On Flavor Production in CMS

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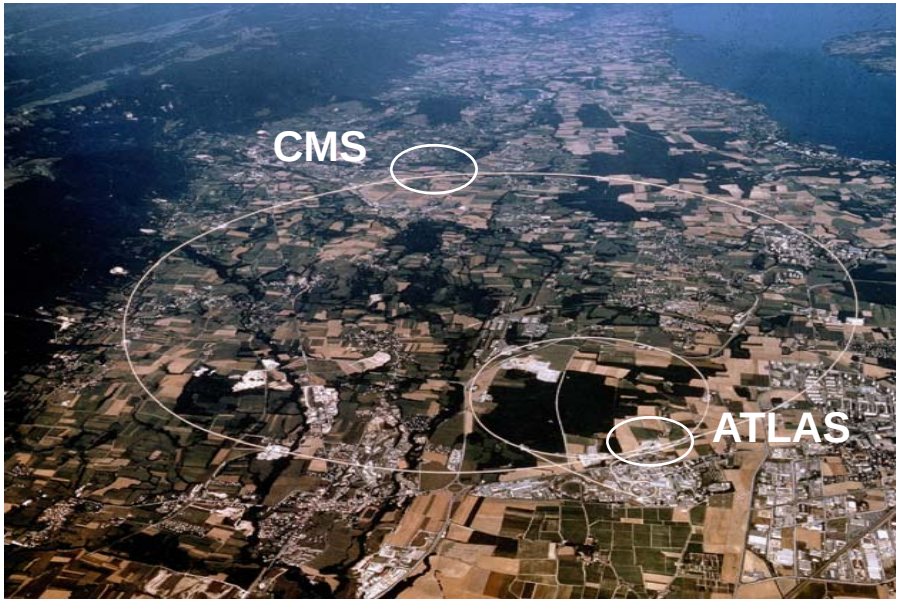
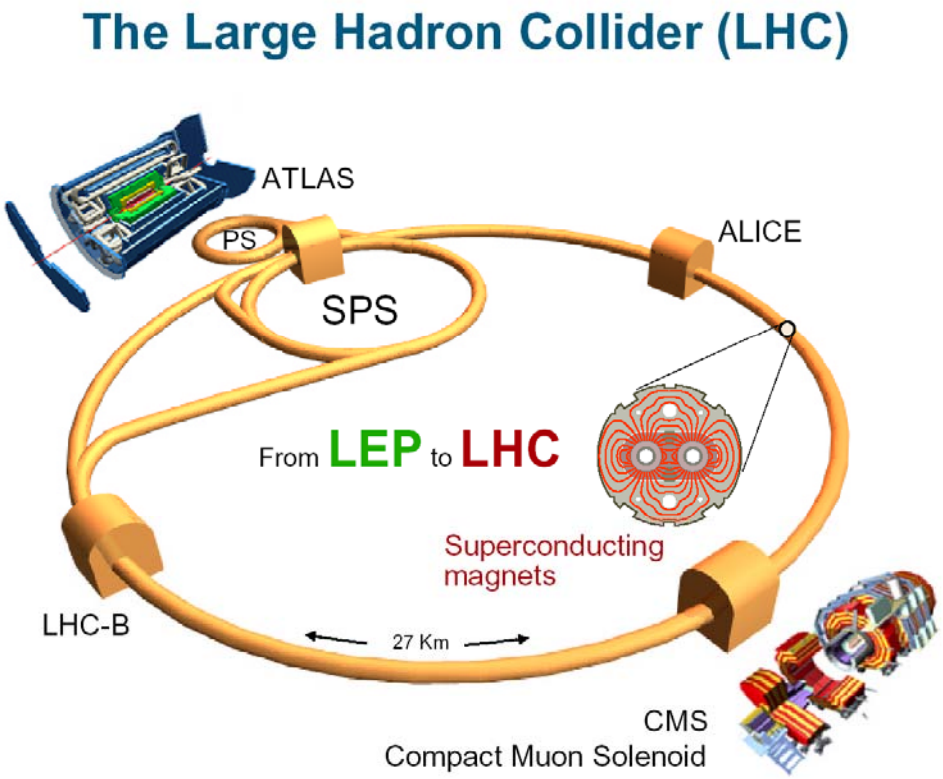
Outline

- **Introduction**
- **Vertex reconstruction in CMS**
- **Inclusive *b* production in CMS**
- **Conclusions / Outlook**

Large Hadron Collider (LHC)





- Design luminosity L = $10^{34}cm^{-1}s^{-1}$
  ~ 100 fb^{-1}/ year
  Pile up ~ 20 collisions/crossing
  40 MHz pp bunch-crossing rate
- Start-up luminosity L ≈ $10^{32}cm^{-1}s^{-1}$
  ⇒ ~ 1 fb^{-1}/ year
- expected completion : mid 2008

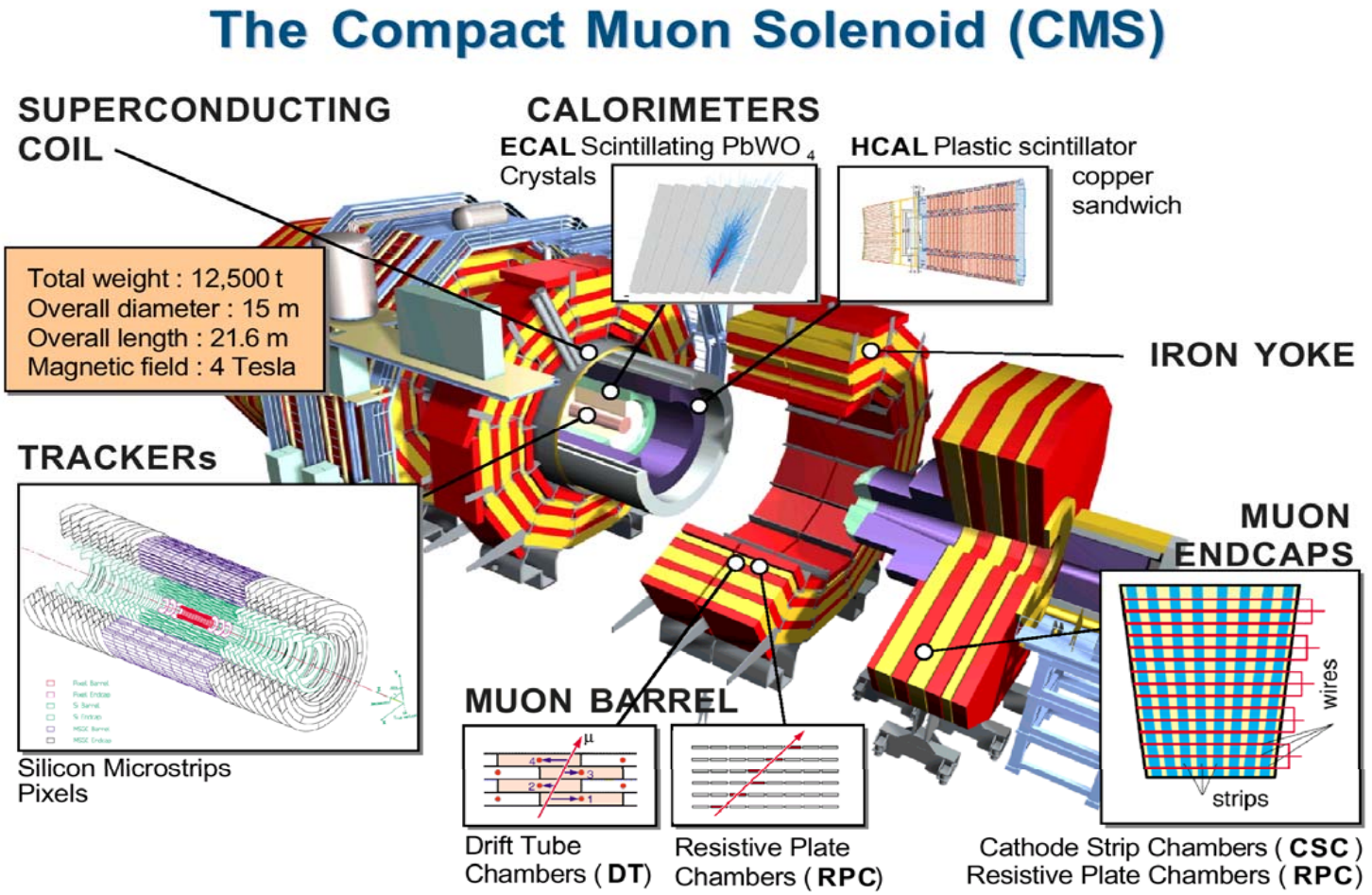
	Beams	Energy		Luminosity
LEP	e^+ e^-	200	GeV	$10^{32}\,cm^{-2}s^{-1}$
LHC	p p	14	TeV	$10^{34}\,cm^{-2}s^{-1}$
	Pb Pb	1312	TeV	$10^{27}\,cm^{-2}s^{-1}$

The CMS detector

General-purpose detector

From *in* to *out*:

- **Tracker**
- **Calorimeters**
- **Muon system**



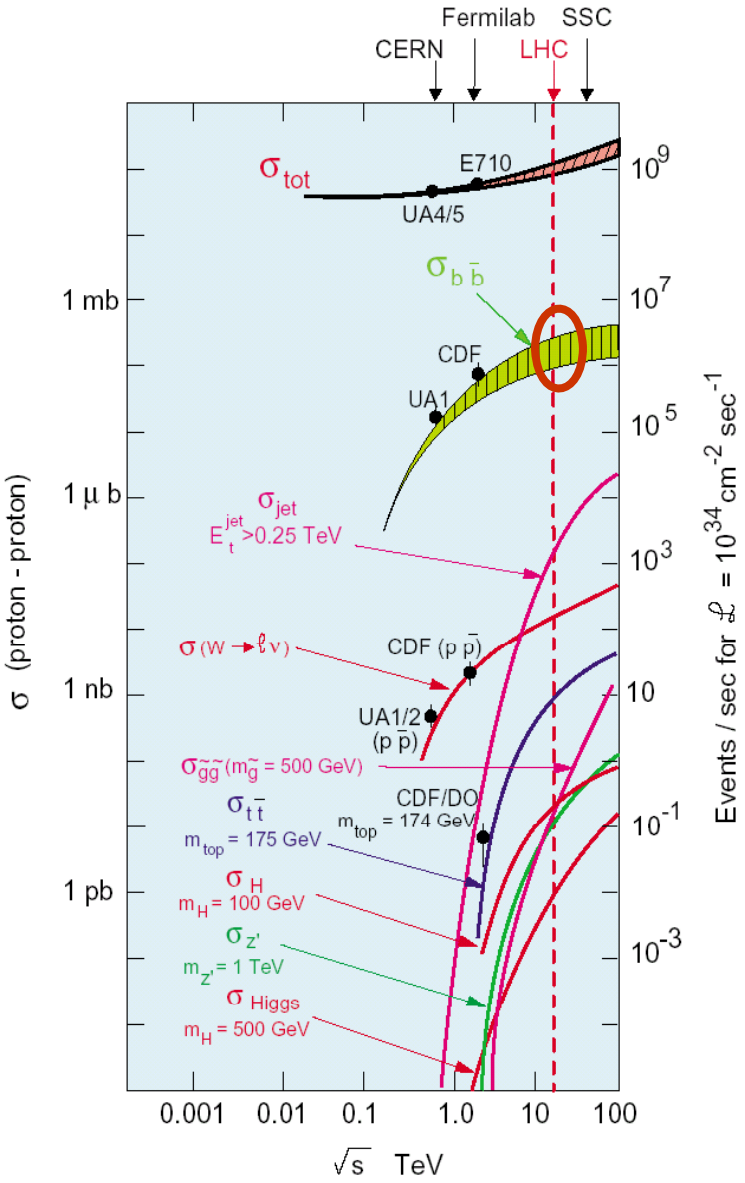
Precise

e, μ, γ, jets, E_T

Efficient

b tagging, τ detection

Beauty production



- ***b production*** at hadron colliders
  - **Huge cross section**
  - **Challenge for perturbative QCD**
  - **Standard model processes**
    - **b in decays of top, Z, …**
  - **New physics searches:**
    - **b jets as a signal feature**
      - **b in decays of Higgs, SUSY, …**
    - **b jets as a background**

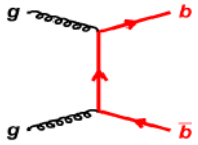
Inclusive *b* production / QCD aspects

- **present status of the production phenomenology at hadron colliders**
  - **The shape of transverse momentum and angular distributions as well as the azimuthal angular correlations in a reasonable agreement with perturbative QCD**
  - **The observed cross-sections are larger than QCD predictions**
  - **The agreement between experiment and theory has improved due to the evolution of latter (M.L. Mangano, hep-ph/0411020 and references therein), mostly a consequence of improved experimental inputs**
    - **More precise parton density function, up-to-date α_s**
    - **Proper fragmentation effects estimate**
  - **The agreement is not complete and the improvement of the phenomenological description requires new experimental input (LHC)**

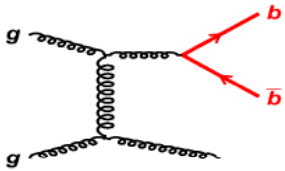
B production at LHC

PYTHIA MC prediction

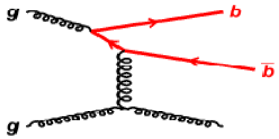
σ_{bb} = 465 μb (~ 500 μb)



Pair creation (LO) :
~50 μb



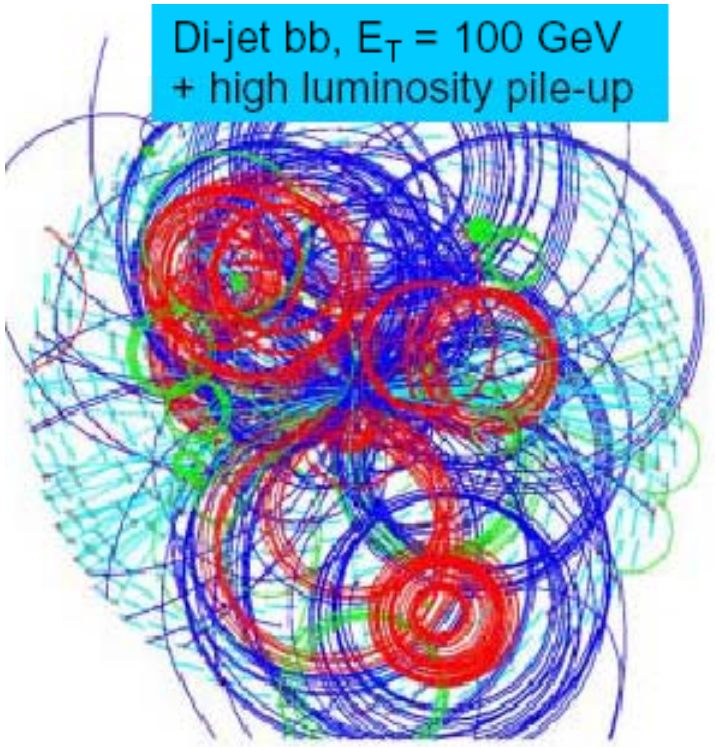
Gluon splitting (NLO) :
~190 μb



Flavor excitation (NLO) :
~220 μb

hep-ph/0003142

$\Delta\varphi_{bb}$ as discriminating variable

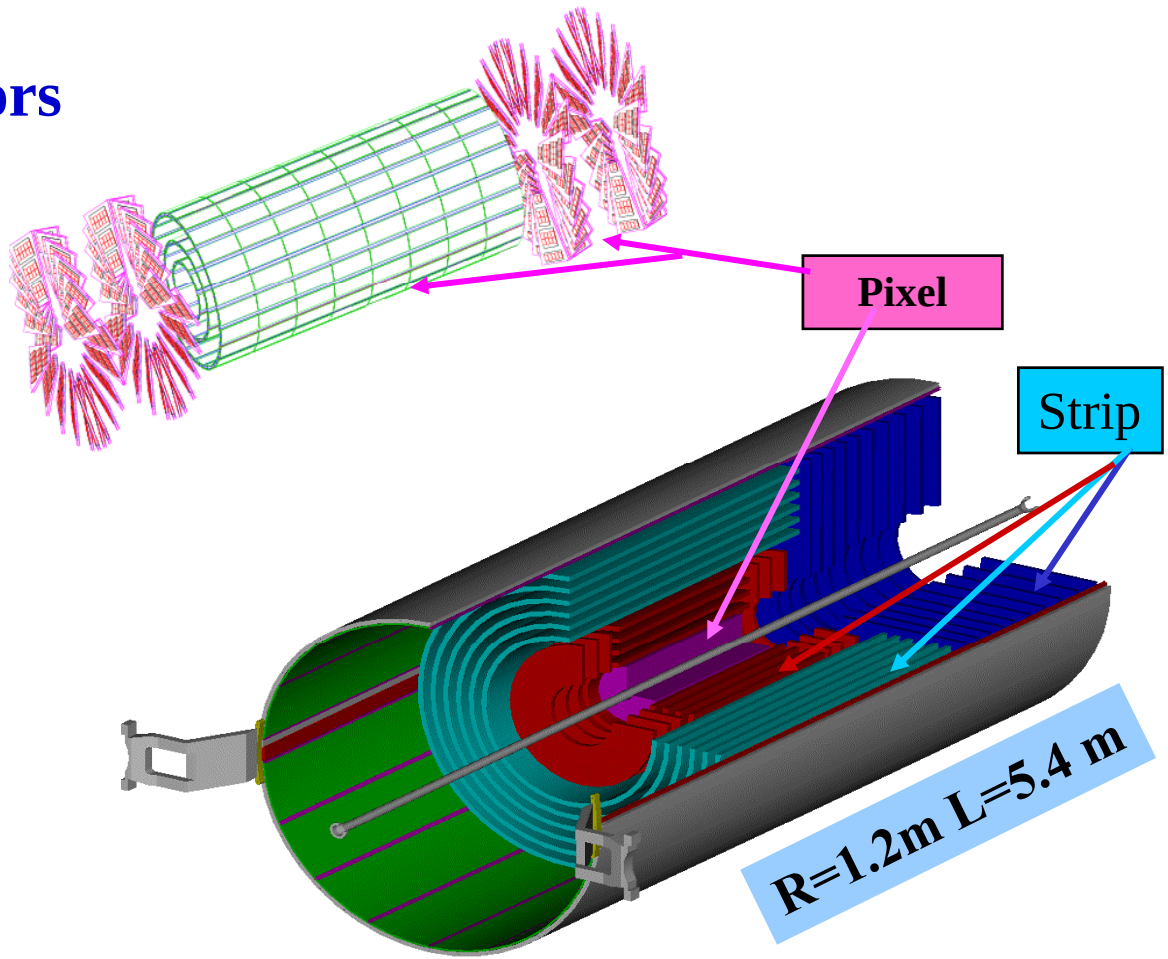


Excellent track impact parameter resolution is needed

CMS inner tracker (I)

All-silicon tracker:
> 220 m^2 of silicon sensors

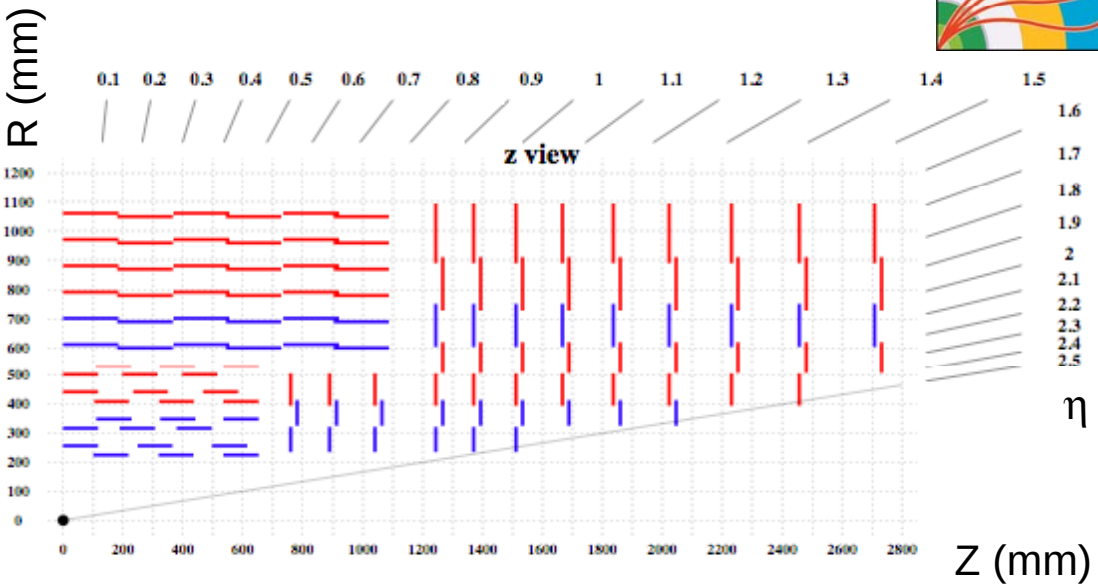
- **Pixel detector**
  - **pixel size 100μm x 150μm**
  - **hit resolution: 10 – 15 μm**
    - **Barrel**
      - **3 layers**
      - **R = 4.4 - 10.2 cm**
      - **48 M pixels**
    - **Endcaps**
      - **2 layers**
      - **|z| = 34.5 / 46.5 cm**
      - **18 M pixels**
      - **Tilted for Lorentz angle**



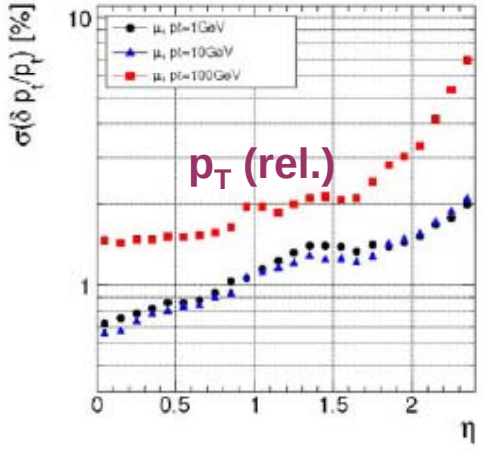
CMS inner tracker (II)

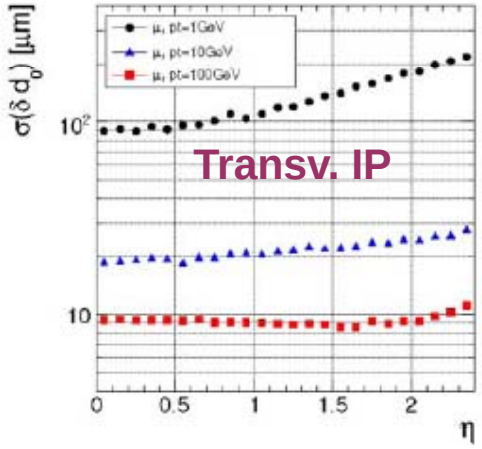
All-silicon tracker:
> 220 m^2 of silicon sensors

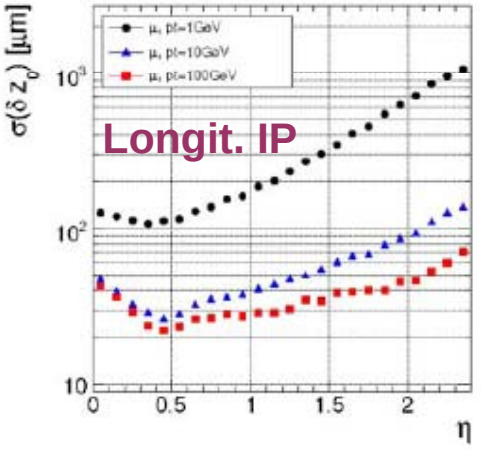
- **Silicon Strip detector**
  - **10 – 15 points**



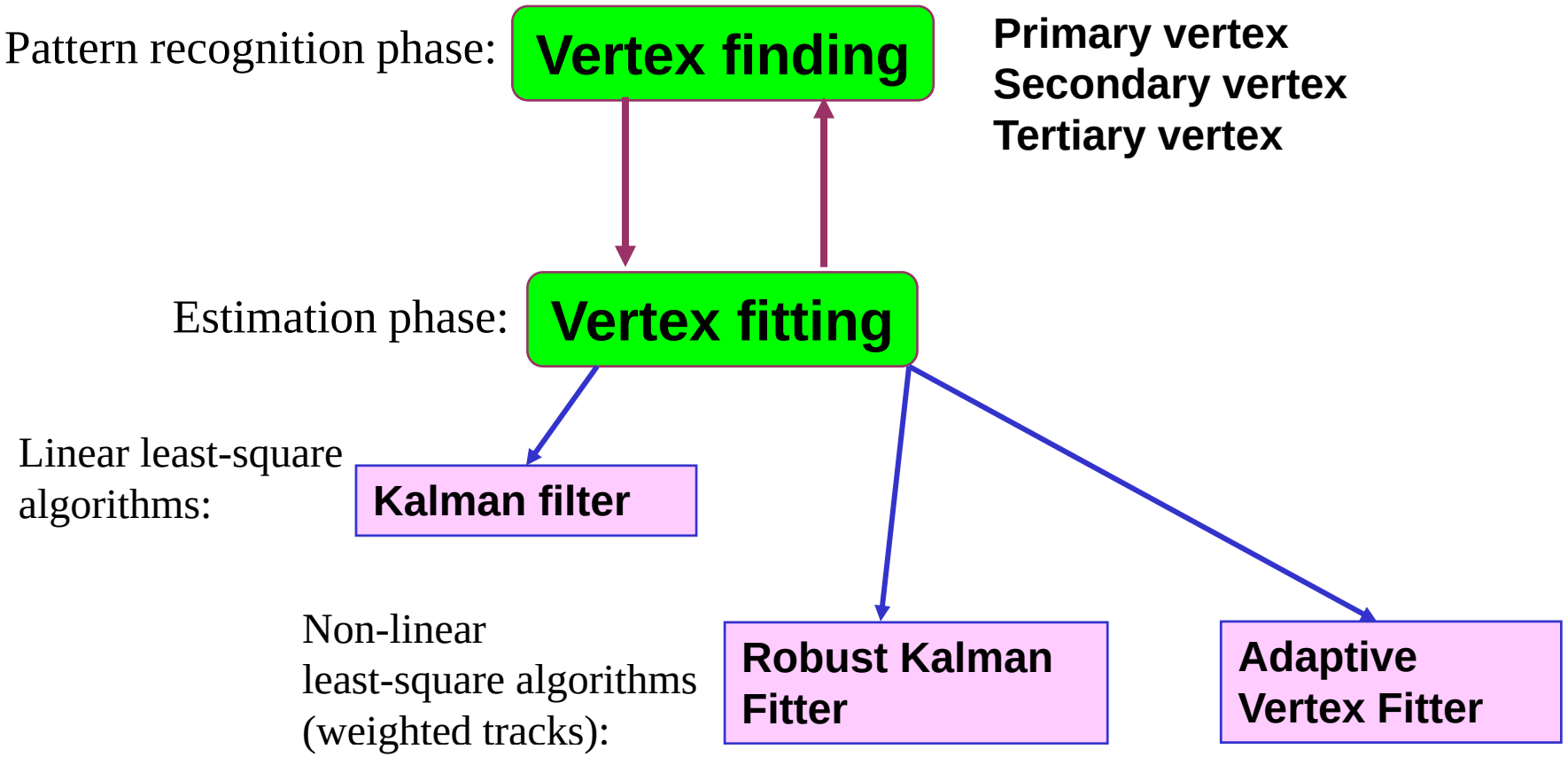
Track resolution:







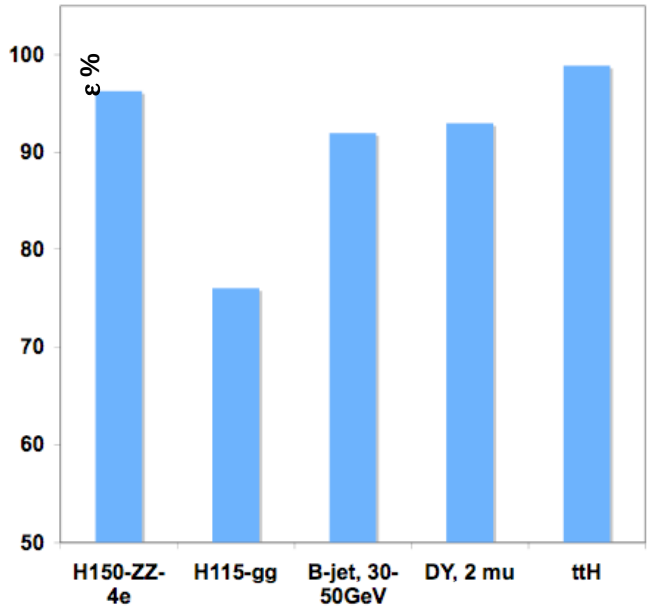
CMS Vertex Reconstruction



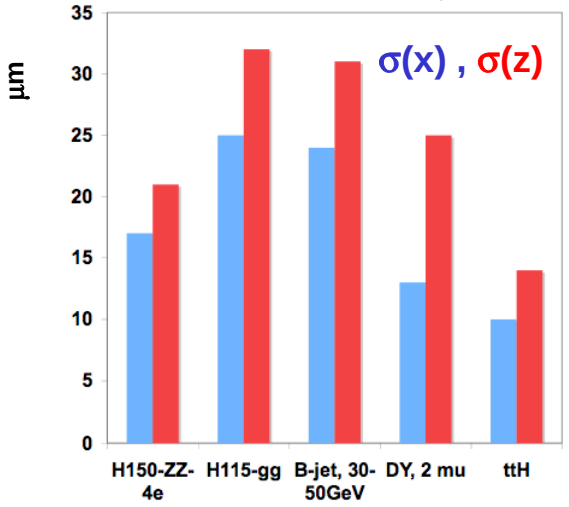
Primary Vertex finding

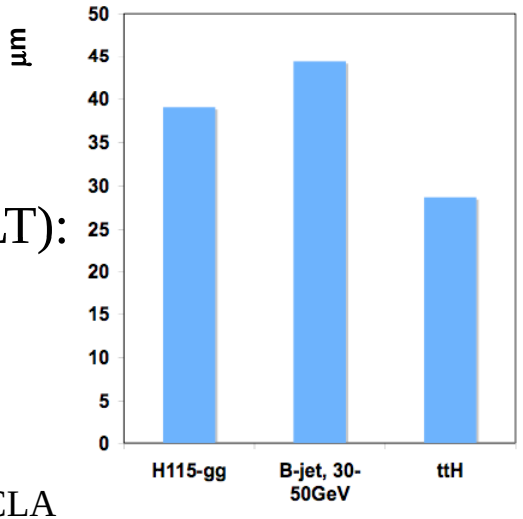
W. Adam – Vertex06

Efficiency for finding PV



PV resolution (μm)





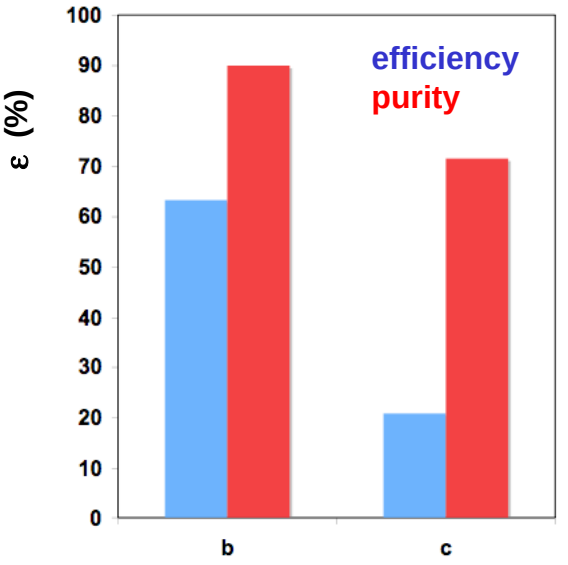
At trigger Level (HLT):

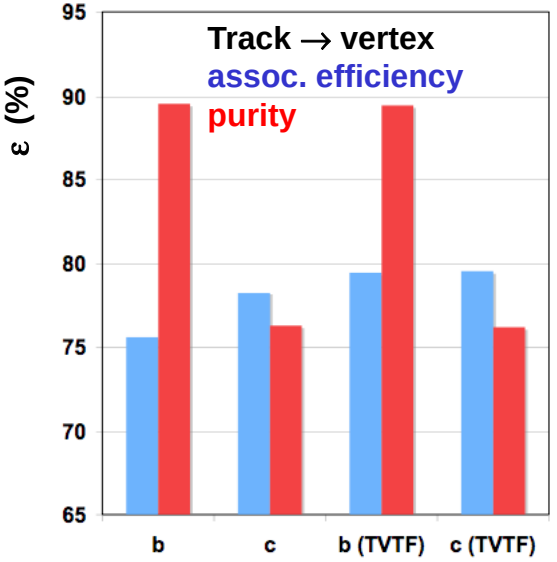
- use pixel triplets

Secondary Vertex finding

W. Adam – Vertex06

- "Trimmed Kalman Vertex Finder"
  - First fit with complete set
  - Continue with rejected tracks
- "Tertiary Vertex Track Finder"
  - Start with TKVF
  - Choose additional tracks close to flight path
  - Only used for kinematics (not for position)



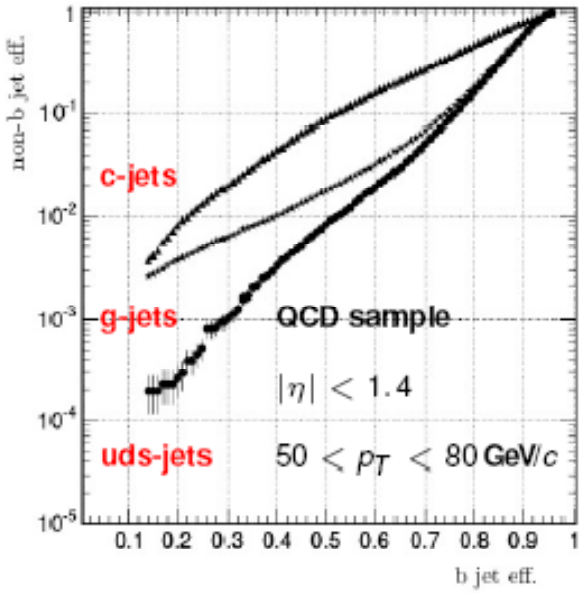


Resolution:

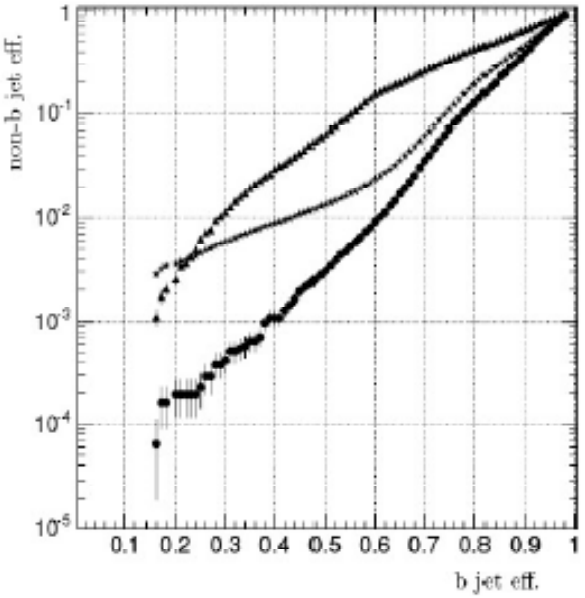
	b	c
• Flight dist.	**765 μm**	**550 μm**
• Angle (3D)	**15.5 mrad**	**8.0 mrad**

B tagging performance

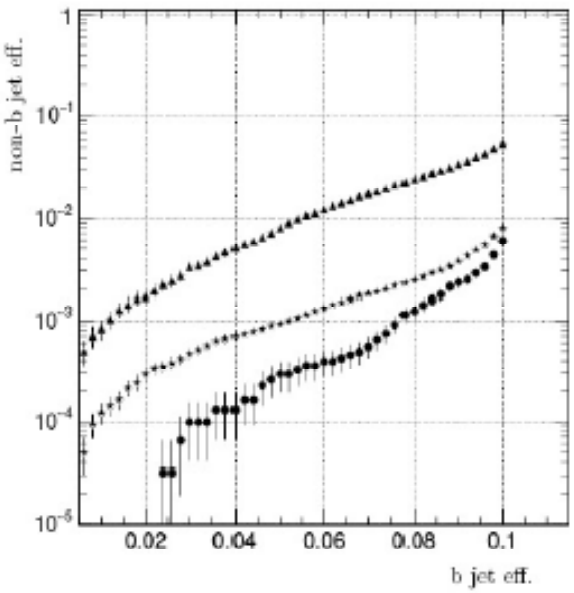
Track Probability b tag



Combined Secondary Vertex b tag

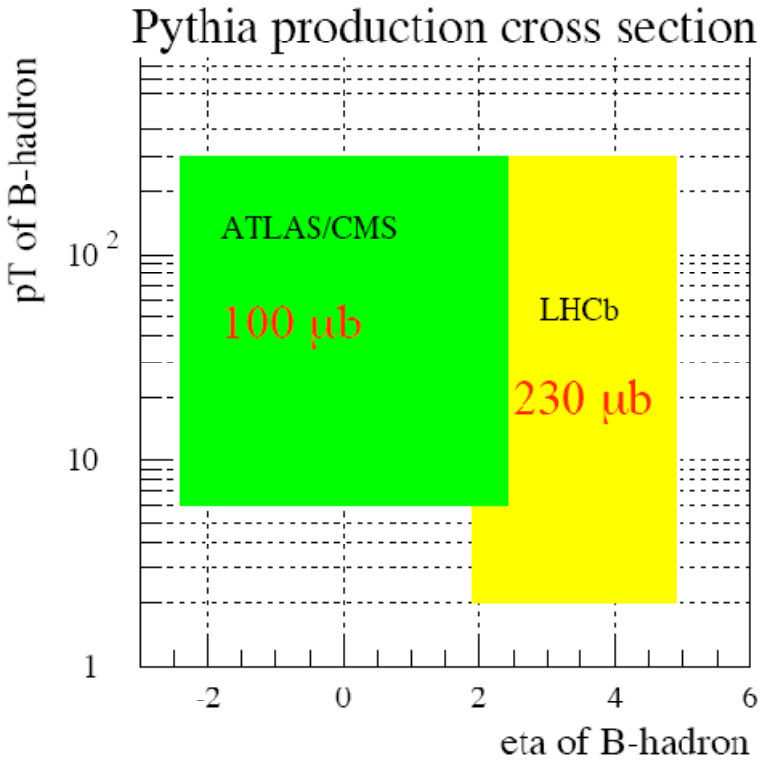


Soft Lepton (semi-leptonic) b tag



b acceptance

- **ATLAS/CMS**
  - **$|\eta| < 2.5/2.4$**
    - **Tracker/muon detector acceptance**
  - **high-P_t muon trigger**
  - **b-tagged jet trigger**
    - **Muon+b-Jet trigger**
- **LHCb**
  - **Forward spectrometer**
    - **$1.9 < \eta < 4.9$**
  - **much softer p_t triggers**



There is an overlap

CMS study: much higher P_t could be reached

CMS Analysis: B production

V.P. Andreev, D.B. Cline, S. Otwinowski
CMS Note 2006/120

- **Inclusive *b* production total cross section**
- **Differential cross sections $d\sigma/dp_t$, $d\sigma/d\eta$**

  - **Selection (b-tag)**
    - **semileptonic b-decays into muons**
  - **Background (b purity)**
  - **Trigger efficiency**
  - **Luminosity**

Event selection

QCD event Generation: PYTHIA

Full simulation of the detector

Trigger

Level-1:

“single μ”,

p_t>14 GeV/c, |η| < 2.1

ε = 18 %

High Level Trigger:

“muon + b-jet”,

P_t^{μ} >19GeV/c, E_t^{jet}>50GeV, |η| < 2.4

ε = 60 %

Off-line selection

- **B-tagged jet: E_t > 50 GeV, |η| < 2.4**

  ε = 65 % (barrel), 55 % (endcap)

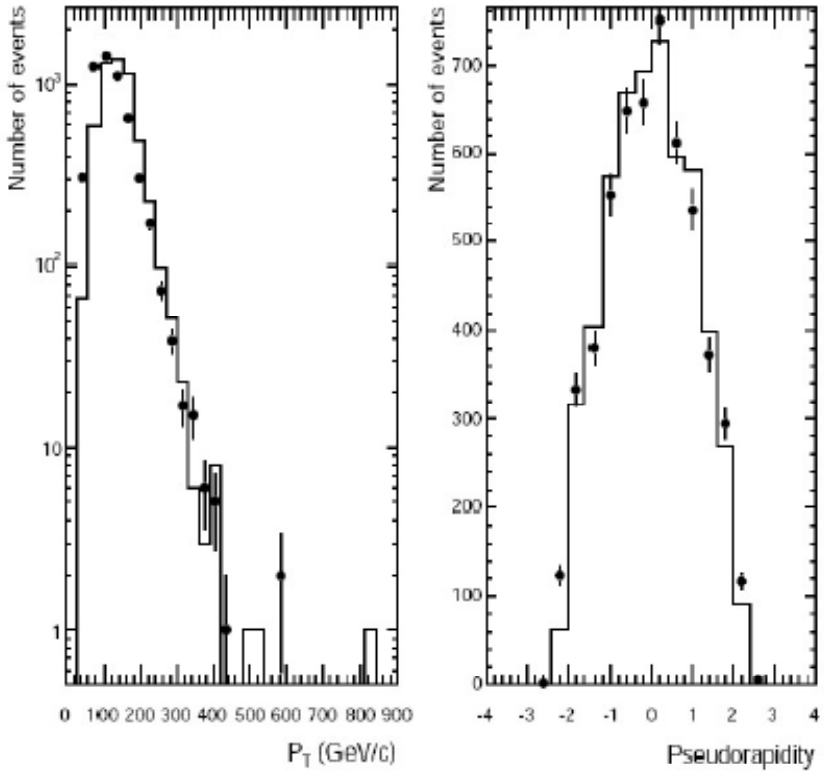
  Muon associated with B-tagged jet

  ε = 75 %

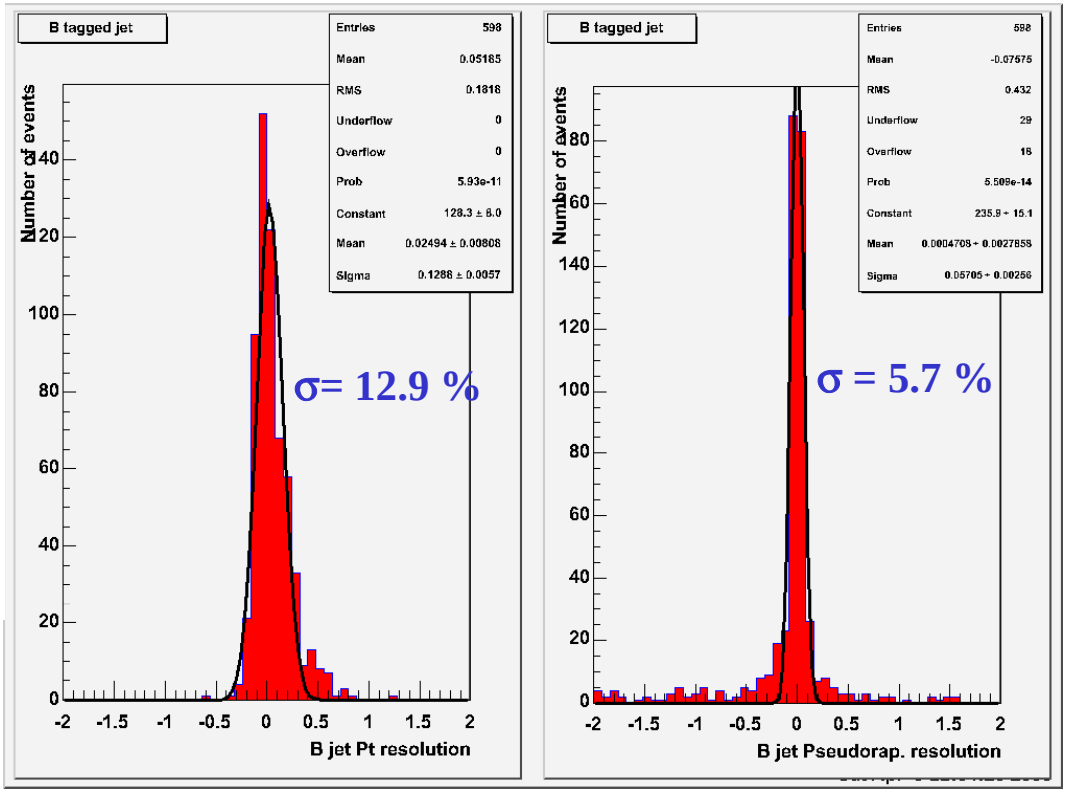
- The most energetic *b* tagged jet as the reconstructed B-particle candidate
- the rate of *b* jets *is a direct measurement of the b production with only small fragmentation systematics*

B-jet resolution

Reconstructed b-jet vs generated B particle



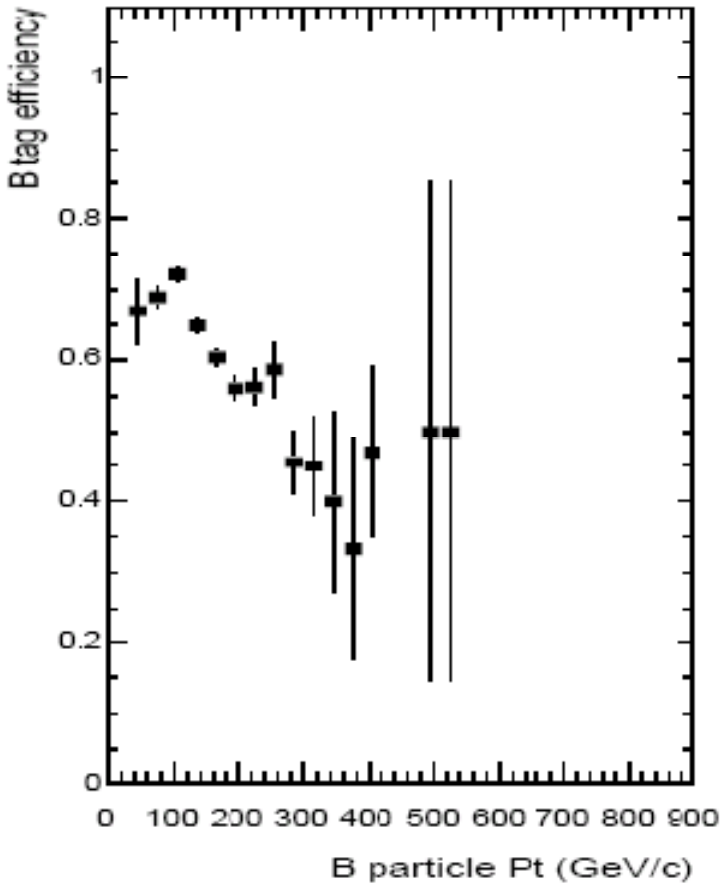
P_t > 170 GeV/c

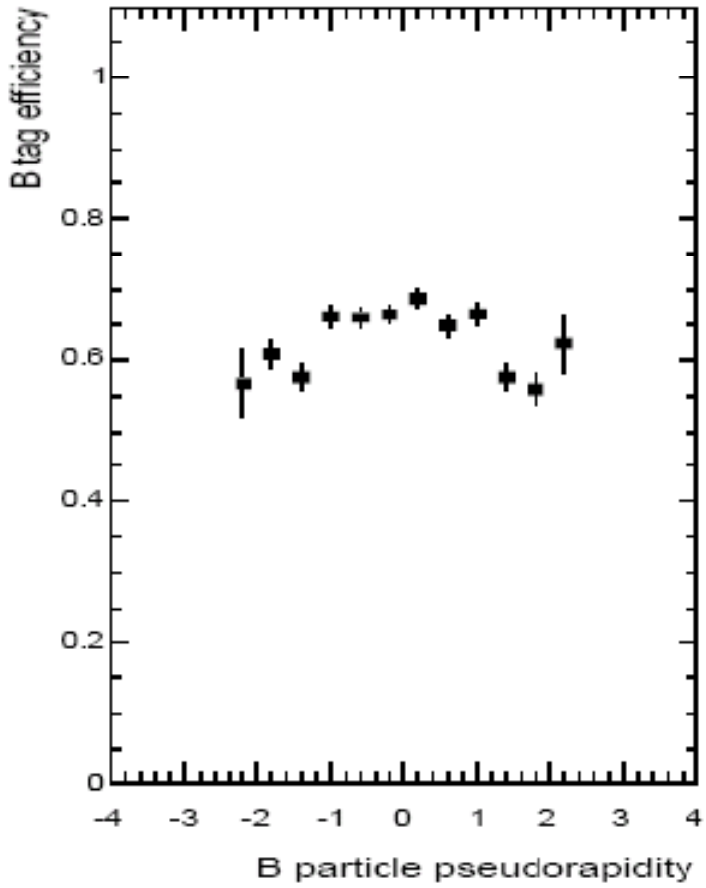


B-tag efficiency

B tag:

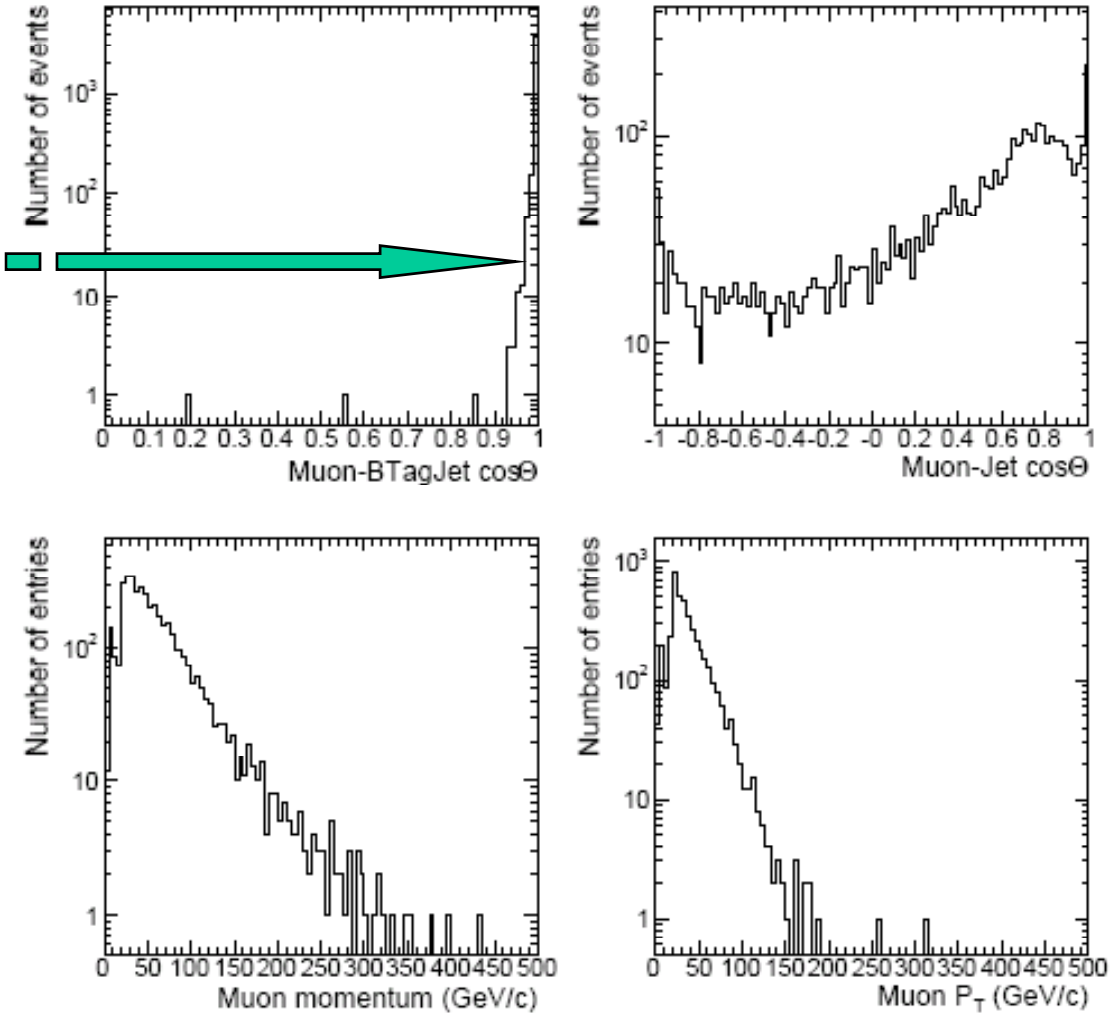
inclusive secondary vertex reconstruction in jets





B tagging with muon

The tagged muon is inside of the *b* jet



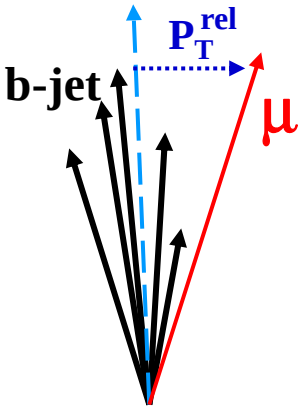
Event selection

2.5 M simulated events processed

Estimate for 10 fb^{-1}

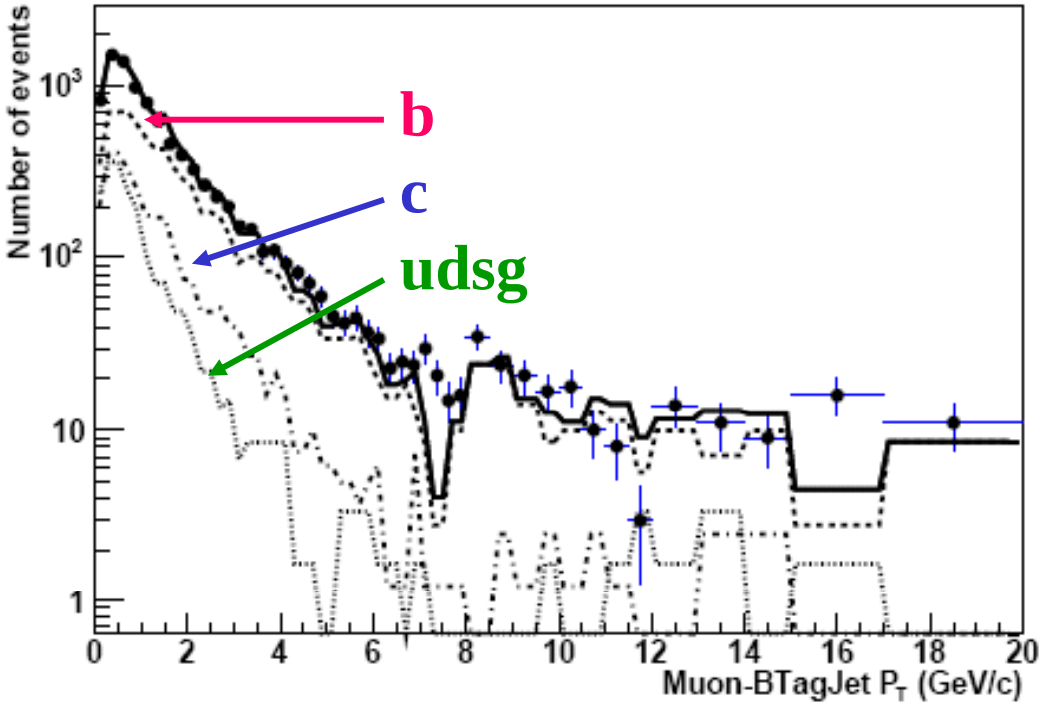
$\hat{p}_T$, GeV/c	σ^{QCD}, μb	$N^{QCD}_{generated}$, events	$b\bar{b}$ purity, %	$c\bar{c}$ fraction, %	uds fraction, %	$N^{b\bar{b}}_{expected}$, events
50 – 80	20.9	198993	66	32	2	1.4 M
80 – 120	3.0	294986	66	32	2	6.1 M
120 – 170	0.5	291982	72	26	2	5.1 M
170 – 230	0.1	355978	71	26	3	2.4 M
230 – 300	2.4×10^{-2}	389978	73	24	3	0.9 M
300 – 380	6.4×10^{-3}	283983	70	25	5	0.3 M
380 – 470	1.9×10^{-3}	191989	68	27	5	88 k
470 – 600	6.9×10^{-4}	190987	64	29	7	34 k
600 – 800	2.0×10^{-4}	94996	60	31	9	10 k
800 – 1000	3.6×10^{-5}	89999	60	30	10	2.0 k
1000 – 1400	1.1×10^{-5}	89998	55	31	14	0.5 k

Fit results



QCD events **MC: 230 < P_t < 300 GeV/c**

Muon P_t w.r.t. the closest B jet



MC:

N_b = 5250 (56 %
N_c = 2388 (26%
N_{udsg} = 1740 (18%

9378 events

Fit:

N_b = 5222 ± 501
N_c = 2050 ± 728
N_{udsg} = 1778 ± 341

9050 events

Systematics (L ≥ 10 fb^{-1})

- jet energy scale 12%
- fragmentation 9 %
- event selection 6 %
- luminosity 5 %
- tagging 5 %
- trigger 3 %
- misalignment 2 %
- tt background 0.7 %
- muon
  - Br. Ratio 2.6 %
  - Eff. 1.0 %

total = 18 %

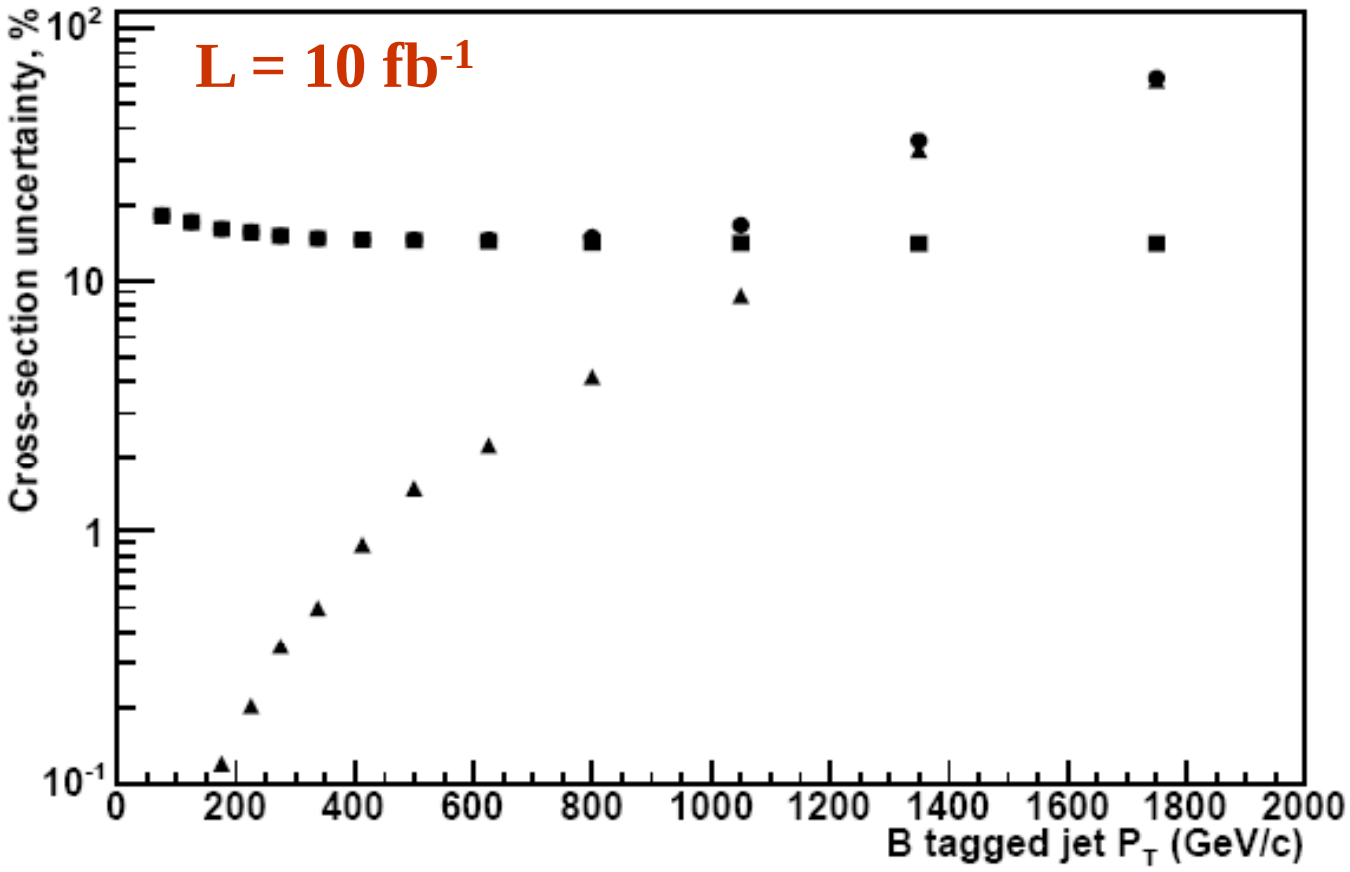
b-quark P_t reach

***B* hadron**

- **$P_t > 50$ GeV/c**
- **$|\eta| < 2.4$**

▲ statistical

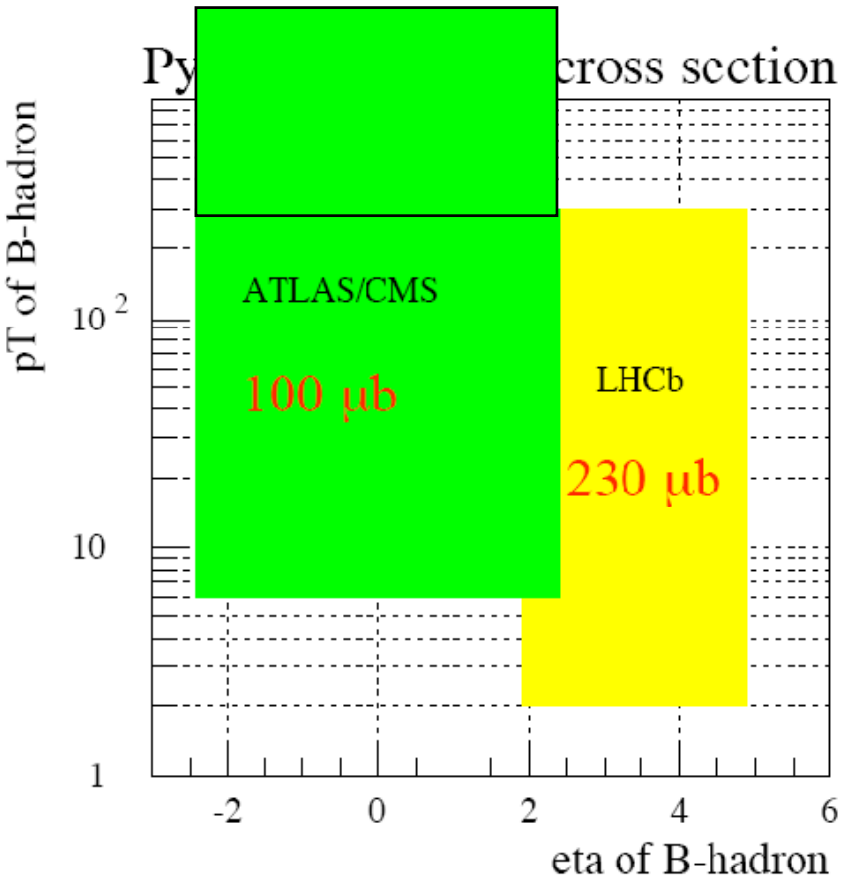
■ systematic



We can reach 1.5 TeV as the highest measured B hadron P_t

B production at LHC: conclusions

Extended P_t reach



CMS analysis summary

- **~16 M *b* events to be selected at 10 fb^{-1} (one year of low lumi LHC)**
- ***b* purity in a range from 70 % to 55 %**
- **up to 1.5 TeV B-hadron P_t reach**

Outlook

- **CMS tracker is capable to provide an excellent vertexing and b-tagging**
- **CMS is looking forward to measure open beauty production rate at 14 TeV**
- **bb-correlations measurements are foreseen to investigate in detail the production mechanisms**
- **New test of QCD is coming**
- **Important for New Physics search**