High p_T b-tagging

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special thanks to V. Kostyukhin, T. Lari, M. Lehmacher, A. Rozanov, L. Vacavant

Introduction – physics case

Diagnosis: 12.0.6 Performance standard algorithms

Tracking and vertexing in high p_T b-jets

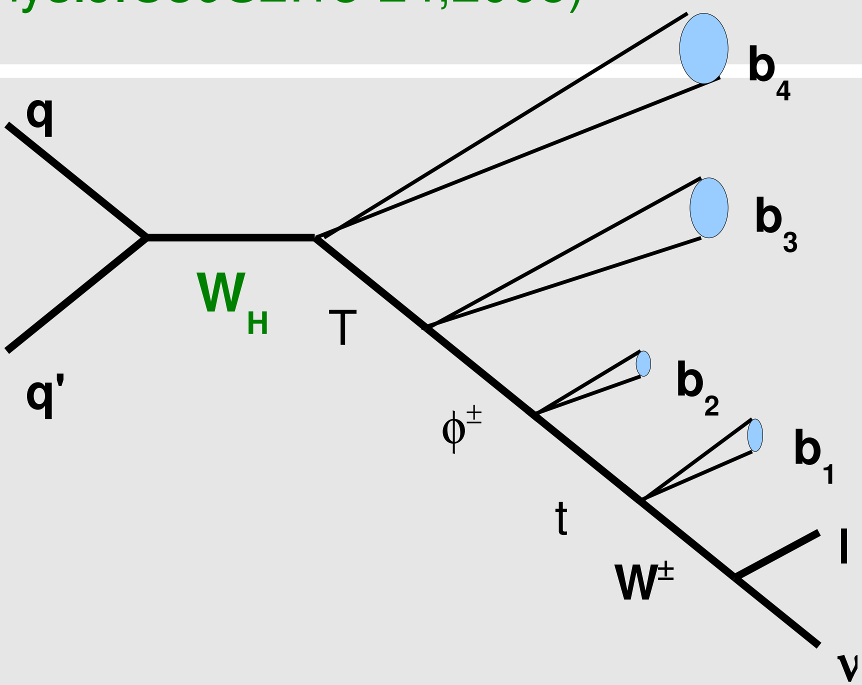
The first steps towards an algorithm with good performance over a broad p_T range

More information: http://ific.uv.es/~vos/Atlas/BTagging/

Physics case for high p_T b-tagging

Typically cater for SUSY cascade decays, exotic physics searches (hadronic decay of heavy resonances), but also the tail of Standard Model physics.

Littlest Higgs model: $Z_H \rightarrow Zh \rightarrow l^+l^- bb$ (E. Ros, J.E. Garcia, Eur.Phys.J.C39S2:13-24,2005)



Cascade decays of heavy gauge bosons in LR twin Higgs model

$W_H \rightarrow Tb$

↳ $\phi^\pm b$

↳ tb

↳ Wb

↳ lν

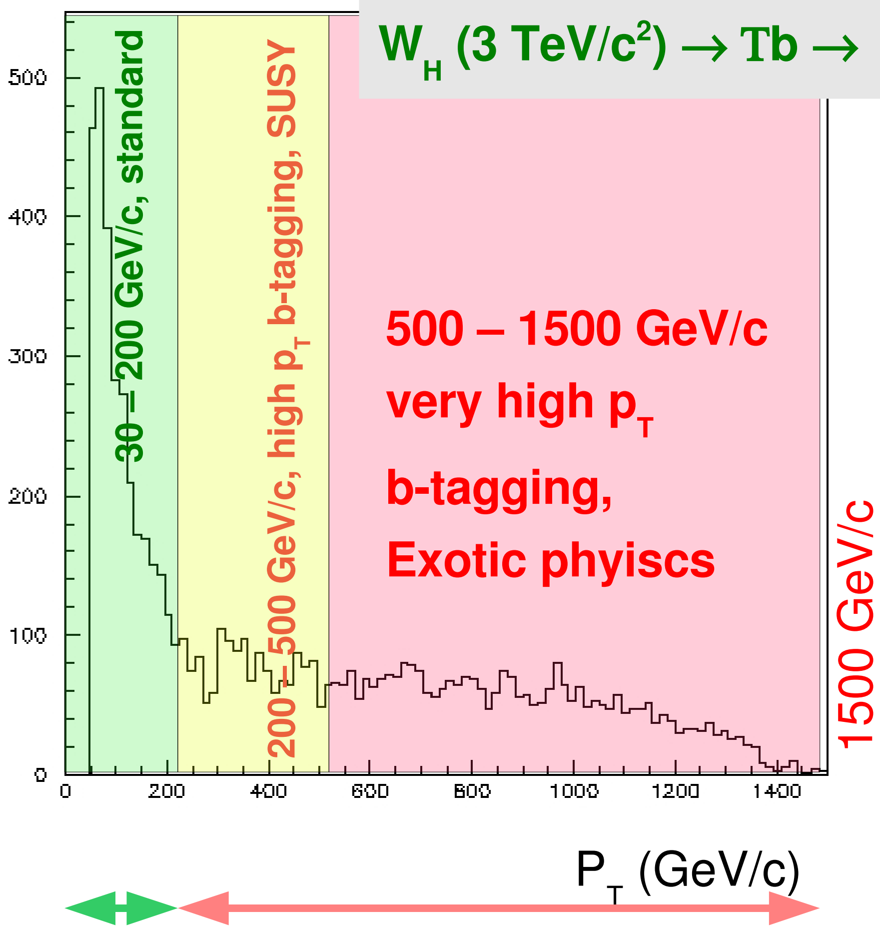
for m (W_H) = 1 TeV **b3: $\langle p_T \rangle$ = 201 GeV** **b4: $\langle p_T \rangle$ = 277 GeV**

(see Les Houches workshop for physics at TeV colliders: http://www.lpthe.jussieu.fr/LesHouches07Wiki/index.php/Preliminary_Programme)

Physics case for high p_T b-tagging

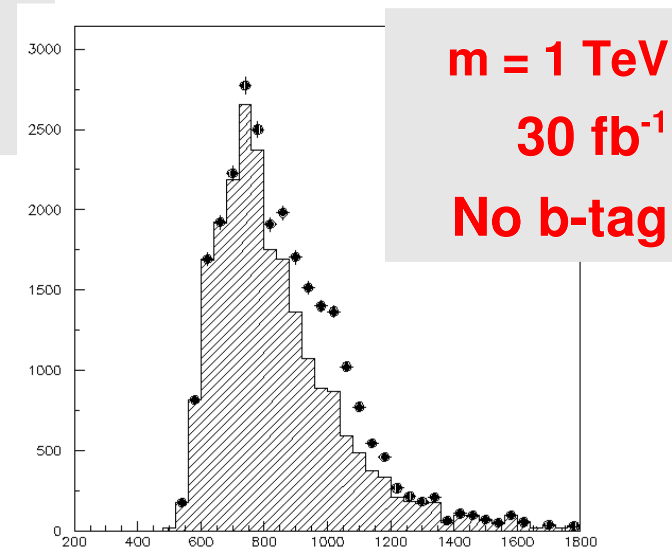
P_T spectrum for b-jets in

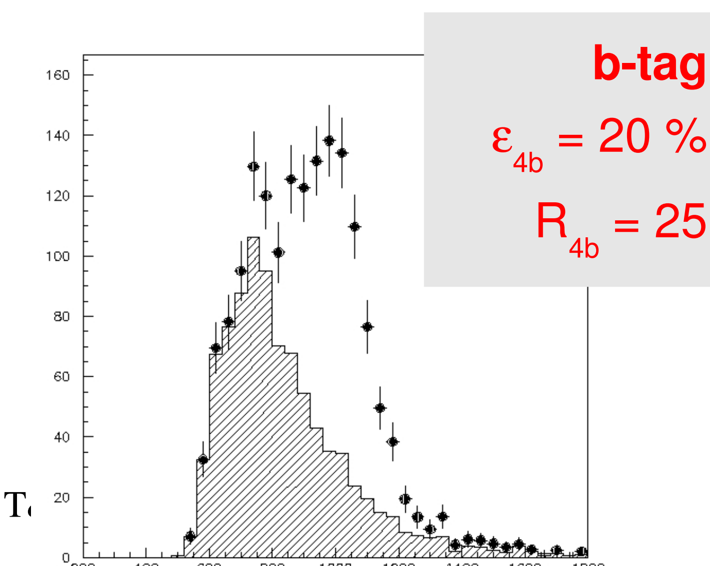
W_H (3 TeV/c^2) → Tb → 4 b + l + E_t^{miss}



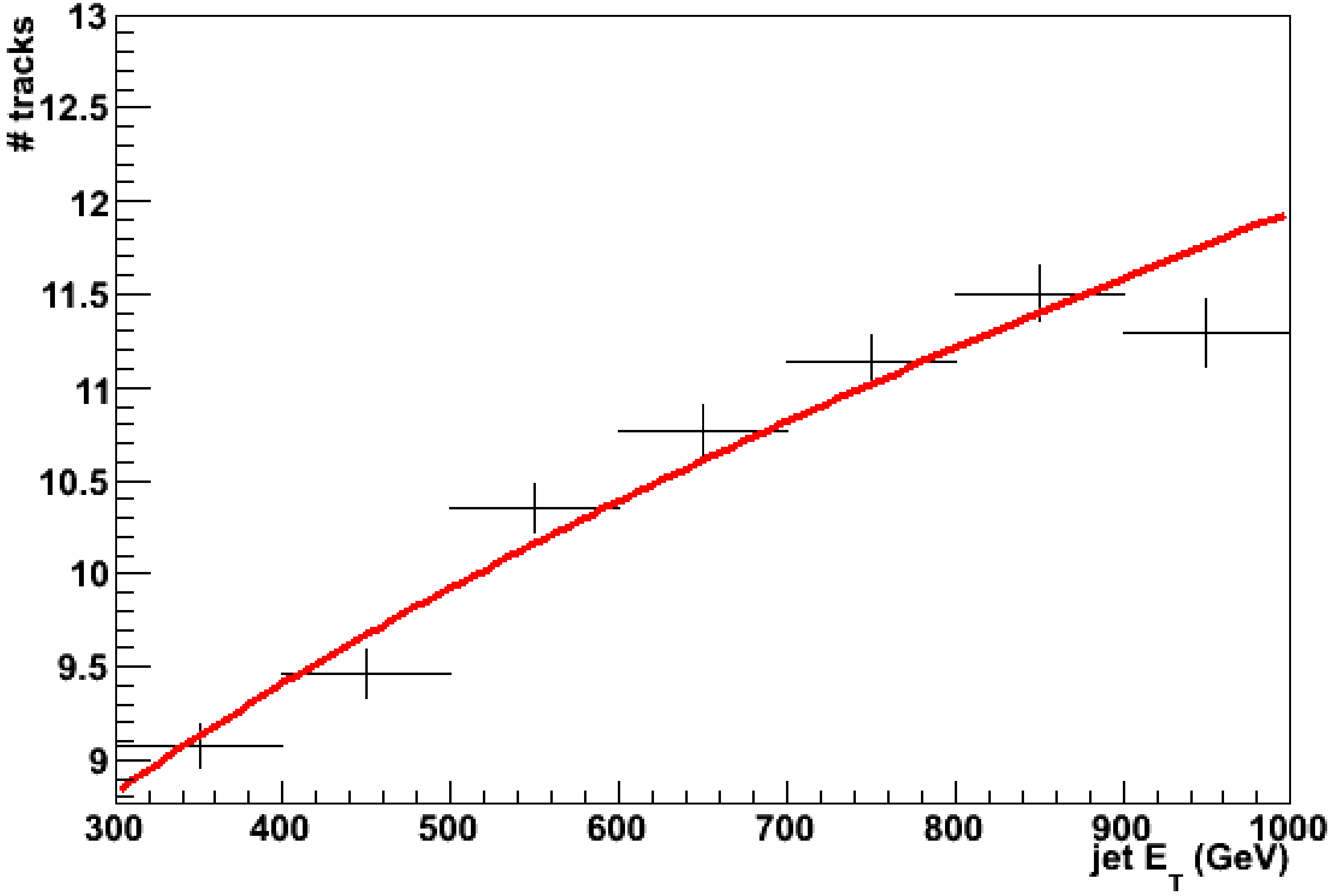
existing studies

uncharted territory





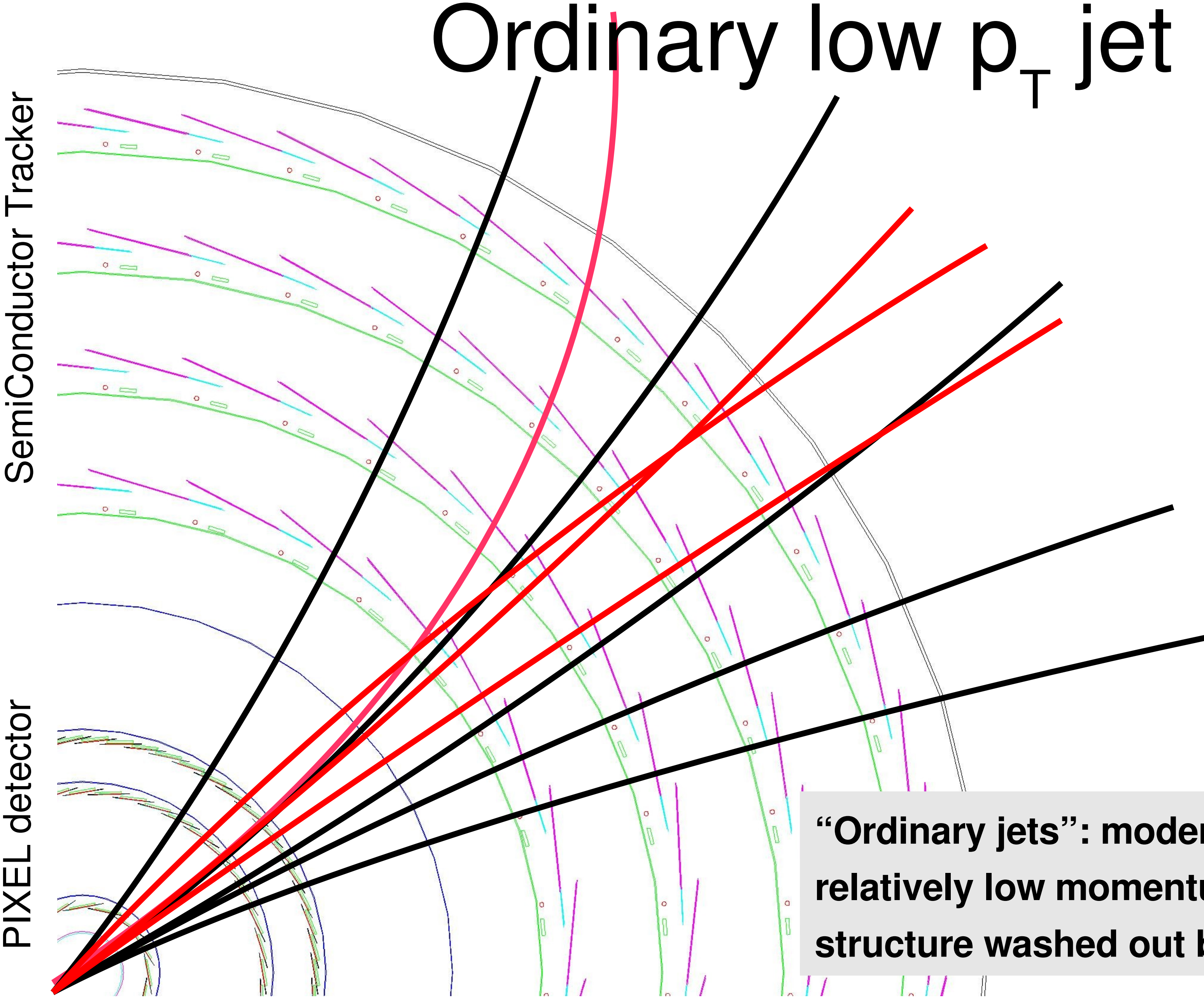
High p_T jets: charged multiplicity in cone



Number of tracks in b-jet (core) increases with jet E_T

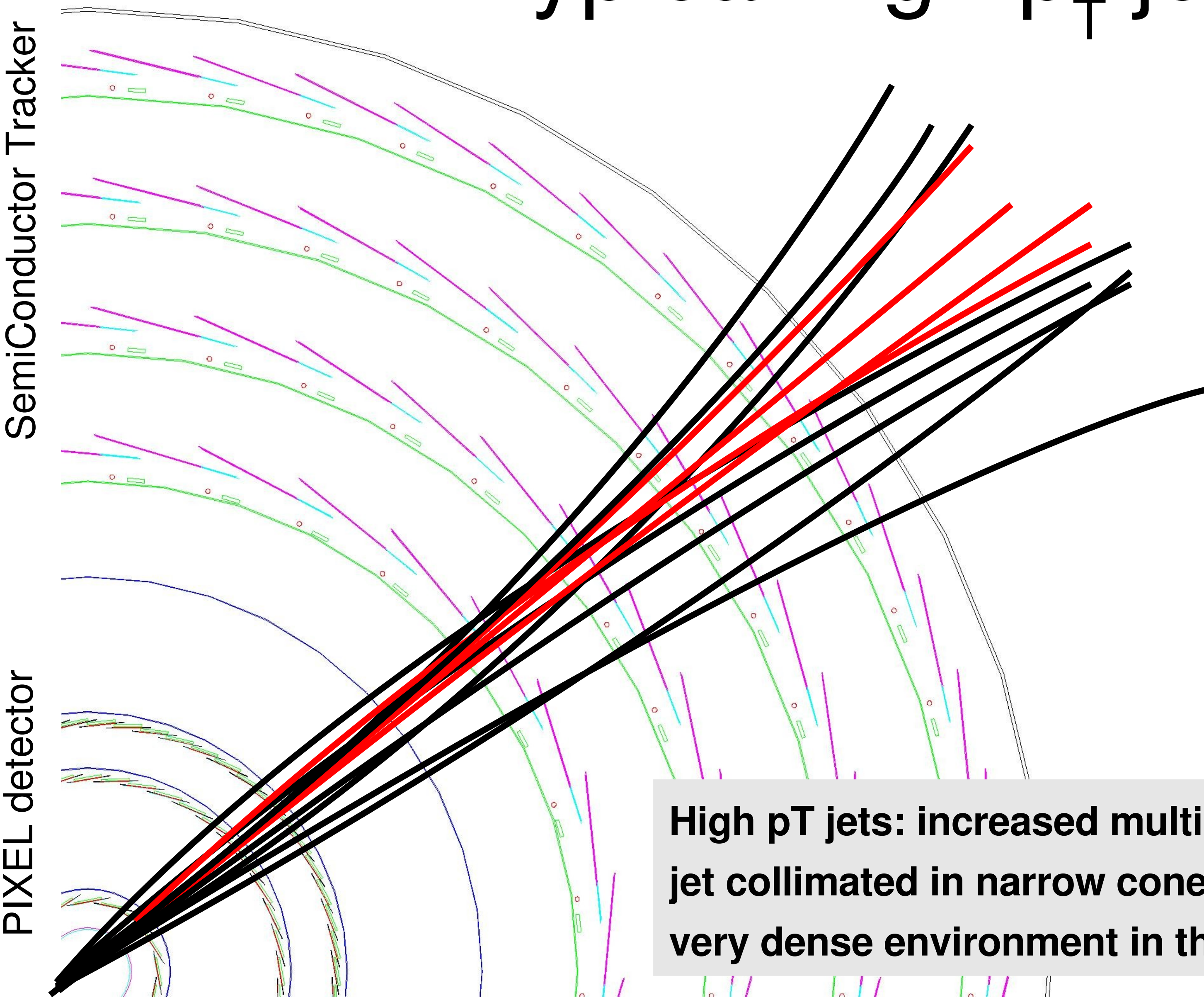
 # tracks from B-decay = constant: relative weight tracks from B-decay decreases

Ordinary low p_T jet



"Ordinary jets": moderate multiplicity of relatively low momentum tracks. Jet structure washed out by magnetic field.

Typical high p_T jet



High pT jets: increased multiplicity, stiffer tracks, jet collimated in narrow cone. All this contributes to very dense environment in the jet core.

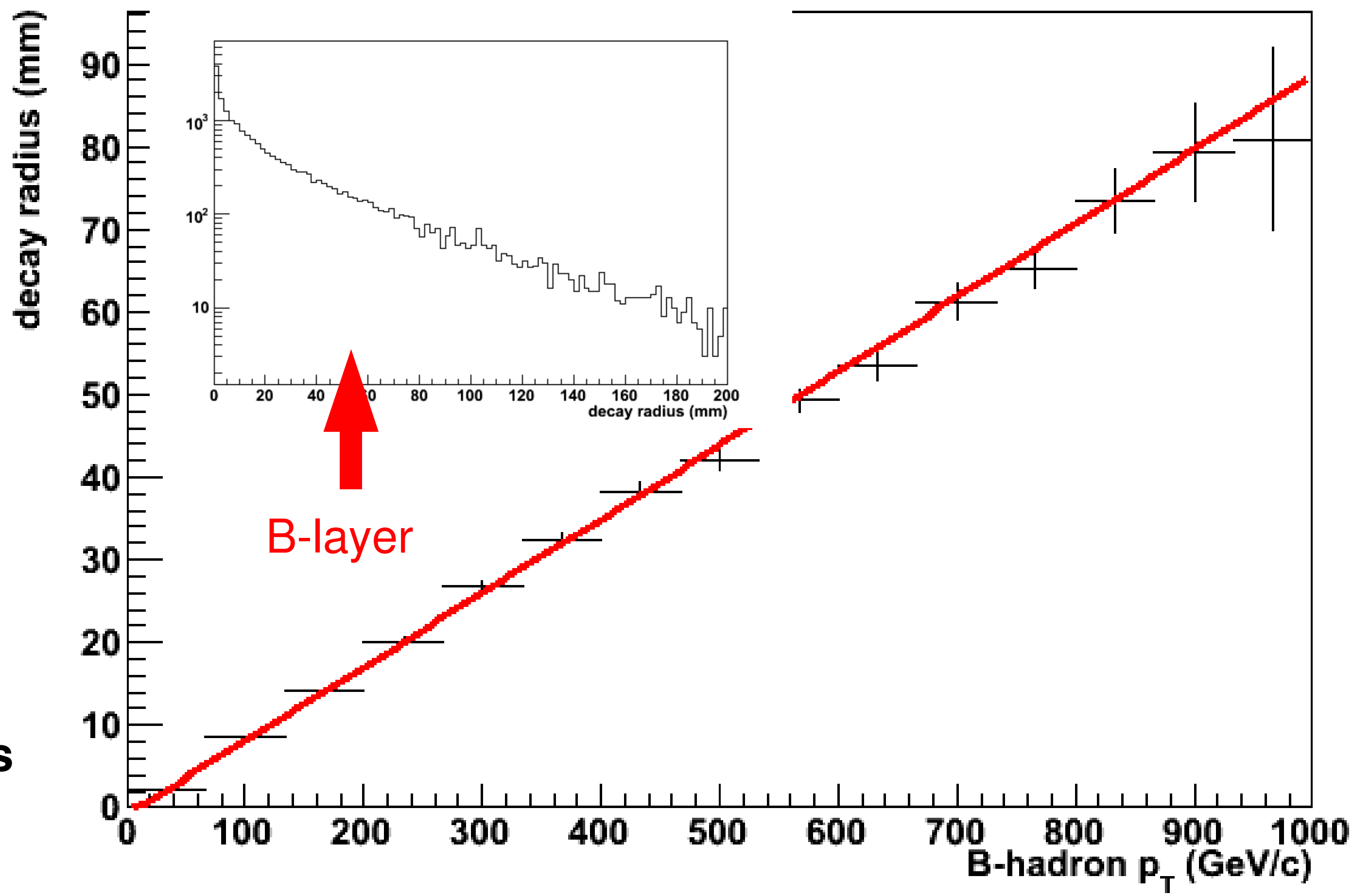
High p_T b-jets: displaced vertex

$L = c\,\tau\,\gamma$

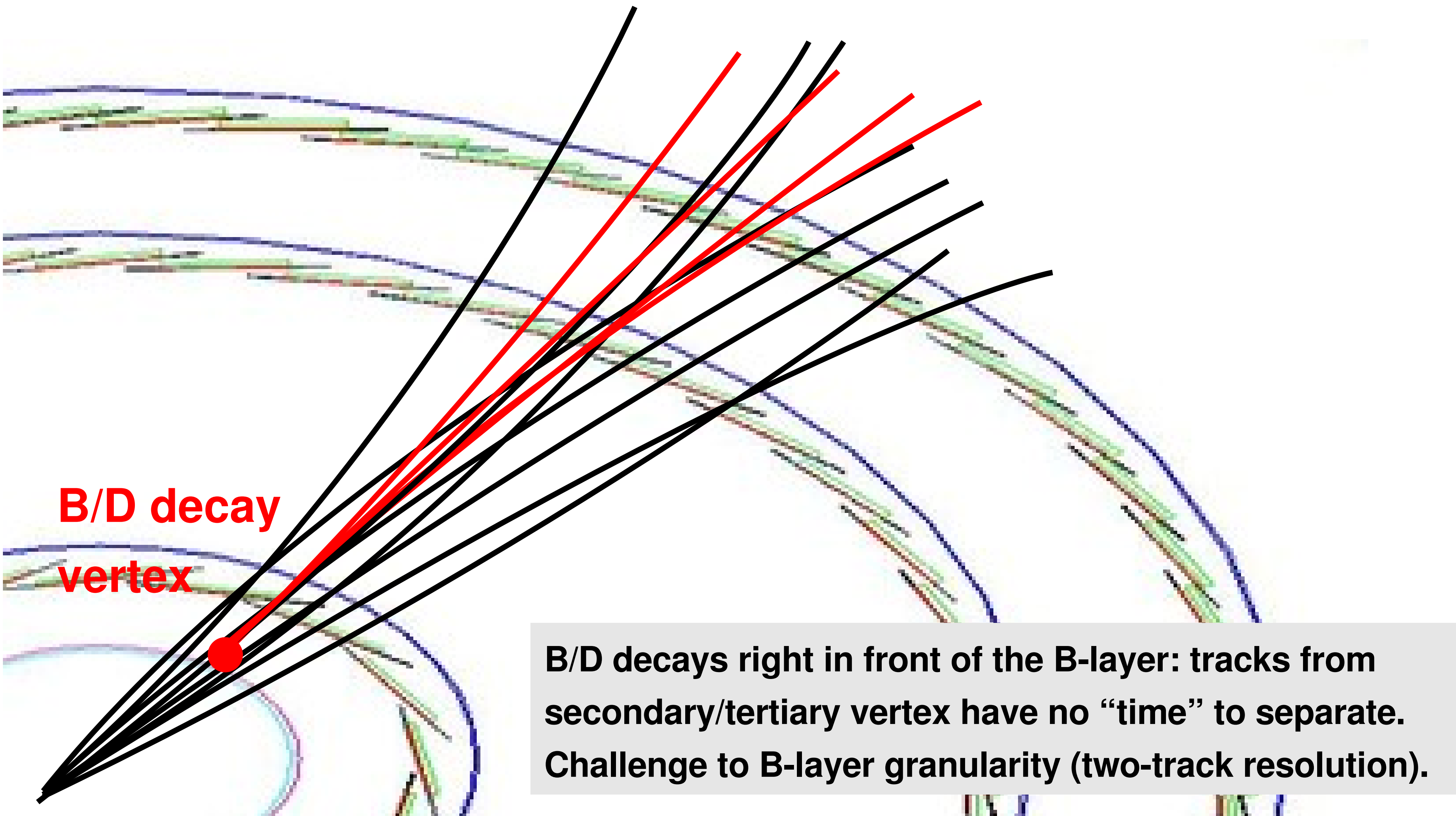
Average decay radius of B hadrons versus B-hadron transverse momentum

Insert plot: decay radius distribution for B-hadrons in Z'->bb events ($m_{Z'}$ = 2 TeV)

L no longer << B-layer radius

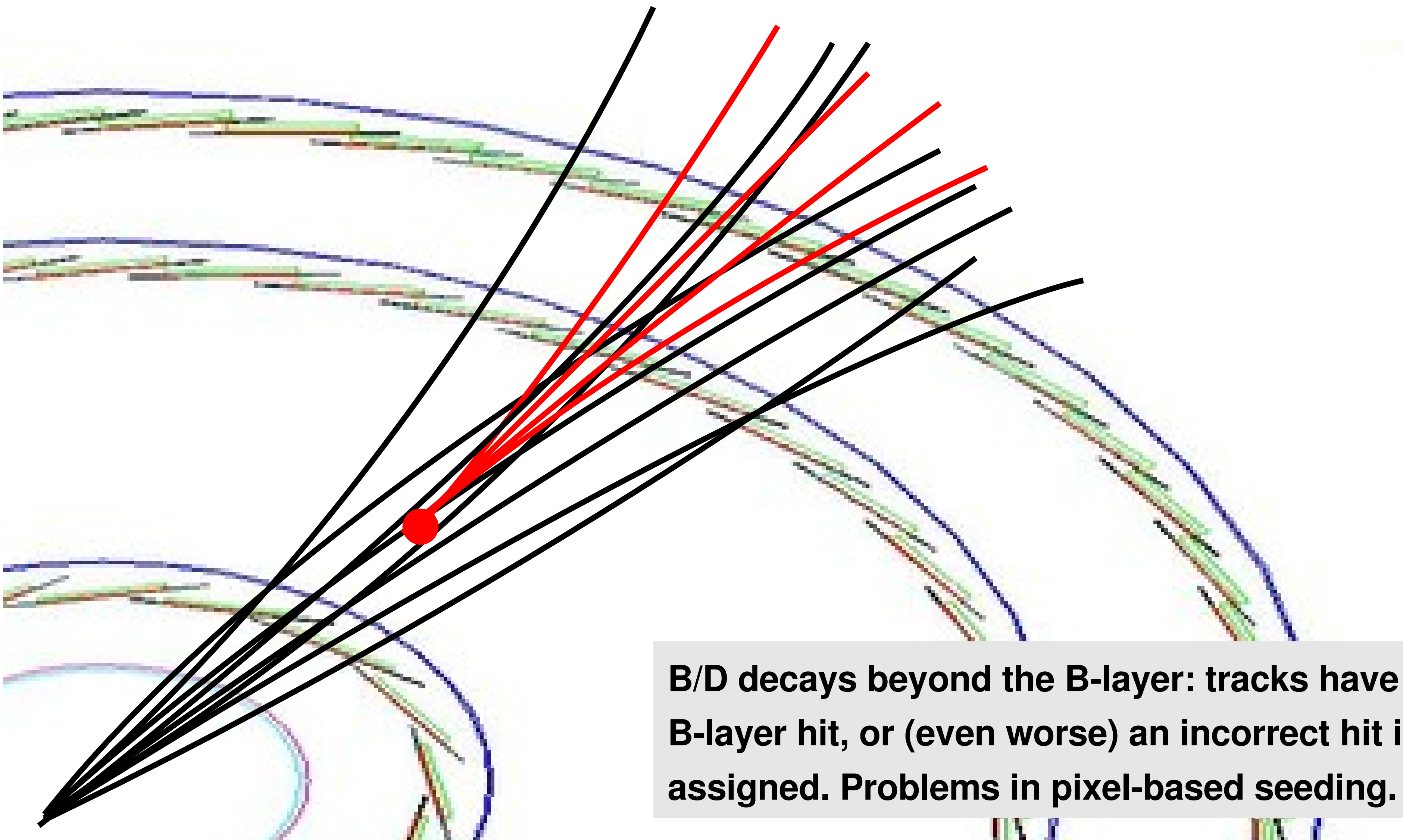


high p_T b-jet: zoom on innermost layers



B/D decays right in front of the B-layer: tracks from secondary/tertiary vertex have no "time" to separate. Challenge to B-layer granularity (two-track resolution).

high p_T b-jet: zoom on innermost layers



B/D decays beyond the B-layer: tracks have no B-layer hit, or (even worse) an incorrect hit is assigned. Problems in pixel-based seeding.

high p_T b-tagging performance: Samples

Z_H → **(2 Tev)**

b b	**20000 events**
u u	**20000 events**
c c	**20000 events**

Private production, validated against small official samples

ATHENA release 10.0.1 - Rome Final Layout geometry

ATHENA release 12.0.6 - ATLAS-CSC-01-02

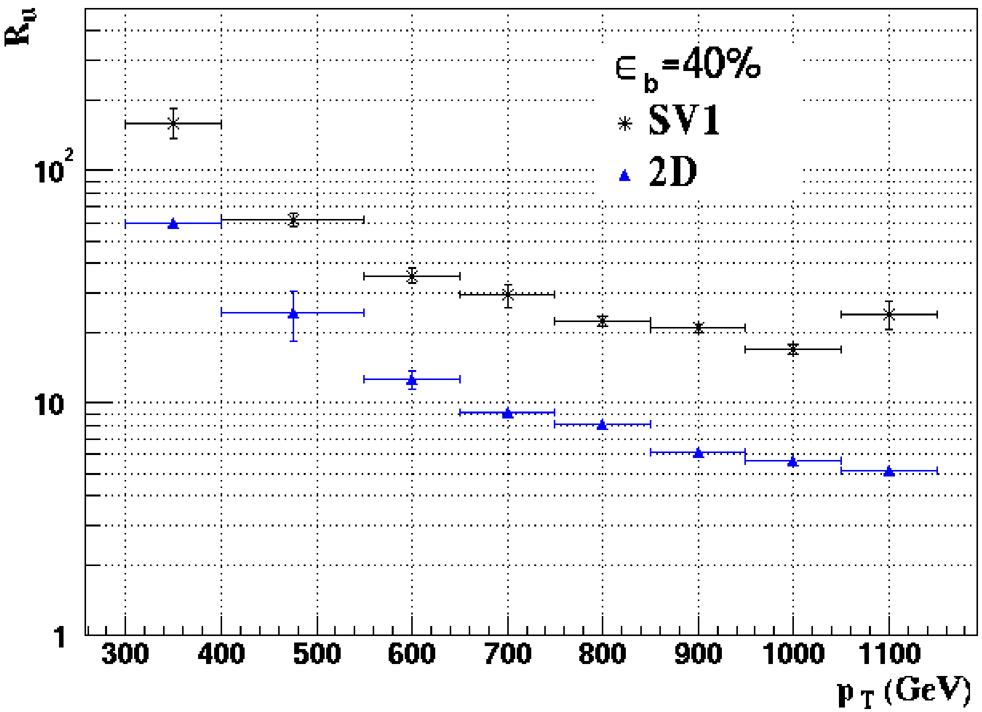
ESD, AOD → **IP2D, SV1 algorithms available**

Performance: 1 1/2 years ago

p_T dependence on Rome samples (SV1 versus 2D)

ATHENA 10.0.1,
Rome layout
Standard ATLAS
b-tagging algorithms,
no retuning,
no re-calibration

L. March et al.



30/05/2006 L. March 9

Performance: 2 months ago

(SV1 versus 2D)

ATHENA 12.0.6

ATLAS-CSC-01-02:

increased realism (material)

Evolution in software from

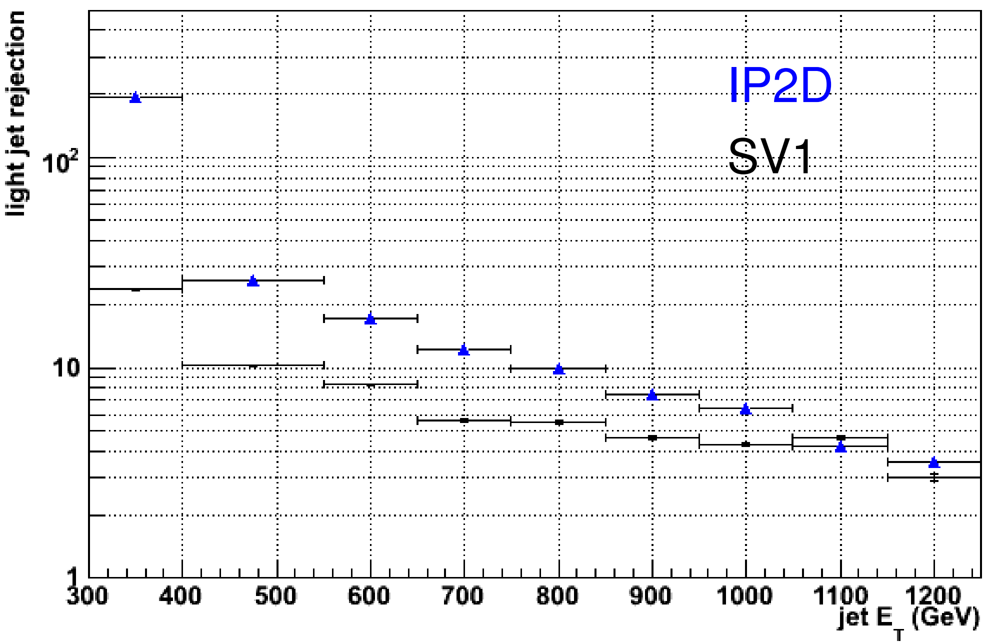
10.0.1 to 12.0.6_01

Standard ATLAS

b-tagging algorithms,

no retuning,

no re-calibration

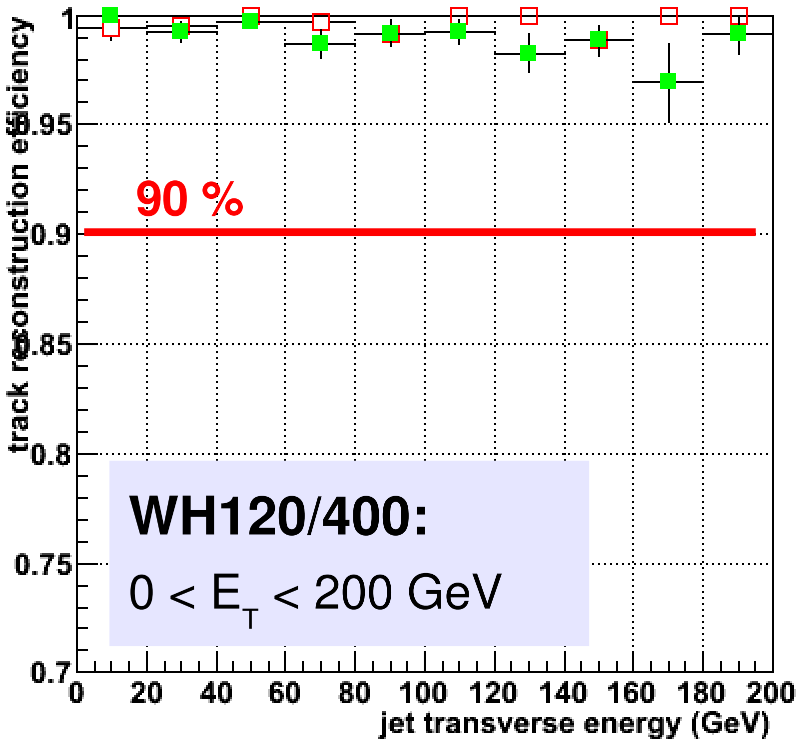


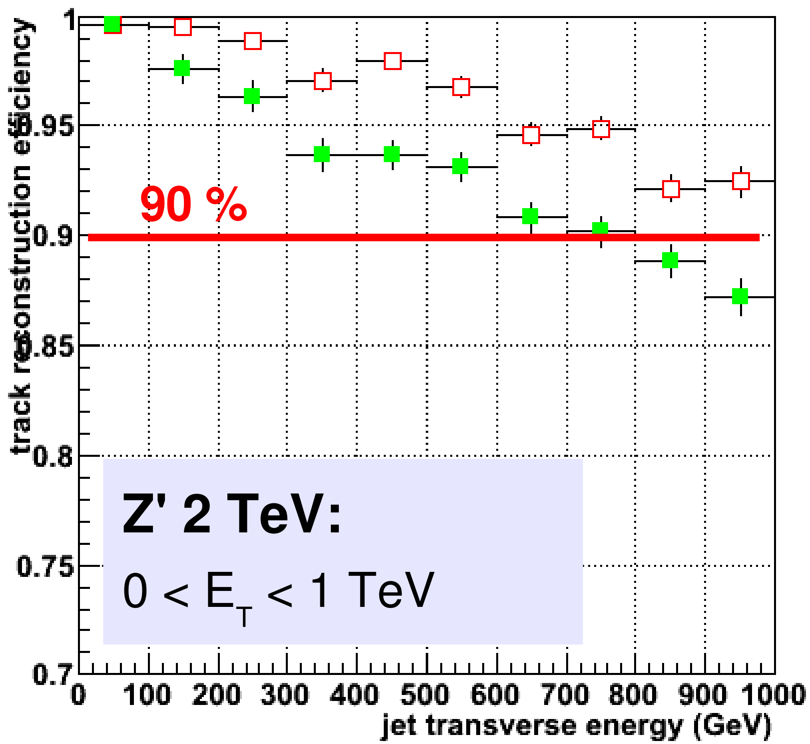
The bad news: SV1 performance dramatically degraded with respect to "Rome"

NOTE: SV1 not intended for stand-alone use

Tracking in high p_T jets I : prompt tracks

$\pi^{\pm}$ with no decay, and R_{vtx} < 10 mm





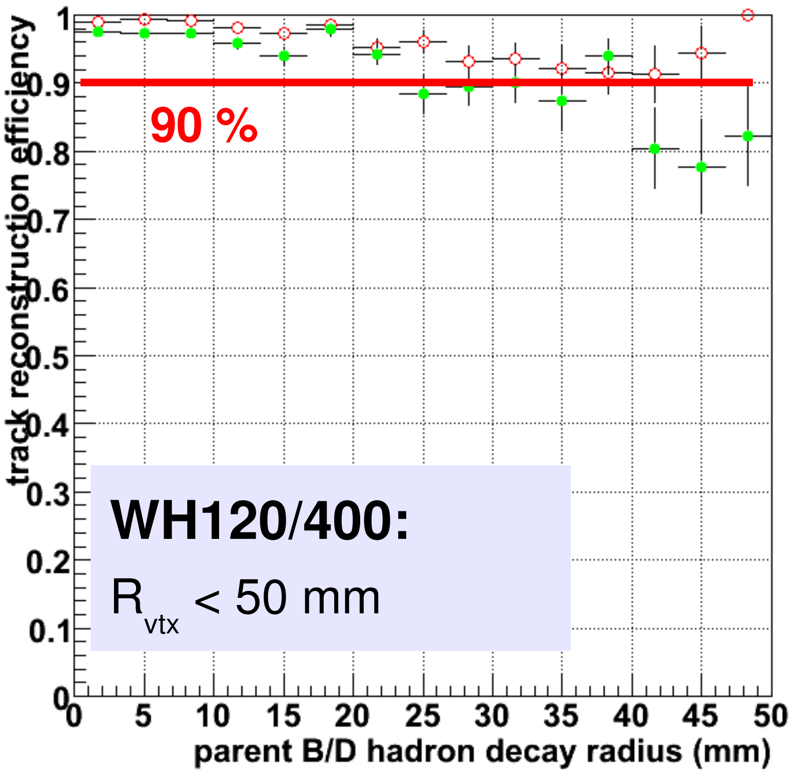
Reconstruction efficiency for "good tracks" from InvertedTruthMap (A. Gaponenko)

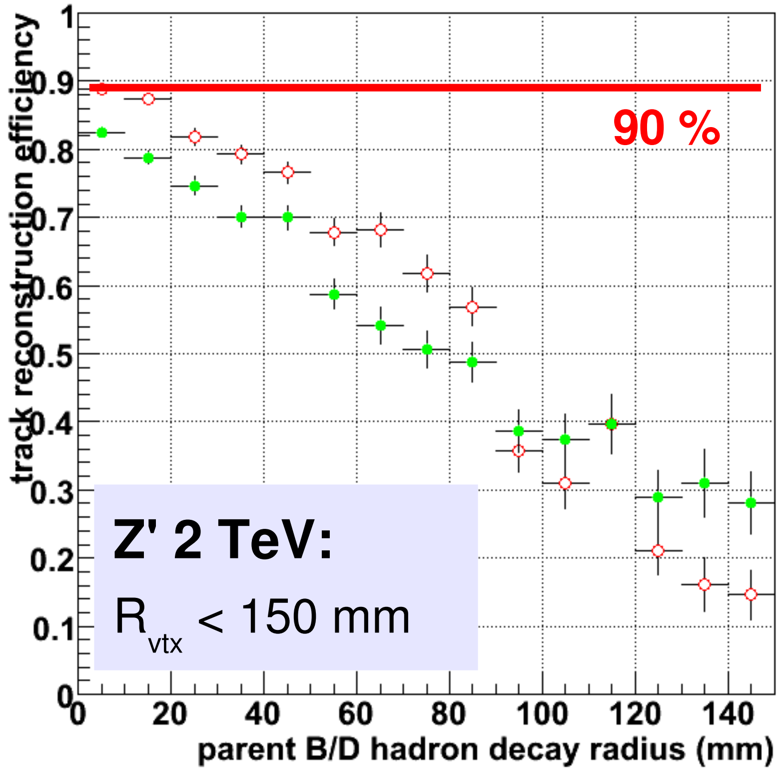
Efficiency >90% inside highest p_T jets!

IpatRec (red) performs slightly better than New Tracking (green)

Tracking in high p_T jets II : displaced vertices

$\pi^{\pm}$ with no decay, $|R_{vtx} - R_{B\text{-}decay}| < 10$ mm

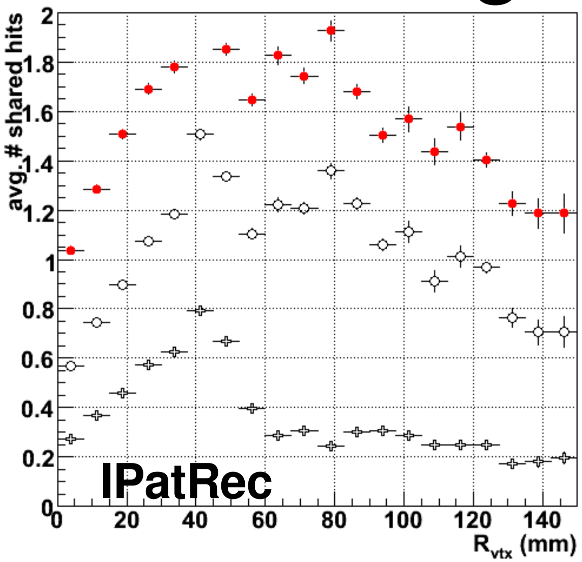


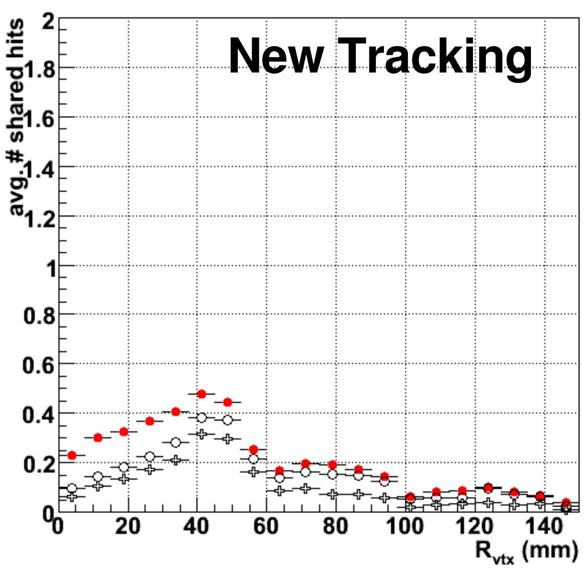


Tracks from displaced vertices present a real challenge!

IpatRec (red) performs slightly better than New Tracking (green)

Tracking in high p_T jets III – track quality





The sharing of hits becomes inevitable in dense jet cores, especially in case of displaced vertices

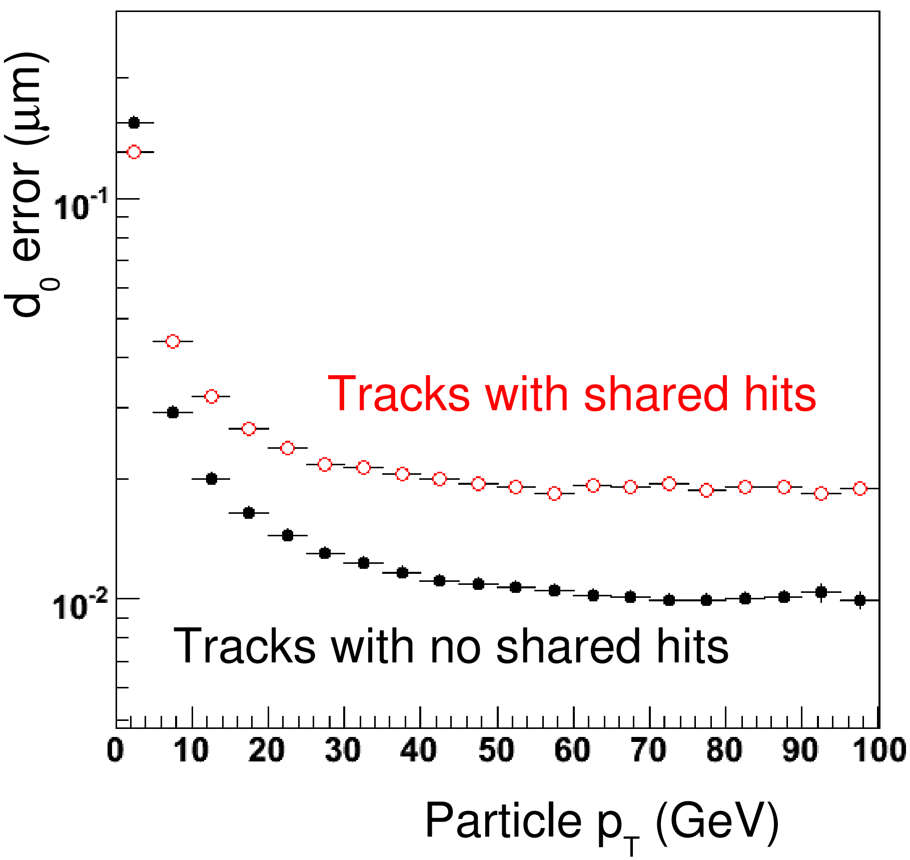
Situation dealt with quite differently by IpatRec and New Tracking

Considering only efficient tracks from B/D decay, count number of shared hits per track

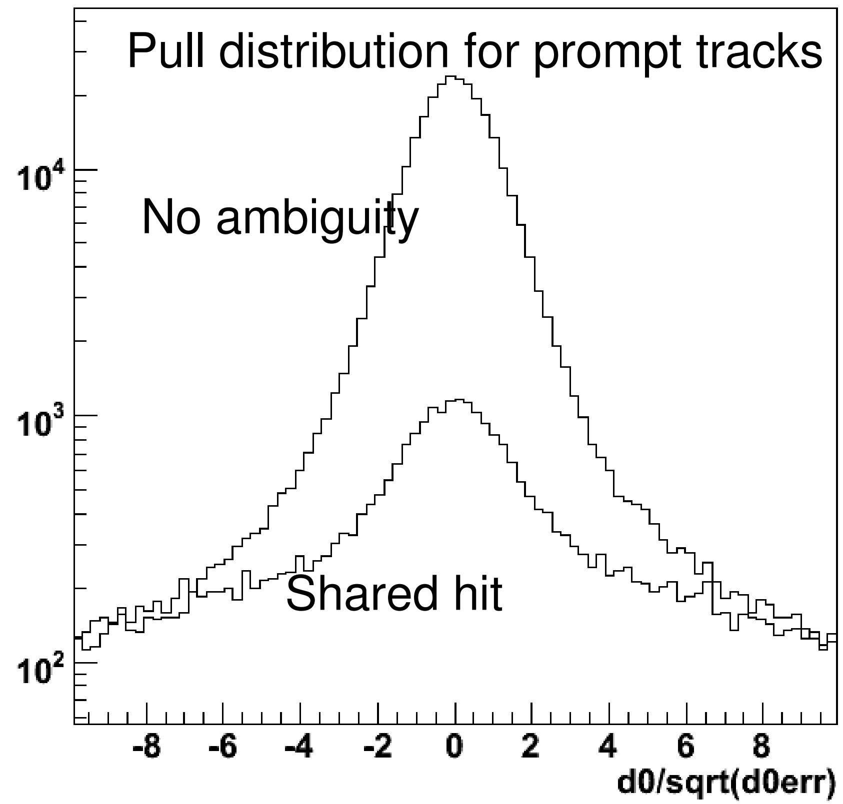
- **total # shared hits**
- **# shared in pixel detector**
- **# shared hits in B-layer**

useful interactions with ID software group

High p_T b-tagging – shared hits



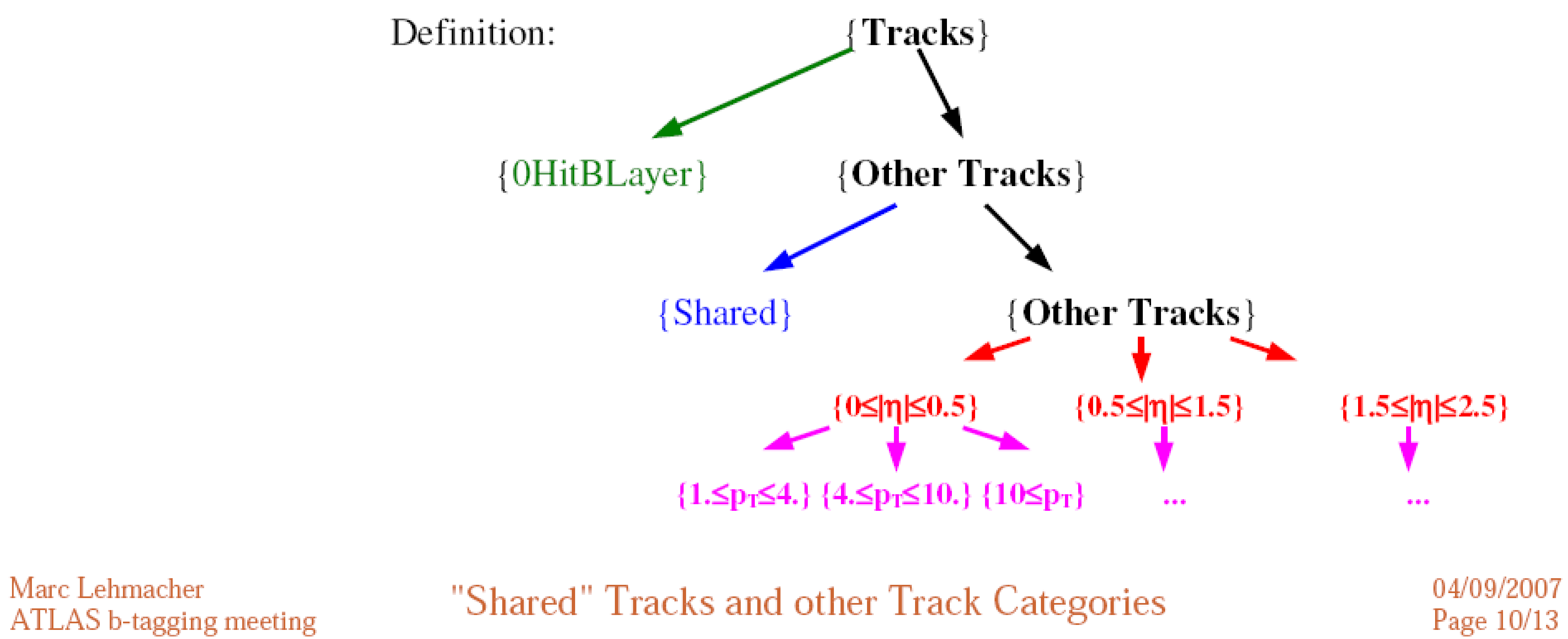
Tracks with shared hits (in the B-layer) provide a less precise measurement of the impact parameter



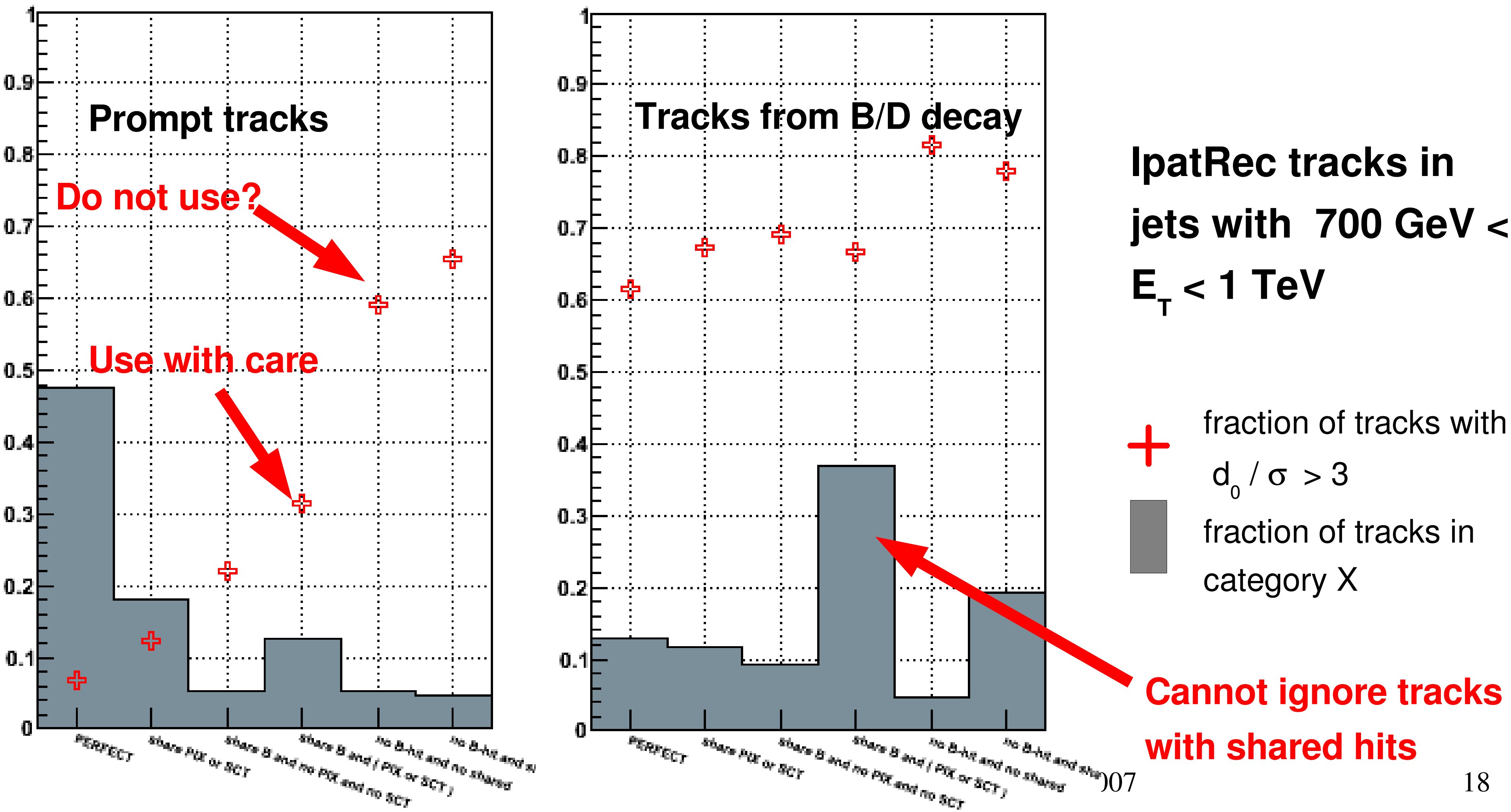
More importantly, tracks with shared hits are less reliable (much more pronounced "tails")

High p_T b-tagging

IPXD B-tagging algorithms deal with variable track quality by introducing categories with their own signed significance PDFs (M. Lehmacher)



High p_T b-tagging



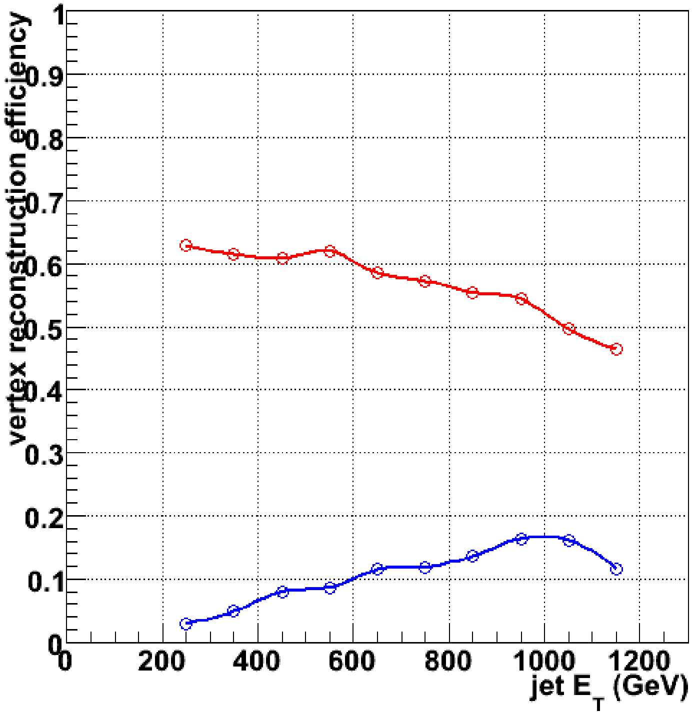
IpatRec tracks in jets with 700 GeV < E_T < 1 TeV

fraction of tracks with $d_0 / \sigma > 3$

fraction of tracks in category X

vertexing in high p_T jets

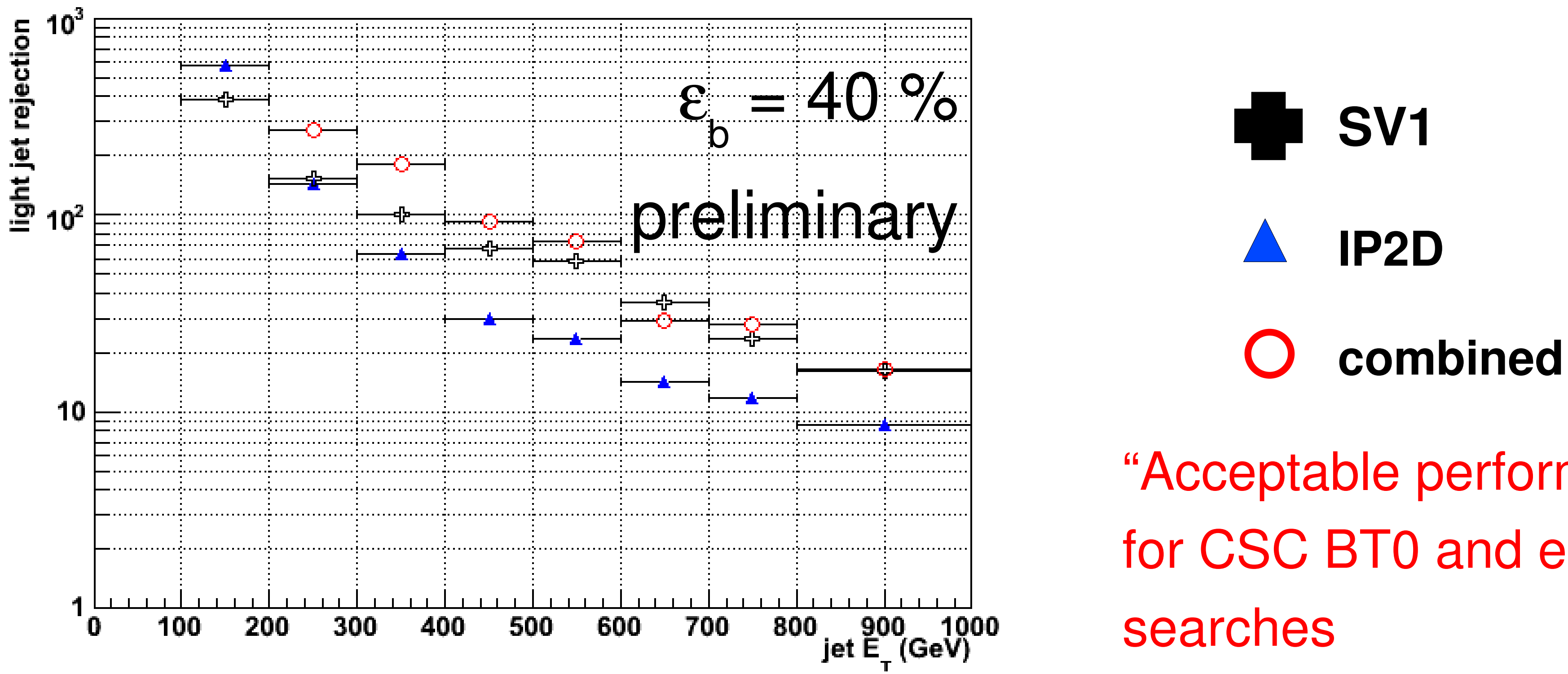
VkalVrt and JetFinder: very active support from Vadim Kostyukhine and Giacinto Piacquadio



VkalVrt: Vertex reconstruction efficiency in b-jets and light jets

Efficiency decreases, fakes increase with jet p_T

b-tagging in high p_T jets



"Acceptable performance" for CSC BT0 and exotics searches

Retune SV1 and IP2D algorithms to deal with high pT jets:

- **IpatRec tracks**
- **jet-track association Δ R**
- **minimal track p_T**
- **shared hits**
- **B-layer hit**
- **same PDFs!**

Conclusions

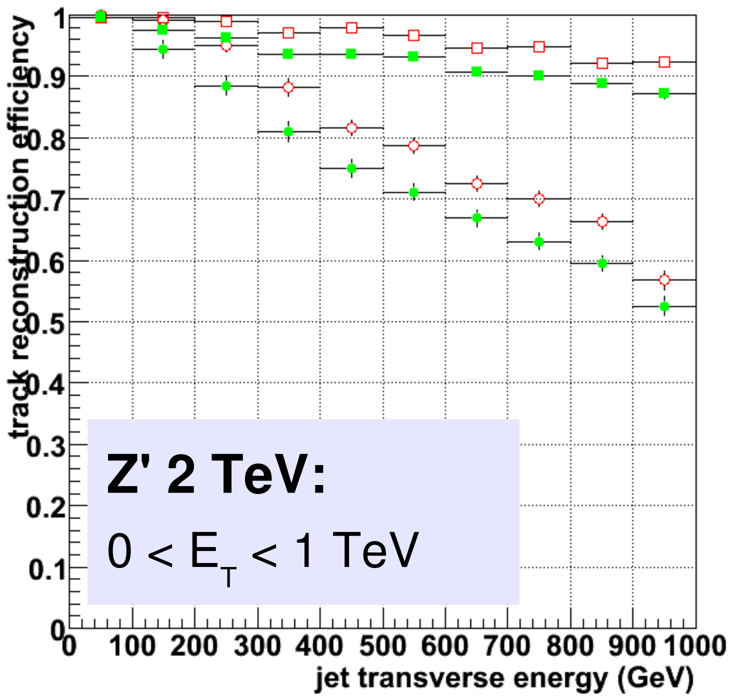
Actively investigating the b-tagging, vertexing and tracking performance in high p_T jets

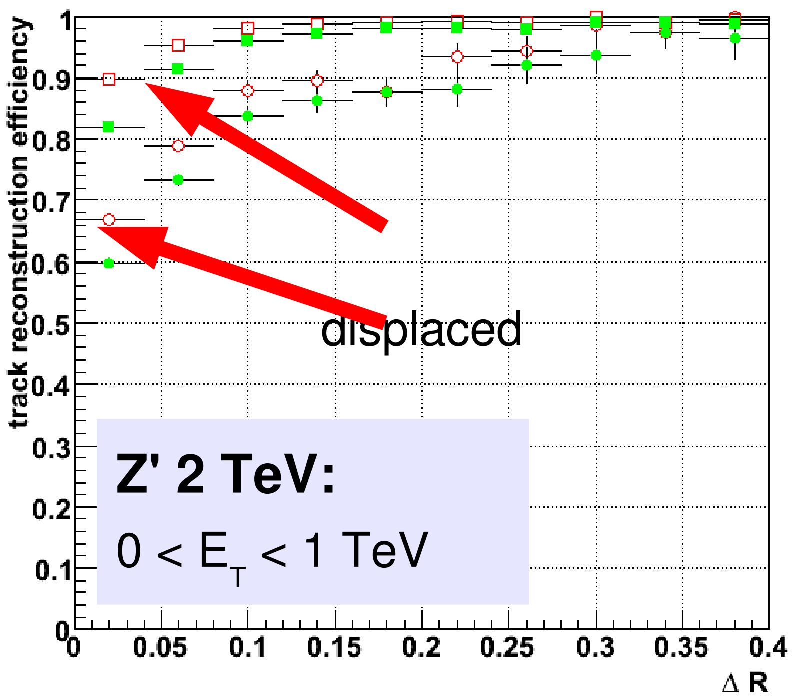
- tracking algorithms (shared hits)
- pixel clustering (with A. Rozanov, T. Lari)
- treatment of low-quality track categories (M. Lehmacher)
- vertexing (with V. Kostyukhin)

Reoptimized standard algorithms (with standard calibration) can provide “acceptable performance” over large p_T range

Tracking in high p_T jets III : displaced vertices

$\pi^{\pm}$ with no decay, prompt vs. displaced





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