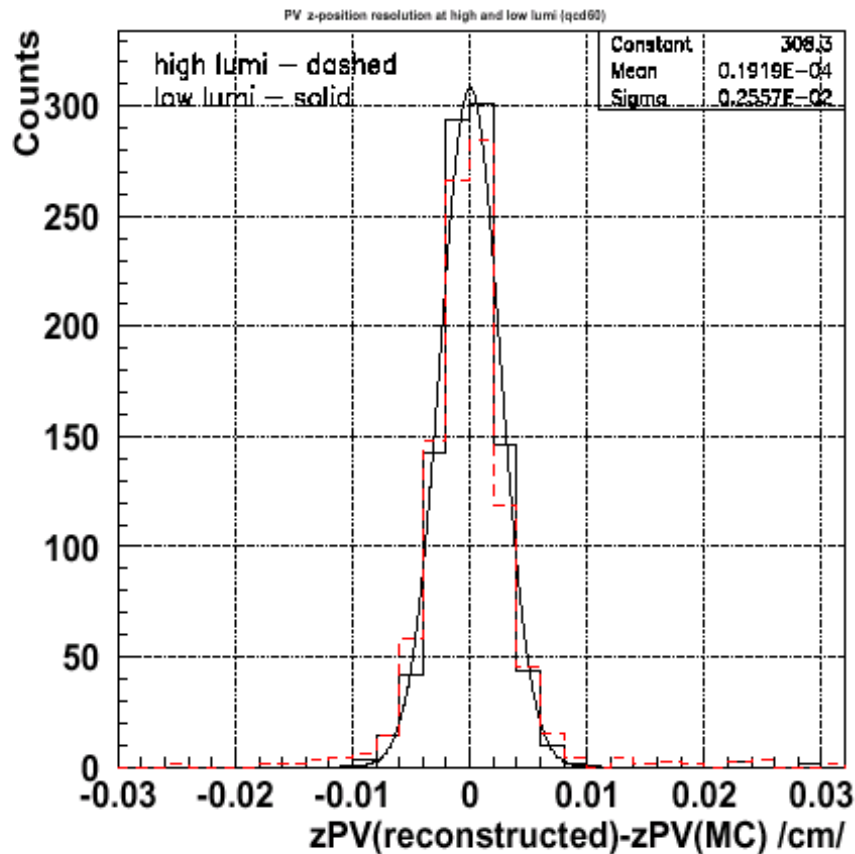
19 mradians in η



12 mradians in Φ

The track charge estimate is also very accurate.

Very good primary vertex reconstruction

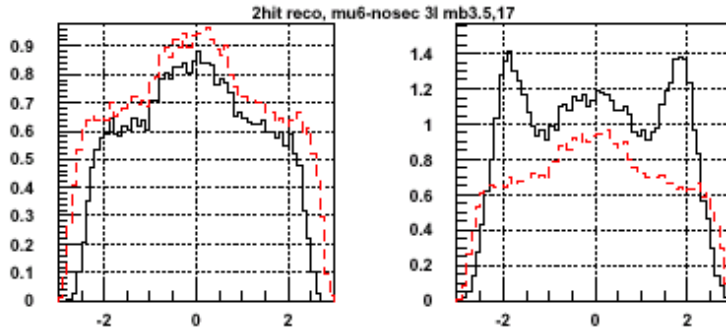


In this case $26\mu\text{m}$.
Very close to the best
resolution with tracks!

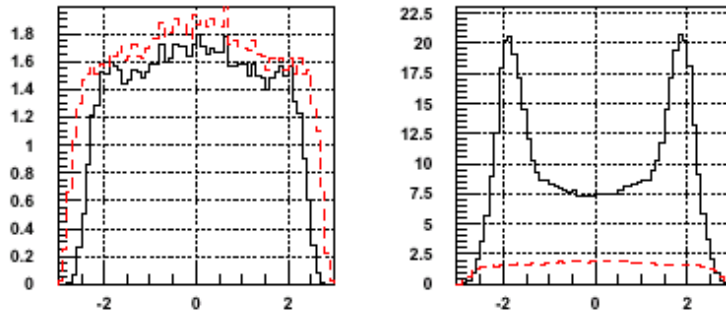
For all channels studied
the signal primary vertex
position resolution
is $< 50\mu\text{m}$.

Pile-up primary vertices
can be also found if they
have at least 2 charged
tracks above 1GeV.

2 hit recovery



Low luminosity

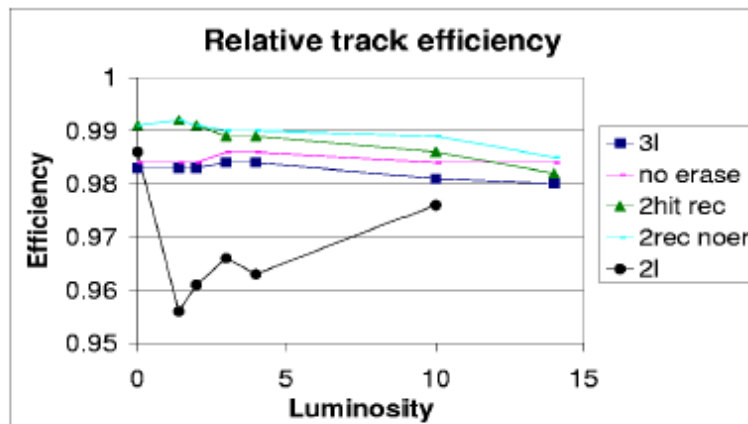
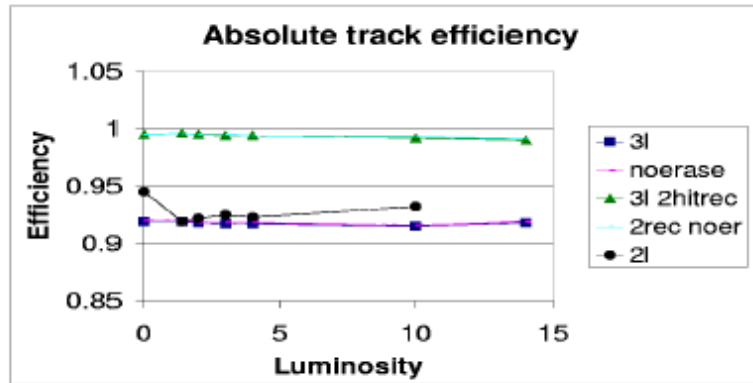


High luminosity

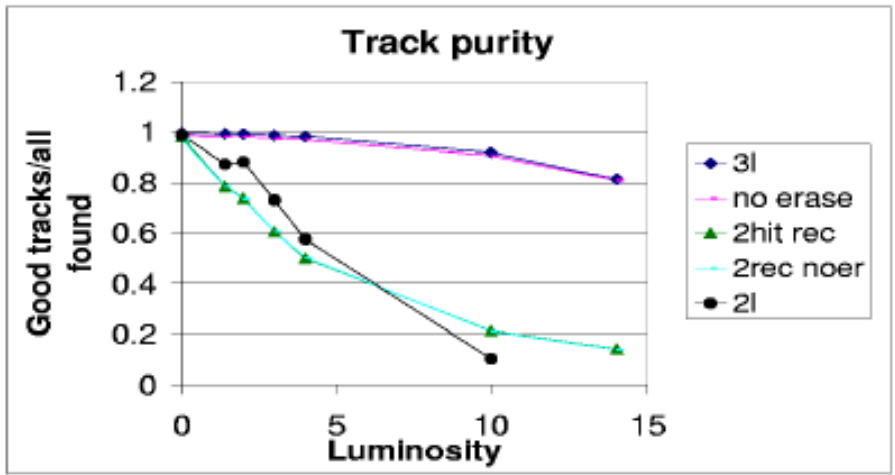
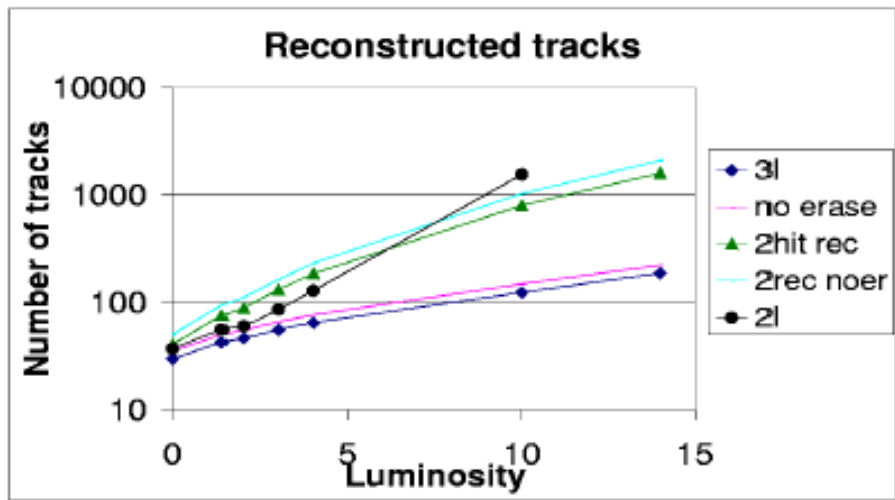
Standard 3l

With 2 hit recovery

Luminosity dependence – tracks finding efficiency



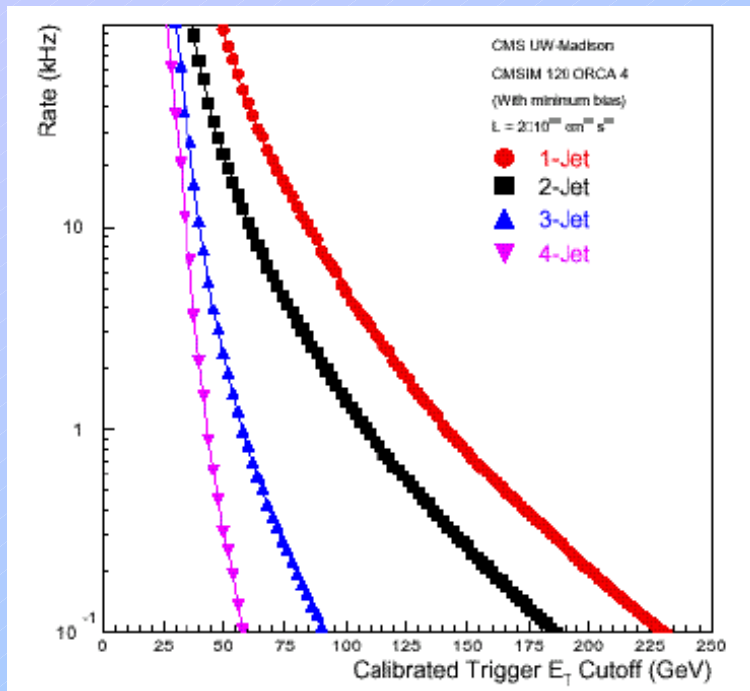
Luminosity dependence – track purity



TRIGGER L1

Necessità di un trigger di primo livello dedicato ai τ .
Insufficiente solo jet trigger.

In particolare: $A \rightarrow \tau\tau$ a bassa m_A



calorimetro

Lvl-1 Jet and di-Jet thresholds at $\sim 2 \text{ kHz}$ for $L=2 \times 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ ~ 120 and 90 GeV
are too high for SUSY $A^0/H^0 \rightarrow 2\tau$ -jet of $M_H = 200 - 300 \text{ GeV}$



the most dangerous for tau's qcd bins

Rate of T || 2T L1 trigger in 12.5 and 8.9 kHz calo rate scenarios
(see * on next slide)

qcd p_t bin, GeV	12.5 kHz scenario, rates (kHz) for T > 80 GeV 2T > 65 GeV	8.0 kHz scenario, rates (kHz) for T > 85 GeV 2T > 70 GeV
20 - 30	0.46 +-0.07	0.37 +- 0.06
30 - 50	0.39 +- 0.06	0.22 +- 0.03
50 - 80	2.12 +- 0.05	1.29 +- 0.04
80 - 120	2.29 +- 0.02	1.89 +- 0.02
120 - 170	0.562 +- 0.008	0.536 +- 0.008
170 - 230	0.107 +- 0.004	0.104 +- 0.004
230 - 300	0.0242 +- 0.0006	0.0236 +- 0.0006
300 - 380	0.0063 +- 0.0002	0.0061 +- 0.0002
380 - 470	0.0019 +- 0.0001	0.0018 +-0.0001
sum rate, kHz T 2T	6.0+- 0.1	4.4 +- 0.1

qcd bins 50-80, 80-120, 120-170 represent > 83 % of L1 (T || 2T) rate

~ 90% efficienza su $A \rightarrow \tau\tau$

HLT: Isolation Algorithms

Signal vertex identified by:

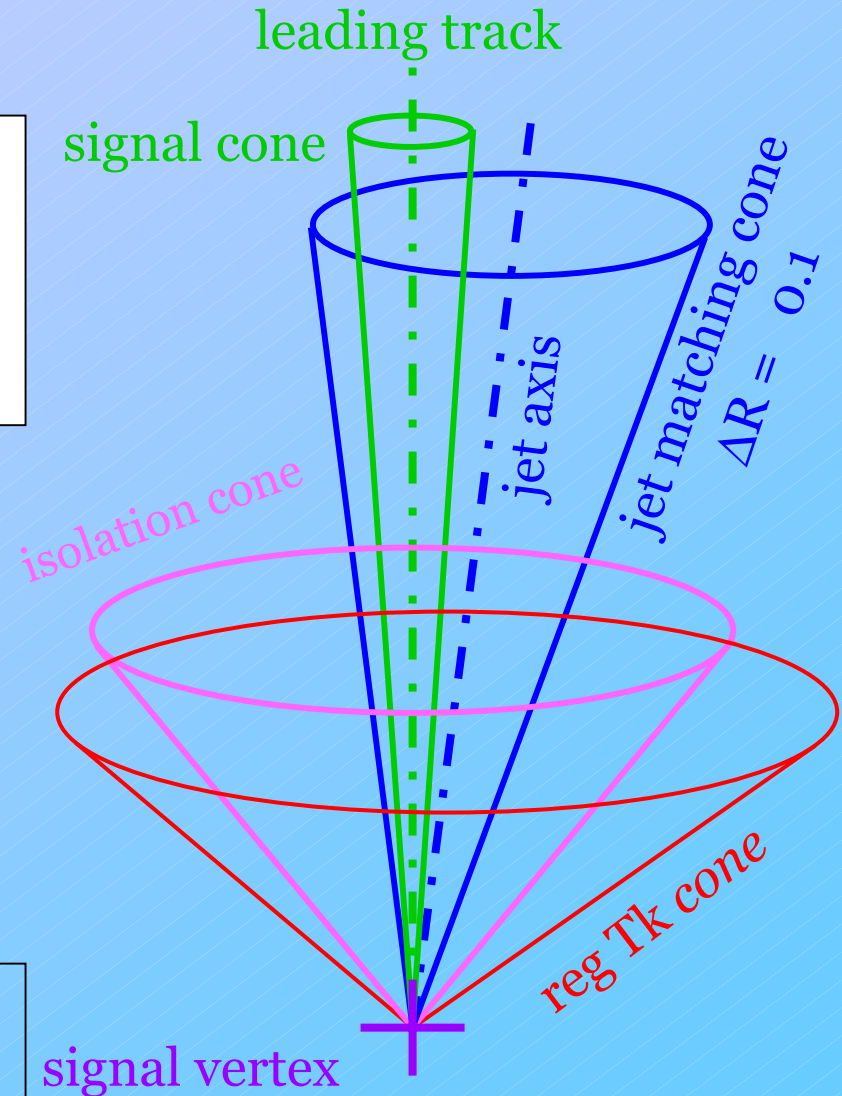
Pxl: leading track ($P_T > 3\text{GeV}$)

Trk: best signal vertex candidate from pixel reconstruction.

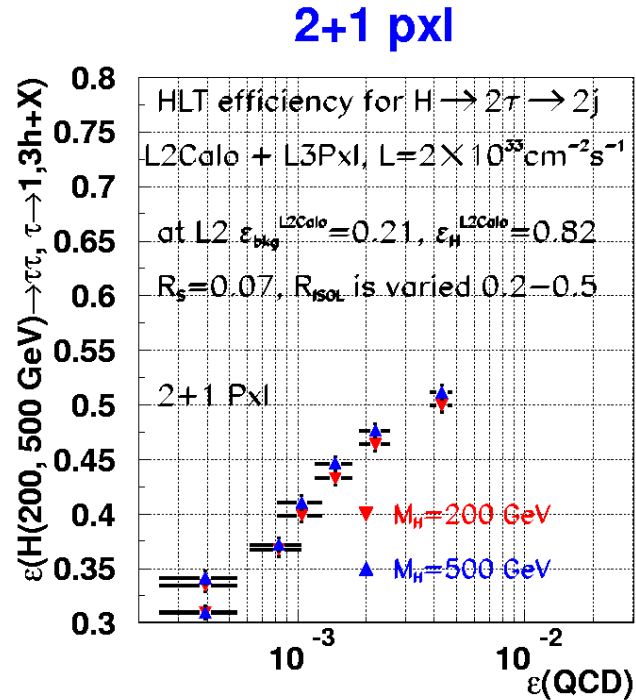
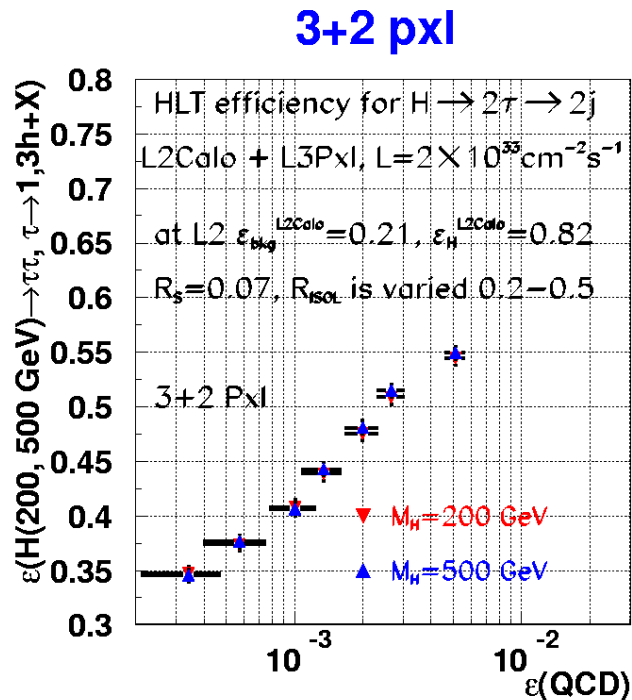
Both algorithms count number of tracks inside signal (N_{SIG}) cone and isolation cone (N_{ISO}). Events is accepted if leading track exists and $N_{\text{SIG}} = N_{\text{ISO}}$

Pxl: use pixel lines (i.e. tracks reconstructed only with pixel layers).

Trk: use regional tracker reconstruction.

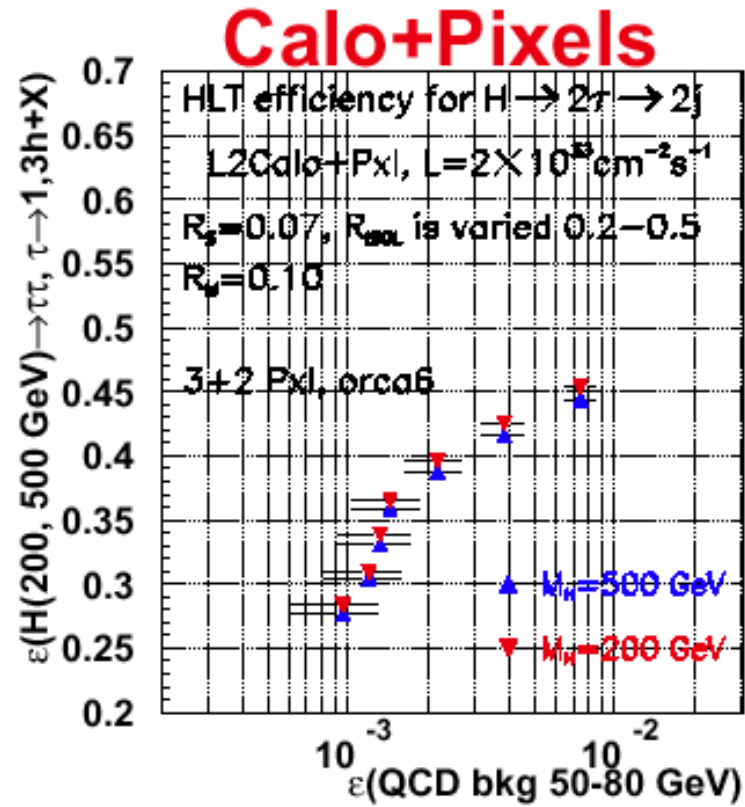
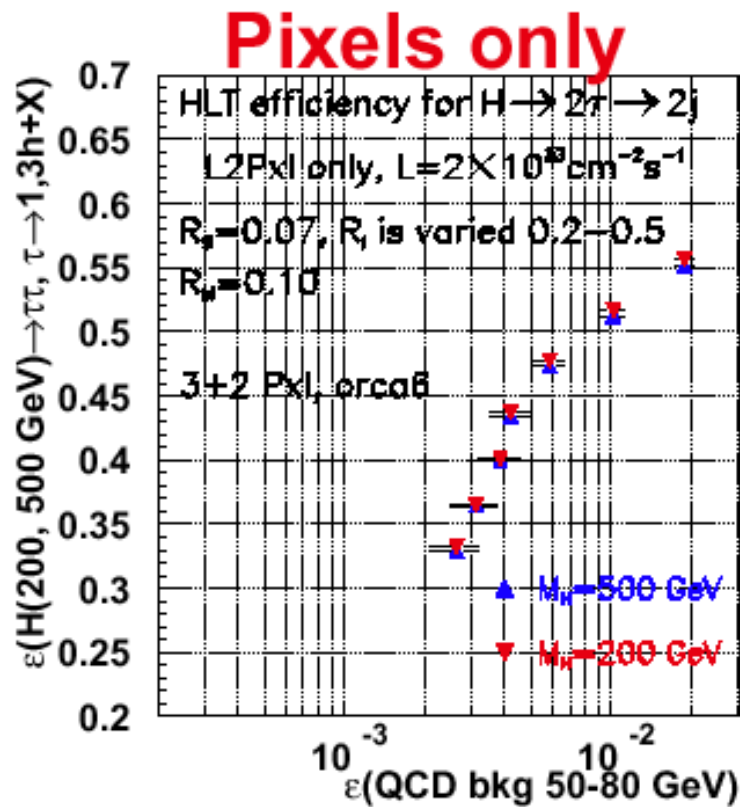


H \rightarrow 2 τ \rightarrow 2j selections at HLT with Calorimeter and Pixel data.



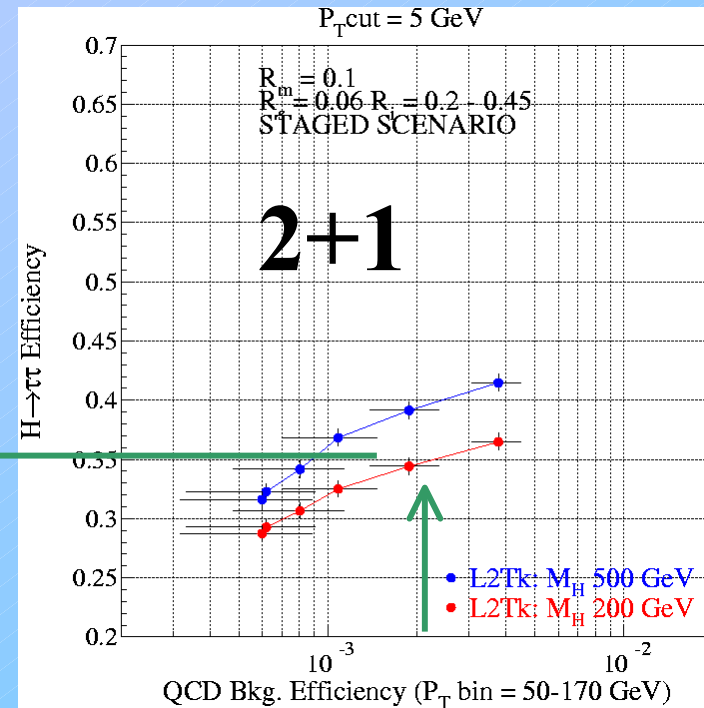
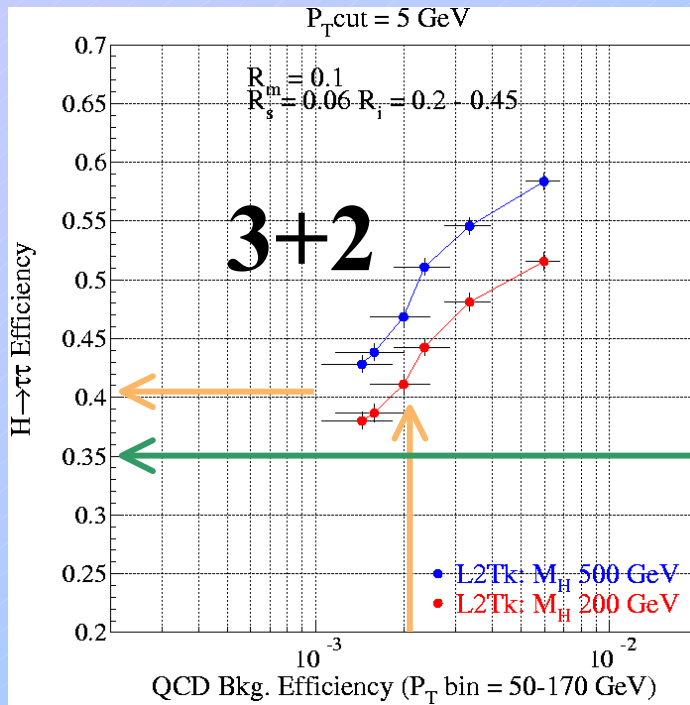
1. performance of Calo+Pxl Tau ID is the same for 3+2 Pxl and 2+1 Pxl configurations
2. for rejection of 1000 Calo+Pxl is $\sim 7\%$ less efficient than Pxl only.

H \rightarrow 2tau-jets, HLT with Calo + Pixels orca6, L=2x10³³cm⁻²s⁻¹



Calo+Pixels provide rejection $\sim 10^3$
Higgs efficiency is $\sim 20\%$ less than in orca5

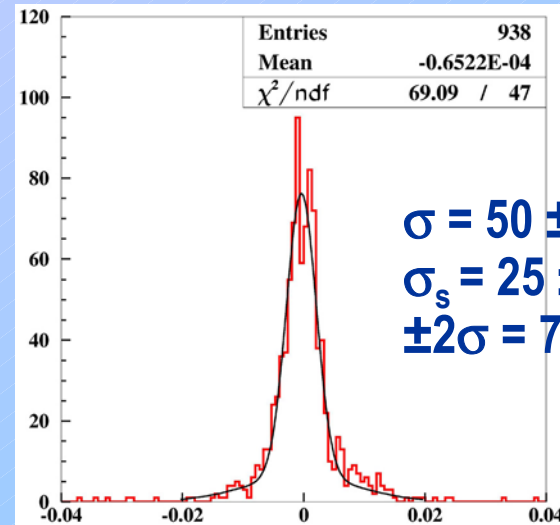
Con tutto il tracker



MSSM $H \rightarrow \tau\tau$ using vertexing

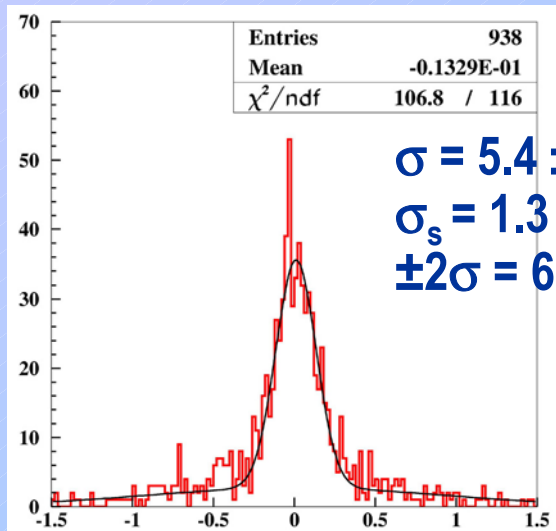
	H200 events	3-prong ratio %	H500 events	3-prong ratio %	QCD 80-120
L1	4464	26.3 ± 0.5	4724	24.2 ± 0.5	13492
L2	3661	25.5 ± 0.6	3836	23.4 ± 0.6	2194
L3 1st jet	2662		2777		255
L3 both jets	1827	24.8 ± 0.7	1841	23.8 ± 0.7	10
Reco both jets	1607	26.1 ± 0.8	1644	24.1 ± 0.7	8

Ortogonale al'asse



$\sigma = 50 \pm 11 \mu\text{m}$
 $\sigma_s = 25 \pm 3 \mu\text{m}$
 $\pm 2\sigma = 78 \%$

H500
2, 3 tracks

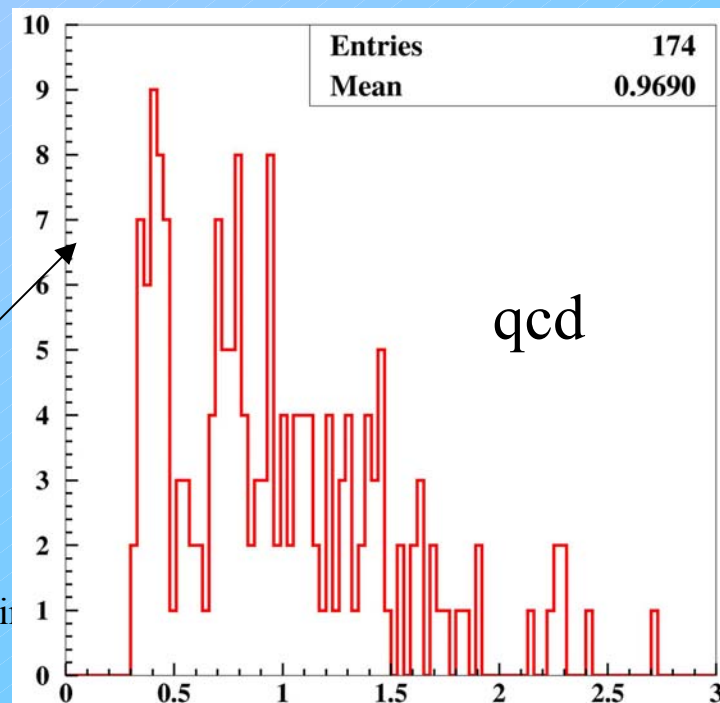
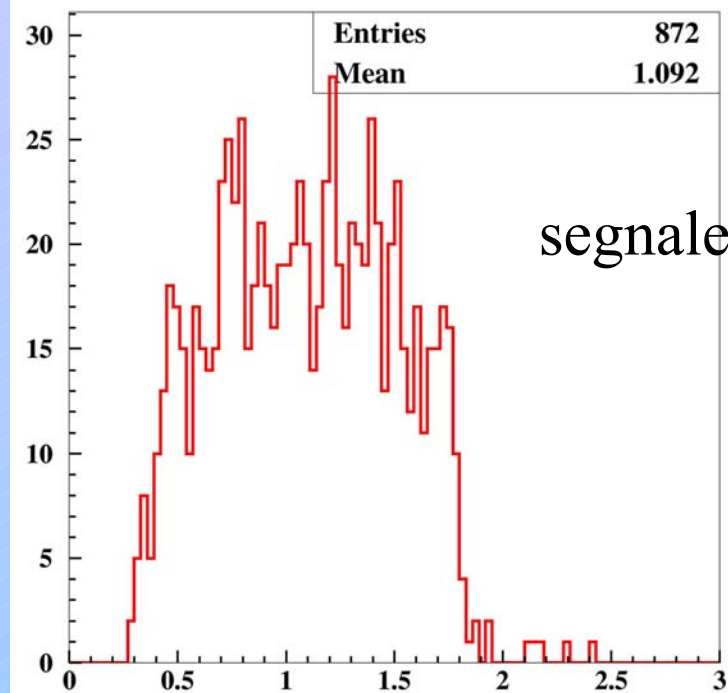
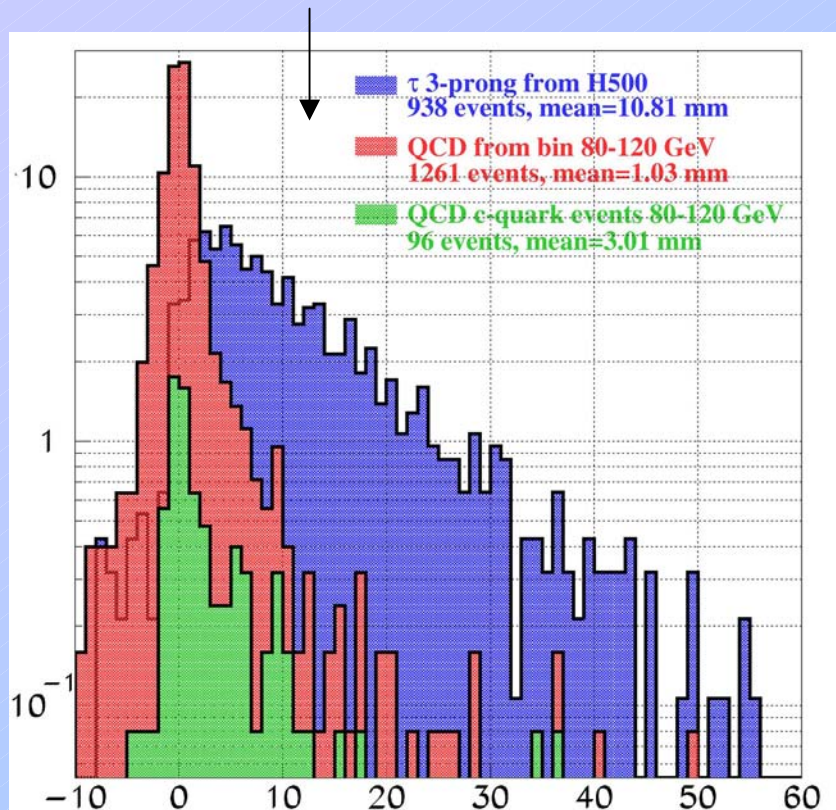


$\sigma = 5.4 \pm 0.5 \text{ mm}$
 $\sigma_s = 1.3 \pm 0.1 \text{ mm}$
 $\pm 2\sigma = 62 \%$

Parallelo all'asse

- Tails come predominantly from jets with low ΔR
- Hit mismatching because of narrowness of jet?

Flightpath



Mass rec.