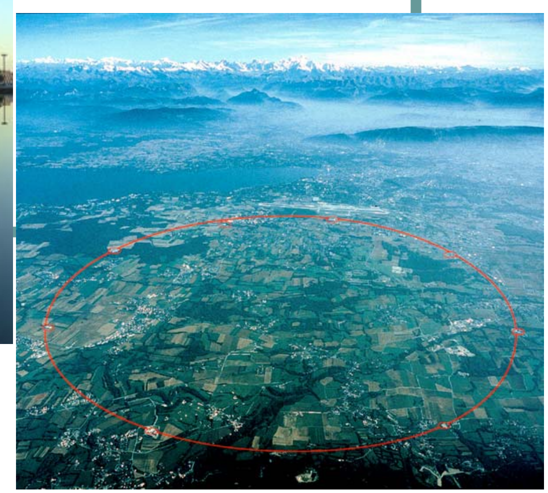
Heavy flavor tagging and collider searches for stop and sbottom

D. Bortoletto
Purdue University



Help from: Rott, Gonzalez- Lopez, Silvestris, Cucciarelli, Palla, Rozanov, Wright, Inchliffe, Duperrin, Greenlee, Guimaraes da Costa, Watts and more

Outline

- Searches for stop and bottom
  - Current status at CDF and D0
  - Plans at CMS and Atlas
- The role of heavy flavor tagging
  - Algorithms
  - CDF and D0 experience
  - Differences between TeV and LHC
- What CMS and Atlas want to know from the Tevatron?

Third generation squarks

- **Third generation squarks could be light, due to large mixing**

$$\tilde{q}_1 = \tilde{q}_L \cos\Theta_{\tilde{q}} + \tilde{q}_R \sin\Theta_{\tilde{q}}$$

Light Sbottom: large tanβ

Light Stop: large m_t

Mass matrix mixing term

$$m_q(A_q - \mu\kappa)$$

$\kappa = \tan\beta$	$\kappa = 1/\tan\beta$
down type quarks	**up type quarks**

- **To suppress FCNC and CP violation might require that first and second generation of squarks is heavy (M~20 TeV)**
- **Stop and sbottom should still be much lighter (M < 1 TeV) to maintain naturalness**

Cohen, Kaplan, Nelson

Stop and sbottom searches RUN 1

- **mSUGRA (m_0,$m_{1/2}$, A_0, tanβ,μ)**
- **Most analysis assumed $R_p = (-1)^{3B+L+2}$ conservation ⇒ stable LSP ⇒MET**
- **Few used b-tagging**

Top to Stop PRD 63, 091101(R) (2001)

$$p\bar{p} \to t\bar{t} \to (\tilde{t}\tilde{\chi}_1^0)(\bar{\tilde{t}}\tilde{\chi}_1^0) \to (b\tilde{\chi}_1^{\pm})\tilde{\chi}_1^0(\bar{b}\tilde{\chi}_1^{\mp})\tilde{\chi}_1^0$$

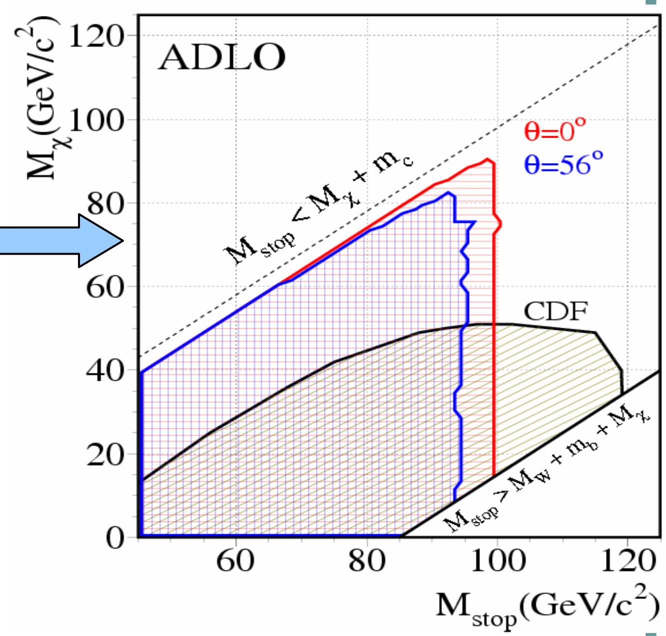
Signature: ≥1 lepton, ≥2 jets, **MET**

Stop/Sbottom in c/b+LSP PRL 84, 5704 (2000)

PRL 93, 011801 (2004)

$$p\bar{p} \to \tilde{t}\bar{\tilde{t}} \to (c\tilde{\chi}_1^0)(\bar{c}\tilde{\chi}_1^0)$$

Signature: ≥**2 HF jets**, **MET**



Stop in lepton + b-jets PRL 84, 5273 (2000)

$$p\bar{p} \to \tilde{t}\bar{\tilde{t}} \to (b\tilde{\chi}_1^+)(\bar{b}\tilde{\chi}_1^-) \to (b\ell^+\tilde{\chi}_1^0)(\bar{b}\ell^-\tilde{\chi}_1^0)$$

Signature: ≥1 lepton, **b-jet (tagged)**, **MET**

Stop in MET+ leptons PRL 84, 5273 (2000)

PRL 88,171802-1 (2002)

$$p\bar{p} \to \tilde{t}\bar{\tilde{t}} \to (bl\tilde{\nu})(\bar{b}\bar{l}\bar{\tilde{\nu}})$$

Signature:2 opposite sign leptons, **MET**

PRL 93, 011801 (2004)

$$\tilde{t} \to b\tilde{\chi}_1^{\pm} \to b\ell\nu\tilde{\chi}_1^0$$

No b-tagging

Sbottom searches Run II

- CDF Run II search in light sbottom scenario [Z. Phys. C64, 499 (1994)]

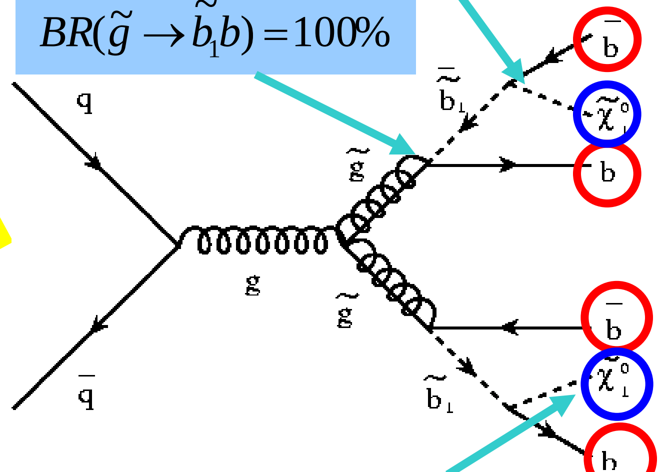
$$p\bar{p} \rightarrow \tilde{g}\tilde{g}$$
$$\tilde{g} \rightarrow b\tilde{b}_1$$
$$\tilde{b}_1 \rightarrow b\chi_1^0$$

Spectacular signature: 4 b-jets + MET

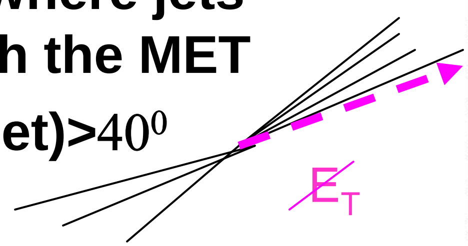
$BR(\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0) = 100\%$

$BR(\tilde{g} \rightarrow \tilde{b}_1 b) = 100\%$

$m(\tilde{\chi}_1^0) = 60\,GeV/c^2$

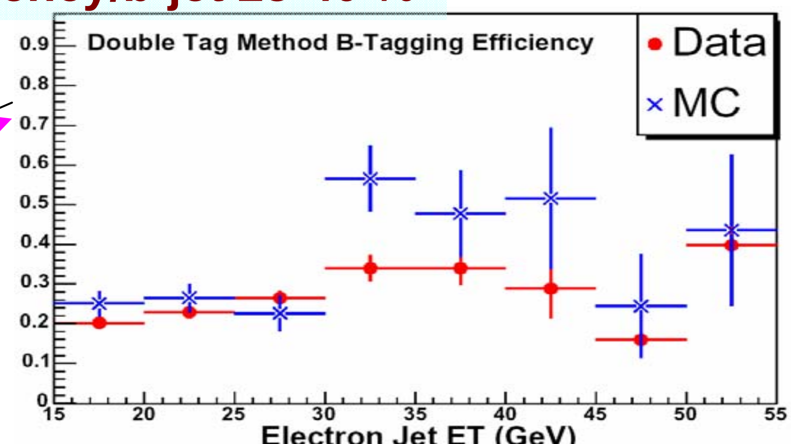


- MET >35GeV+ jet trigger
- 3 or more jets
- Reject events where jets are aligned with the MET
  - $\Delta\phi$(Met,1-3.jet)>40^0

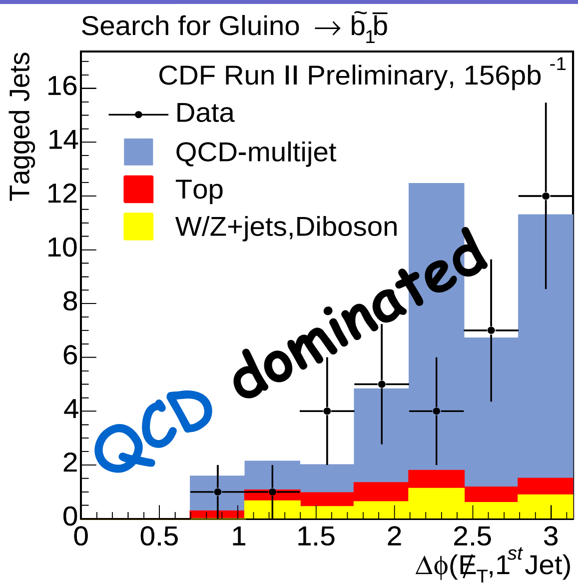


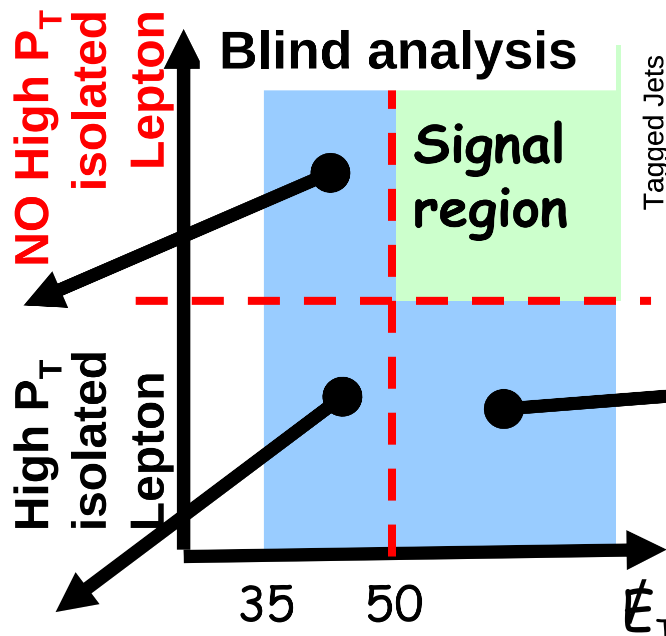
- Separate analysis for single and double b-tag

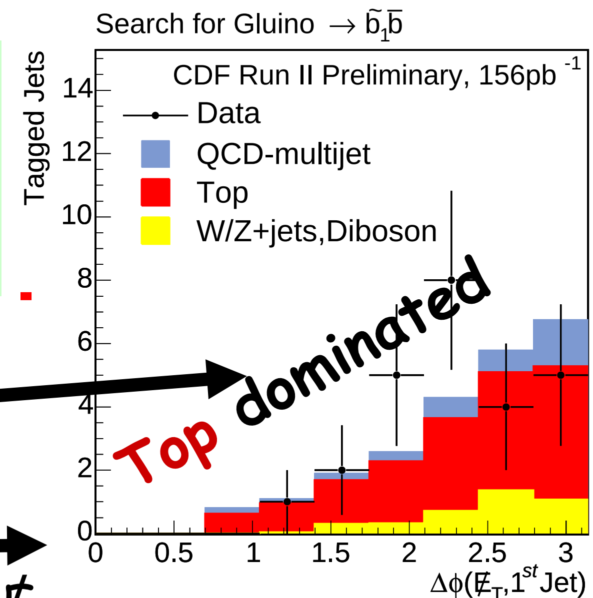
Fake rate/jet ~0.3%
Efficiency/b-jet 25-40 %

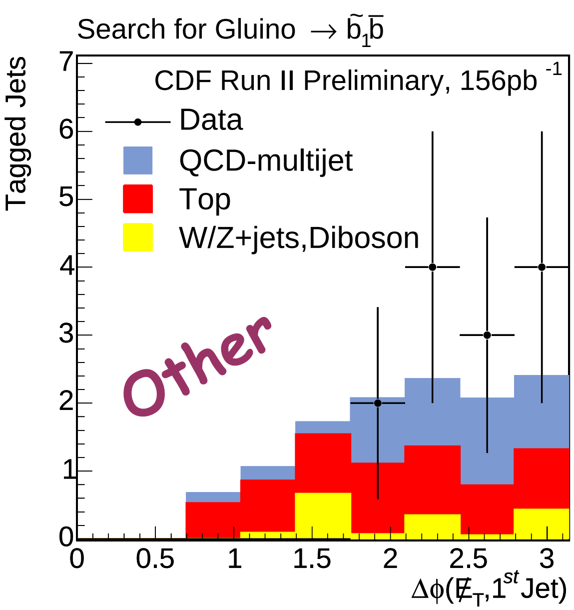


Control regions









	Other	QCD dominated	Top dominated
EW	3.9±0.8	11.0±1.2	9.6±1.2
Top	11.7±0.2	8.2±0.1	35.2±0.3
QCD	19.2±4.1	129.6±17.3	10.9±4.5
BCK	34.8±4.2	148.8±17.3	55.7±4.7
OBS	36	121	63

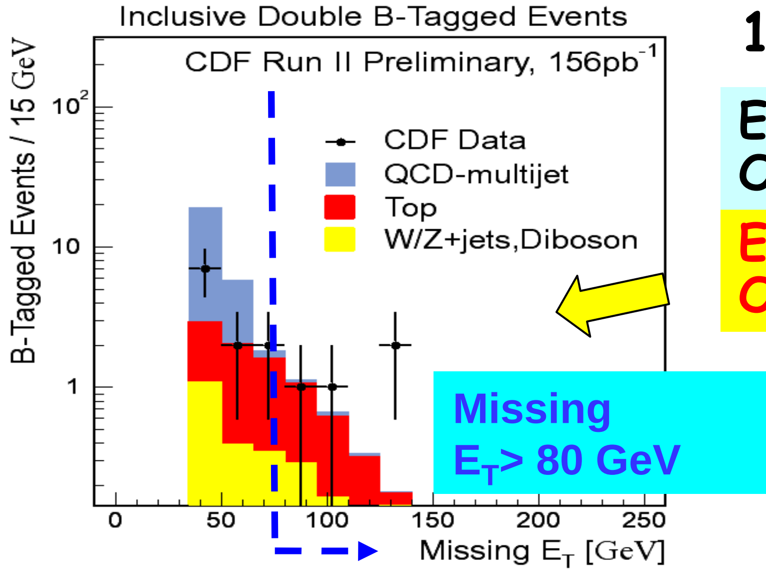
Signal region

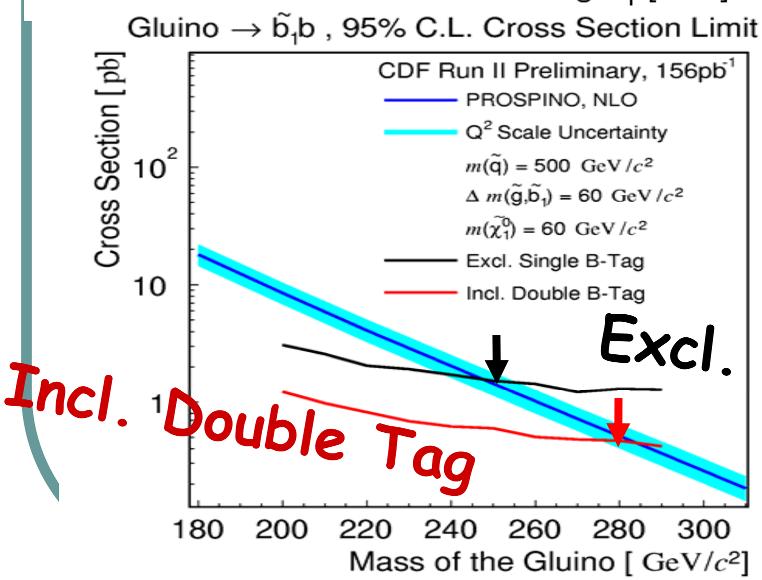
$156 pb^{-1}$ of data taken 2002-2003

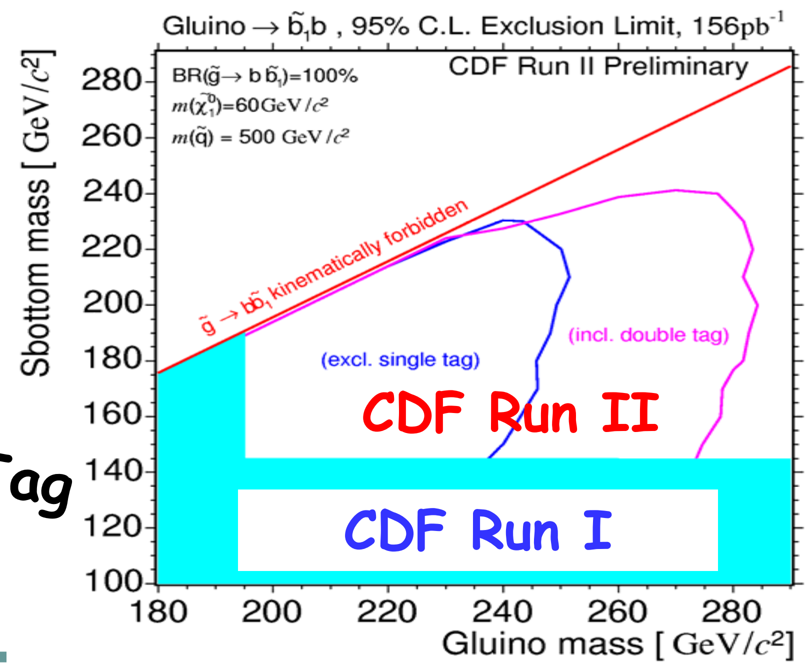
Expected Excl.single tag 16.4±3.7
Observed 21

Expected incl. double tag 2.6±0.7
Observed 4

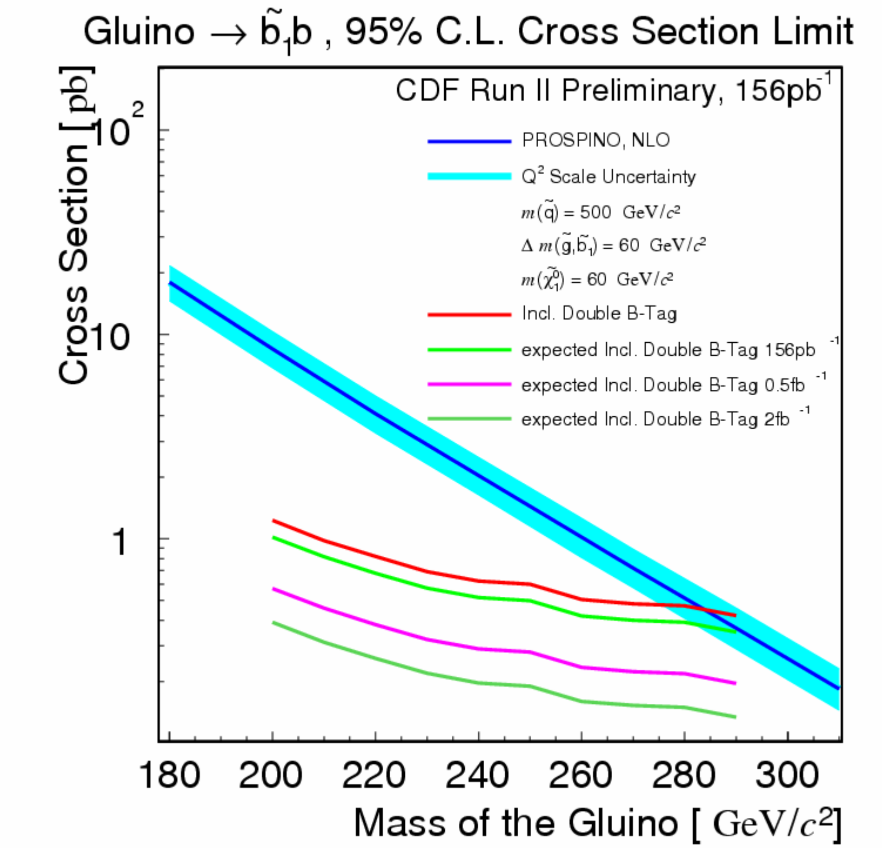
Acceptance:Exclusive SingleTag=7.7%
Inclusive DoubleTag= 9.0%

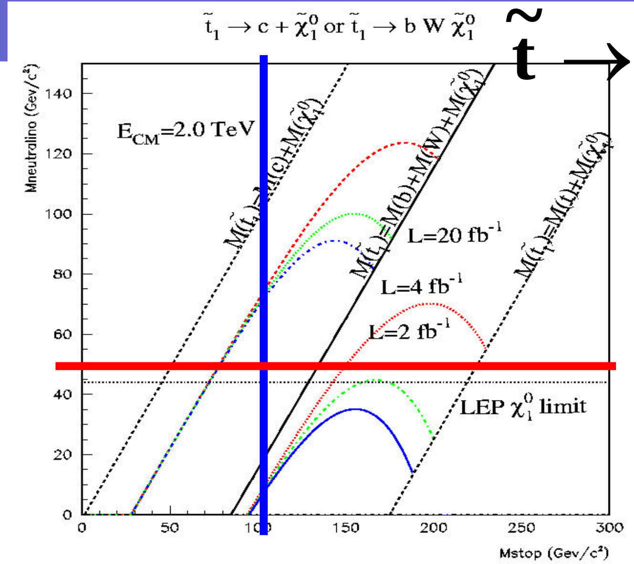


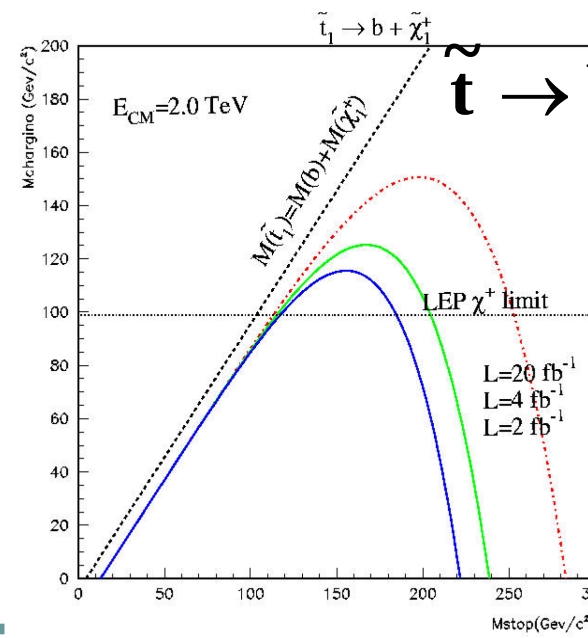




Prospect for run II







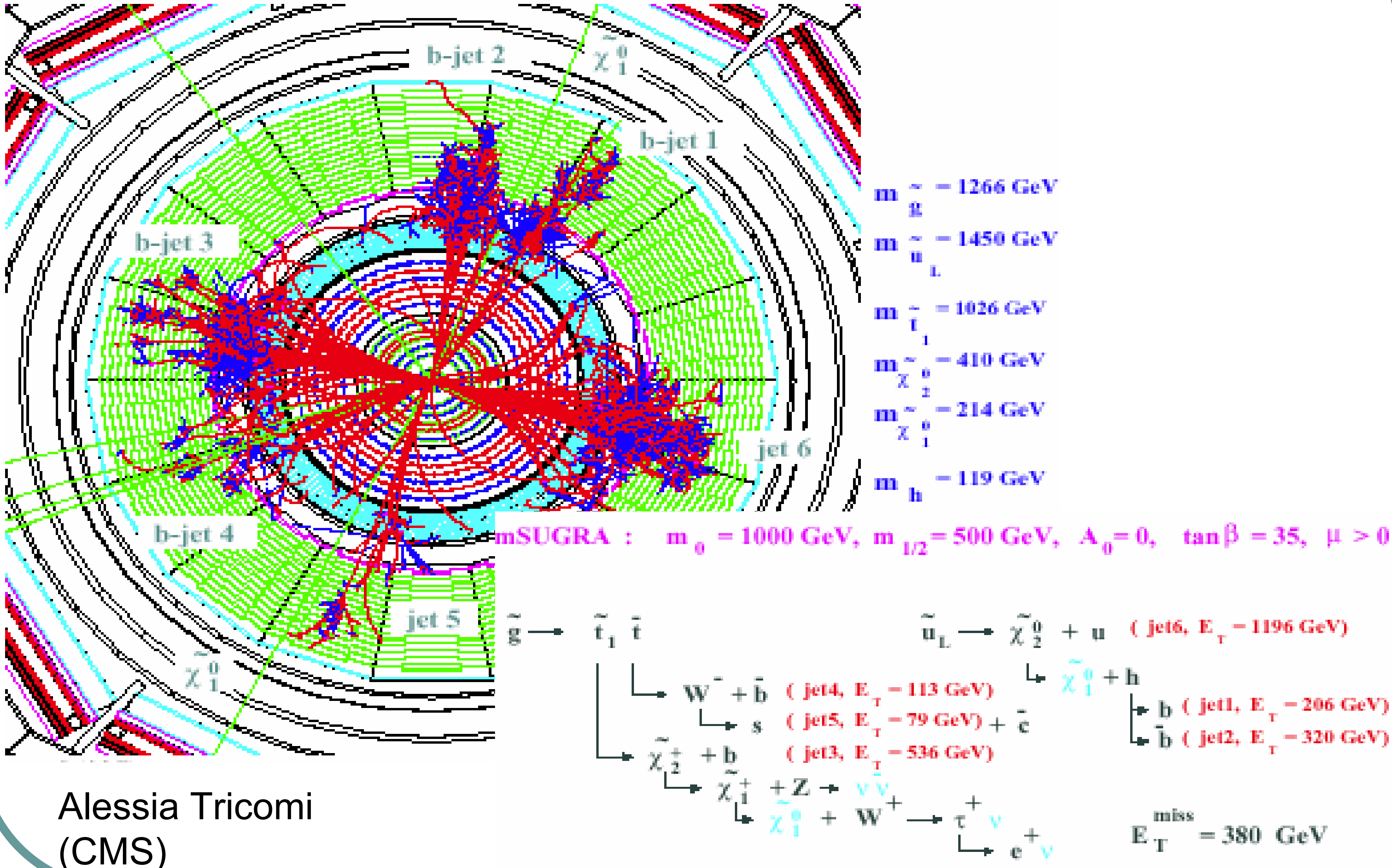
TeV will explore stop and sbottom well above top mass

Beyond Minimal SUSY

- Even the MSSM (100+ parameters) may not be general enough.
- **For example, the LEP-II bound on the Higgs mass implies that the stop mass is greater than ~ 700 GeV**.
  - This would make looking for stops pretty hopeless at run II.
  - It's disturbing because it starts to recreate the hierarchy problem.
- Specific extensions (**NMSSM**, "**Gauge Extended MSSM**", "**Fat Higgs**", etc.) are already appearing to relax this requirement.
  - They often have more states (i.e. Z's, exotic Higgses).
  - There are also often special properties for the new states related to the 3rd family, like enhanced decays to τ, **b**, and **t**.
- What about R-parity violation? It still allows the hierarchy solution, though it does give up SUSY dark matter. It's interesting!
- **MORAL 1: Keep looking for those stops!**
- **MORAL 2: Realistic SUSY theories are probably somewhat richer than we naively expect. The first hints may not look like SUSY.**

Tim Tait's talk at CDF Collaboration meeting

Searches at the LHC



Alessia Tricomi
(CMS)

Searches at the LHC

- **Expectations at the LHC depend on the scenarios**

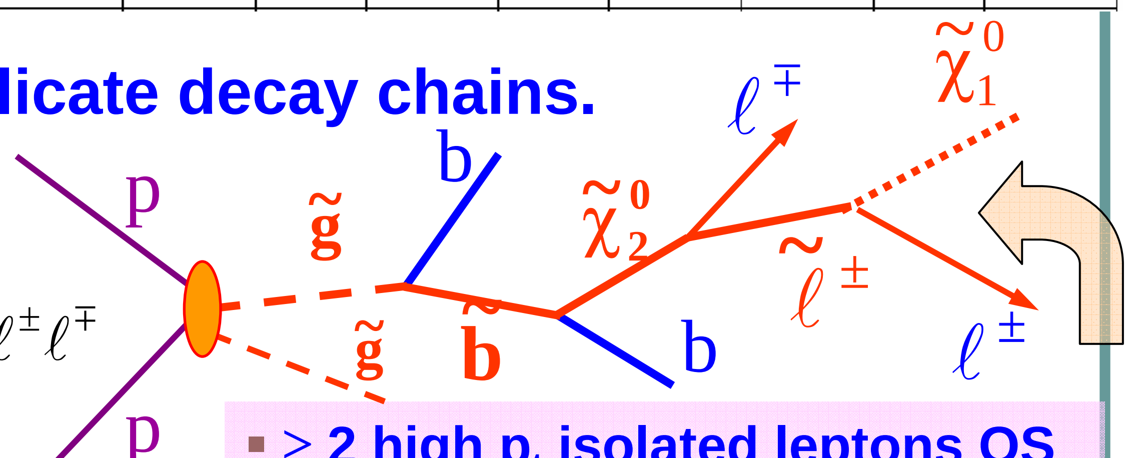
Proposed Post-LEP Benchmarks for Supersymmetry, M. Battaglia *et al*. (hep-ph/0106204)

Model	A	B	C	D	E	F	G	H	I	J	K	L	M
$m_{1/2}$	600	250	400	525	300	1000	375	1500	350	750	1150	450	1900
m_0	140	100	90	125	1500	3450	120	419	180	300	1000	350	1500
$\tan\beta$	5	10	10	10	10	10	20	20	35	35	35	50	50
$\mathrm{sign}(\mu)$	$+$	$+$	$+$	$-$	$+$	$+$	$+$	$+$	$+$	$+$	$-$	$+$	$+$
$\alpha_s(m_Z)$	120	123	121	121	123	120	122	117	122	119	117	121	116
m_t	175	175	175	175	171	171	175	175	175	175	175	175	175

- **Many lead to complicate decay chains.**

$$pp \to \tilde{g} \to \tilde{b}b$$
$$\hookrightarrow \tilde{\chi}_2^0 b$$
$$\hookrightarrow \tilde{\ell}^{\pm}\ell^{\mp} \to \tilde{\chi}_1^0 \ell^{\pm}\ell^{\mp}$$

$$pp \to \tilde{g} \to \tilde{q}q$$
$$\hookrightarrow \tilde{\chi}_2^0 q$$
$$\hookrightarrow \tilde{\ell}^{\pm}\ell^{\mp} \to \tilde{\chi}_1^0 \ell^{+}\ell^{-}$$



- $\geq$ 2 high p_t isolated leptons OS
- $\geq$ 2 high p_t b jets
- missing E_t

Searches at the LHC

- **Scenario has been investigated by CMS. For point B, gluino heaviest sparticle, neutralino is LSP**

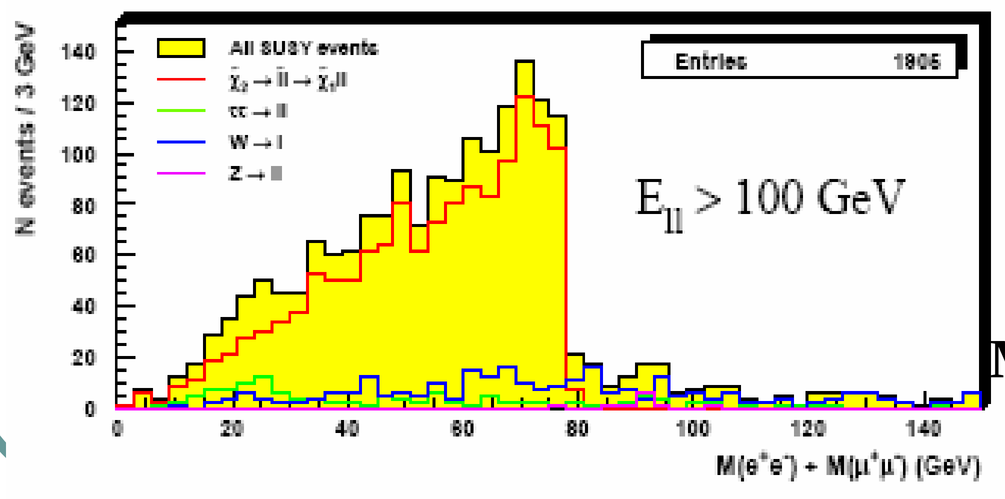
$$m(\tilde{g}) = 595\,\text{GeV} \qquad m(\chi_1^0) = 95\,\text{GeV}$$

$$BR(\tilde{g} \to \tilde{b}_1 b) + BR(\tilde{g} \to \tilde{b}_2 b) \approx 27.5\%$$

$\tilde{b}_2$	
Decay channel	BR(%)
$\tilde{\chi}_1^{\pm} t$	34.06
$\tilde{\chi}_1^0 b$	17.32
$\tilde{\chi}_2^0 b$	25.04
$\tilde{\chi}_3^0 b$	0.17
$\tilde{\chi}_4^0 b$	1.53
$\tilde{t}_1 W$	2.19

- **Fast detector simulation**
- **Selection starts with dilepton end-point invariant mass distribution**

$\tilde{b}_1$	
Decay channel	BR(%)
$\tilde{\chi}_1^{\pm} t$	46.37
$\tilde{\chi}_2^0 b$	37.05
$\tilde{\chi}_1^0 b$	5.35
$\tilde{\chi}_3^0 b$	0.19
$\tilde{\chi}_4^0 b$	1.80
$\tilde{t}_1 W$	9.23



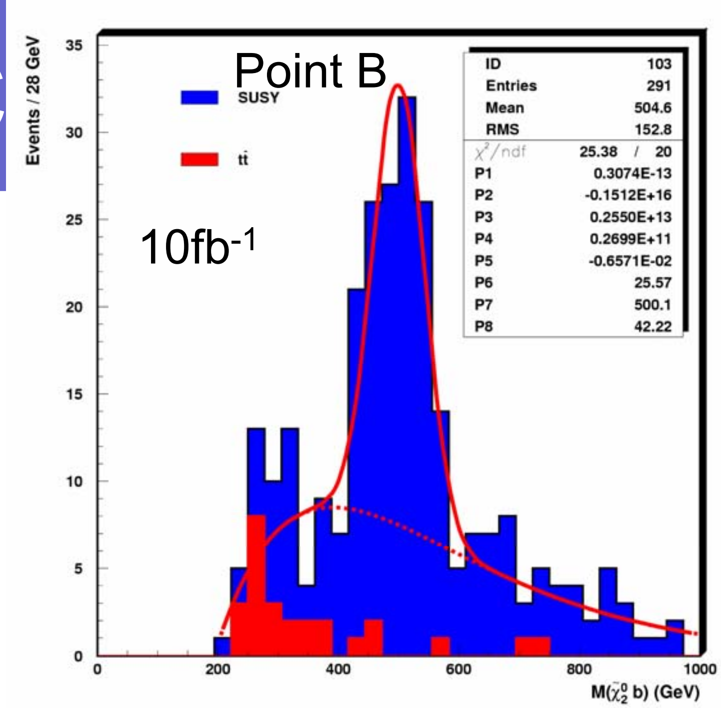
$$M_{\ell^+\ell^-}^{max} = \frac{\sqrt{(M_{\tilde{\chi}_2^0}^2 - M_{\tilde{\ell}}^2)(M_{\tilde{\ell}}^2 - M_{\tilde{\chi}_1^0}^2)}}{M_{\tilde{\ell}}}$$

Searches at the LHC

- B-tagging used to reconstruct sbottom and gluino decay
- Also used to anti select b-jets for squark reconstruction
- Select b-jet with $E_{b\text{-jet}}$>250 GeV:

$$M(\tilde{\chi}_2^0 b) = (500 \pm 7)\text{GeV}$$

- **Reconstruction of strongly interacting sparticle possible**



M. Chiorboli, Physics at the LHC- Prague 2003

Point B:

- **first few weeks of LHC running period:**
  - **reconstruction of squark (resolution ~12%)**
- **first year:**
  - **reconstruction of sbottom and gluino (resolutions ~6÷8%)**
  - **reconstruction of gluino in the squark chain (independent channel)**

Point I (tan β=35):

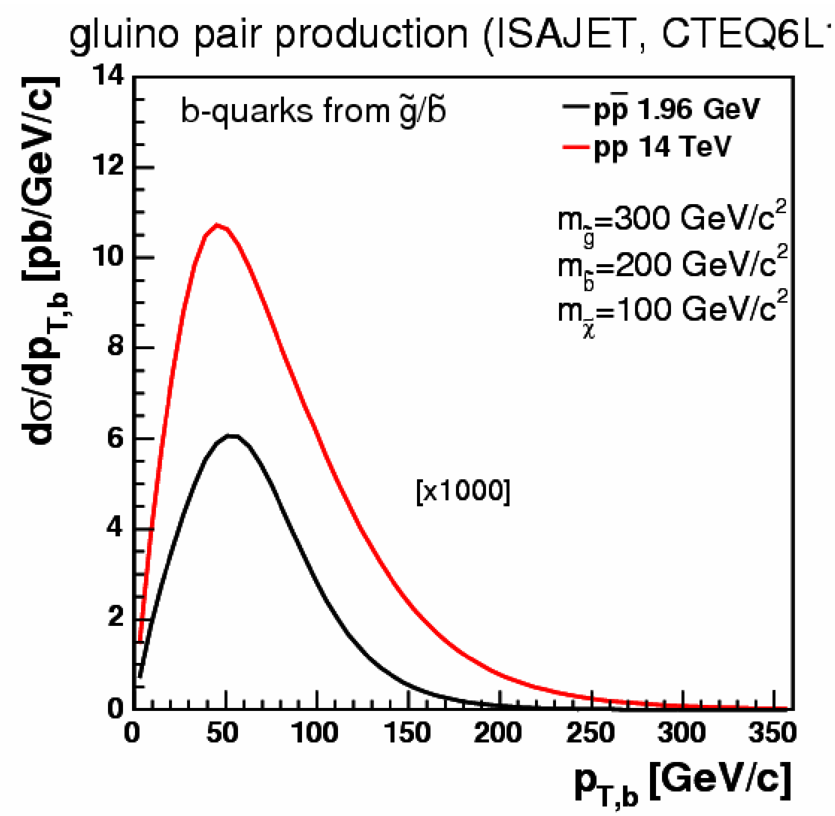
- **no reconstruction possible in the leptonic final state even with high accumulated statistics**
- **tau final state is under investigation**

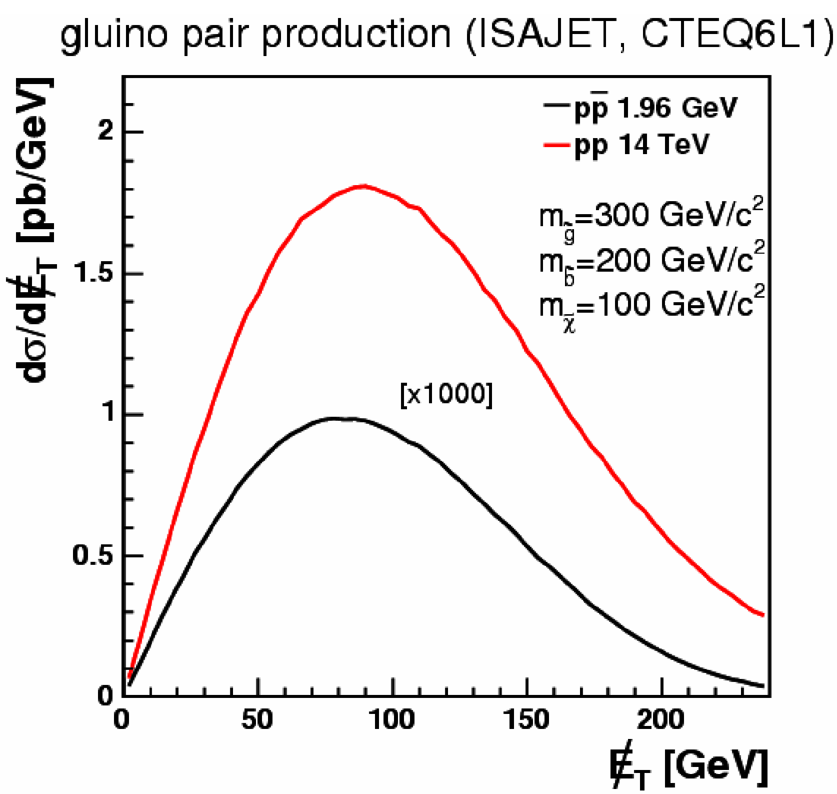
Sbottom from gluino decays at LHC

- The search for sbottom from gluino decay in MET + 2b-tag jets is also interesting for the LHC
- Analysis is just starting for CMS. Huge cross section!!!!

$$BR(\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0) \approx 5\%$$

$$BR(\tilde{b}_2 \rightarrow b\tilde{\chi}_1^0) \approx 17\%$$



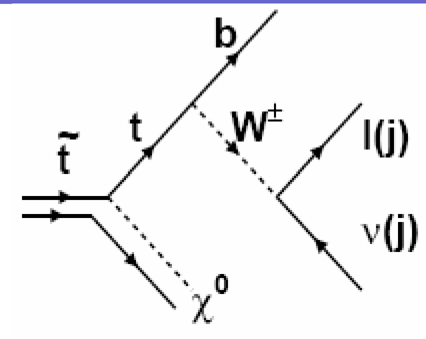


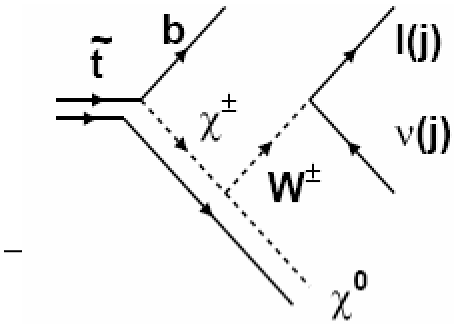
Searches for the stop at the LHC

- **Decay chain for**

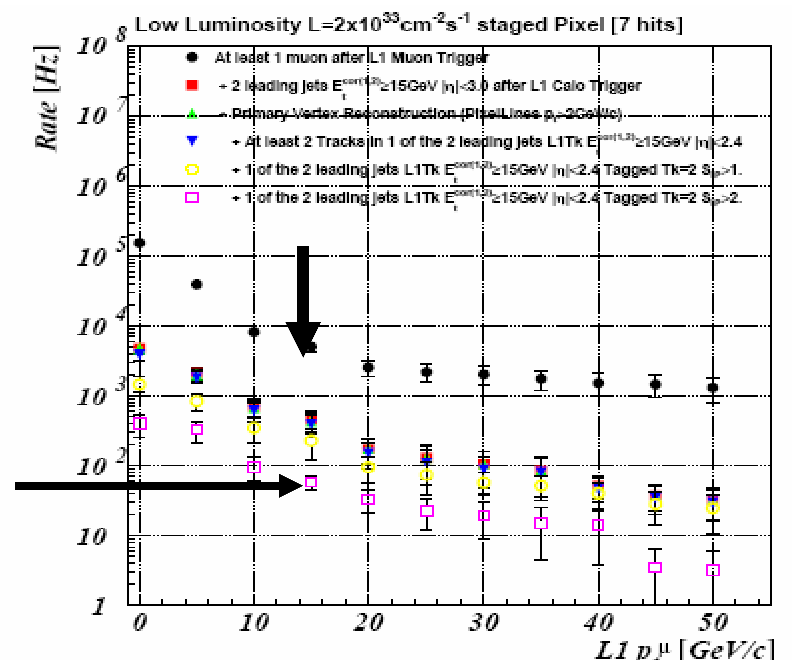
  $\tilde{t} \to t\chi_1^0$ and $\tilde{t}_1 \to b\chi_1^\pm$

- **Trigger rate can be reduced to 30Hz by requiring at least one of the b-jets to be tagged**

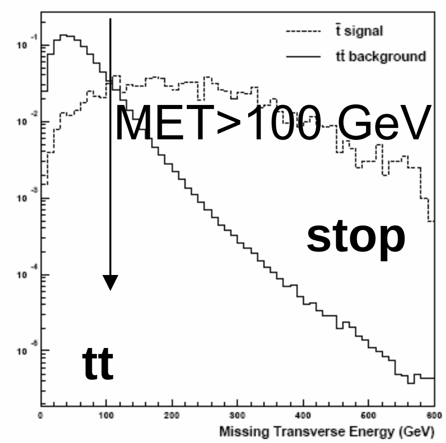


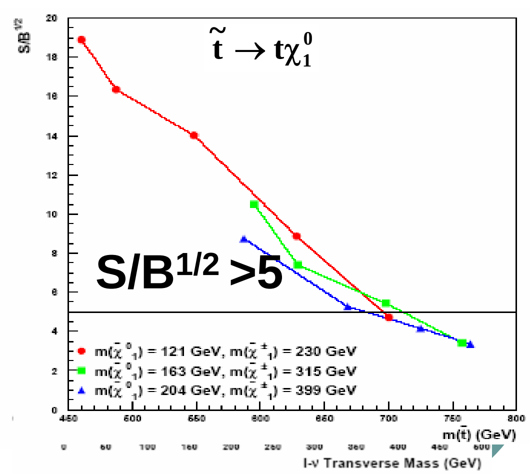


- **Large tt background can be reduced by MET>100 GeV**
- **Stop can be discovered up to about 600- 700 GeV**



Gabriele Segneri- CMS



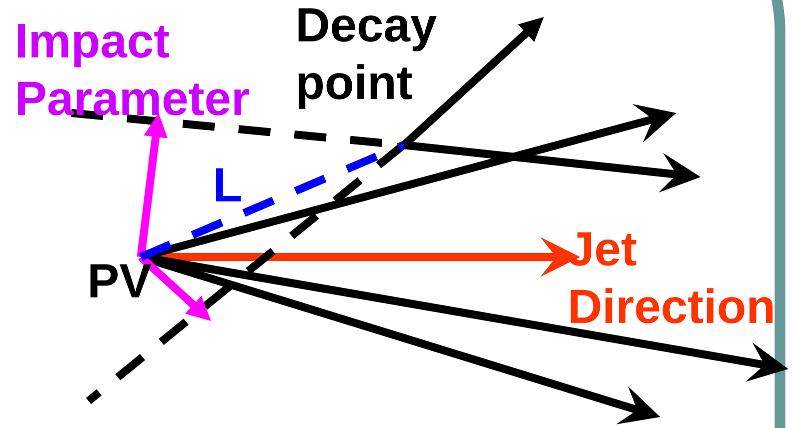


Impact Parameter Methods

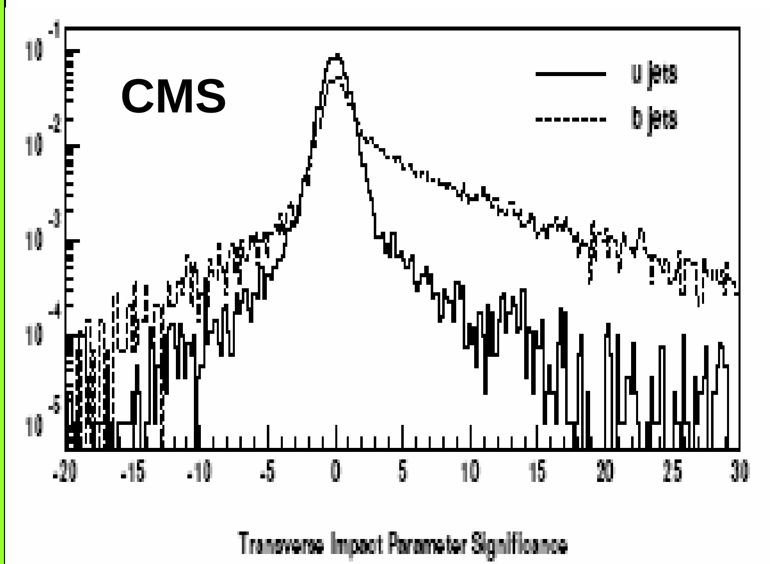
- Track Counting Methods
  - Minimum N(good tracks) with IP Significance S_{IP}

$$S_{IP} = \frac{IP}{\sigma_{IP}} > 2 \text{ or } 3$$

  - Quick optimization and feedback

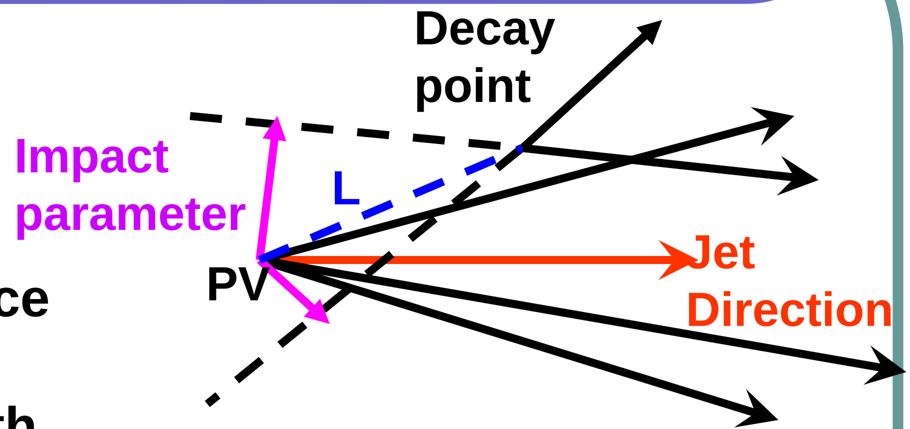


- Probability method
  - Estimate probability that tracks come from primary (2D or 3D)
  - Computed using $S_{IP}<0$. The IP is negative if tracks appear to originate from behind PV
  - Could be optimized for b, c, u
  - Continuous Output {0-1} but tagging efficiency, fakes can be determined for fixed values (1%, 5%)

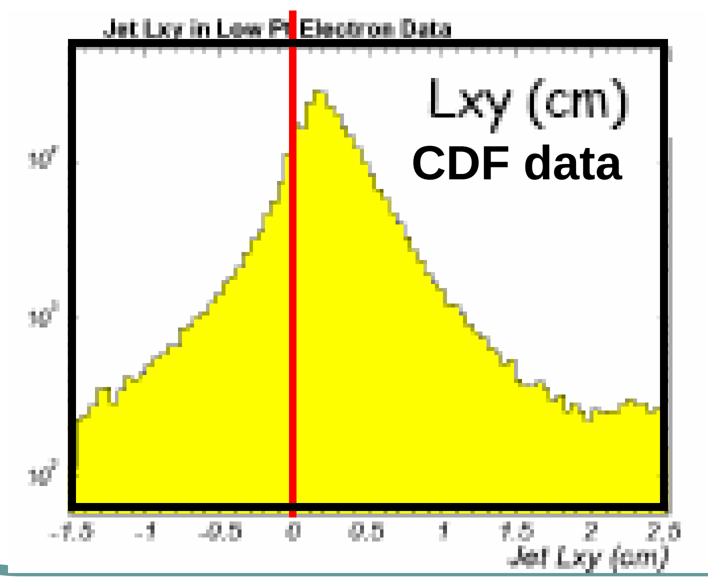


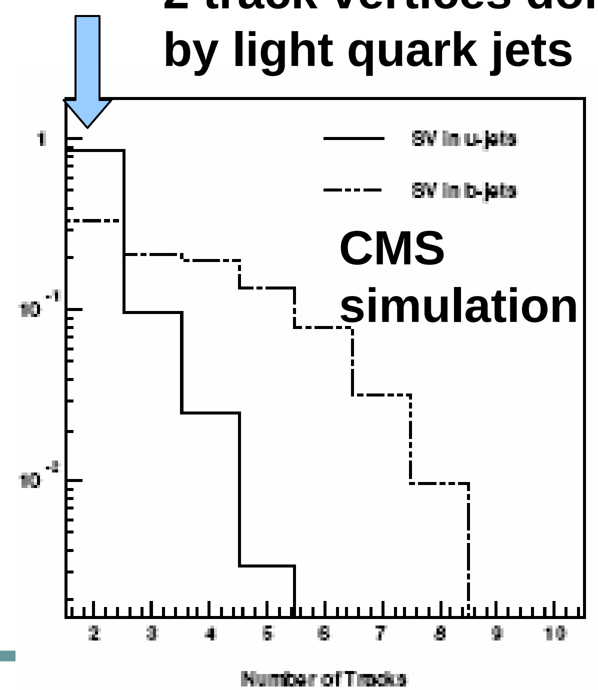
Secondary Vertex Methods

- Use tracks with large S_{IP} to find secondary vertex
- Find >2 or 3 tracks secondary vertices
- Calculate 2D or 3D decay distance L and classify SV based on L
- Fake vertices due interaction with material and long lived particles



2 track vertices dominate by light quark jets





B-tagging at CDF and D0

CDF

- **Jetprob** **(Probability algorithm)**
- **SecVTX (secondary vertex algorithm)**
  - Loose and tight tagger

CMS

- **Track counting**
- **Jet Probability method**
- **Secondary Vertex reconstruction Method**

D0

- **Counting Signed Impact Parameter (CSIP)**

$$S_{IP}^{RAW} = \frac{IP}{\sigma_{IP}^{RAW}}$$

  - **Tag if >2 tracks has S>3**
  - **Tag if >3 traks have S>2**
- **Jet Lifetime Probability (JLIP)**
  - **Probability algorithm**
- **Secondary Vertex reconstruction (SVT)**
- **Loose, Medium and Tight for mistag rate of 1%, 0.5%,0.25%**

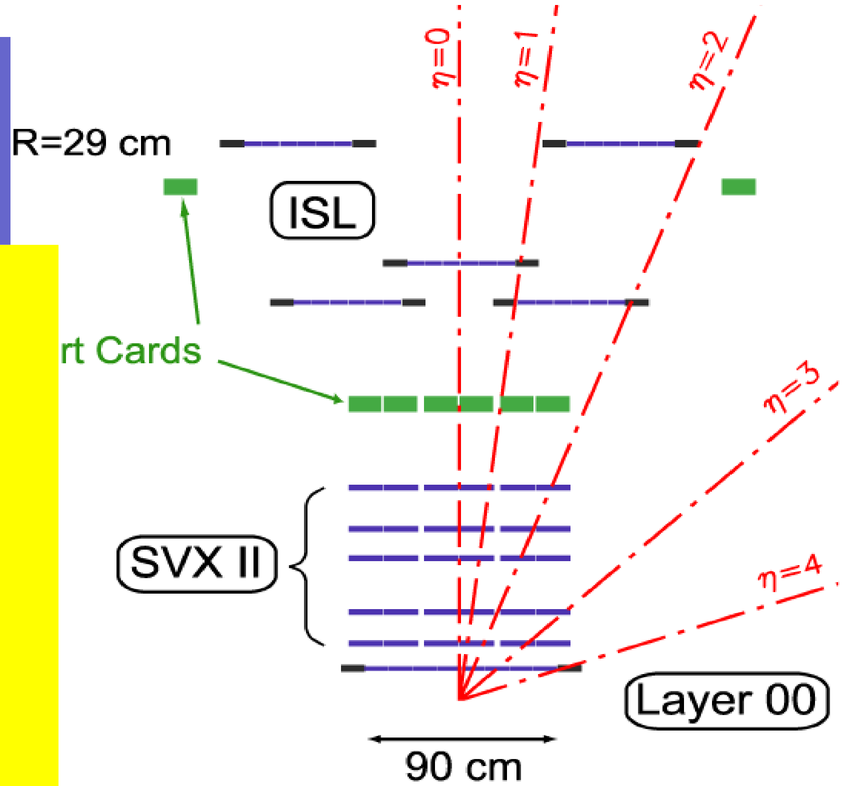
Atlas

- **Likelihood Method Approach**

$$r_i = \frac{f_b(S_{IP})}{f_u(S_{IP})}$$

B-tagging at CDF

- Tagging algorithms depends on:
  - Hardware performance
  - Tracking
  - Vertexing
  - Alignment
- Retuning must be done after initial detector and reconstruction performance is understood.
  - Hardware changes
  - Improved tracking, primary and secondary vertexing, alignment
  - Hardware performance needed to tune realistic MC

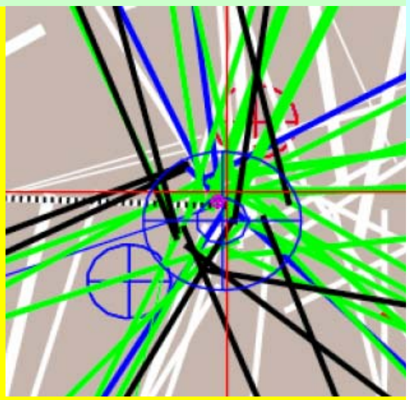


Run II started in APRIL 2001
- ISL cooling
  - April 2003 ISL included in tracking
  - May 2003 ISL and z-side included in SECVTX
- Detector noise on L00
  - L00 to be included in next release (later in 2004)

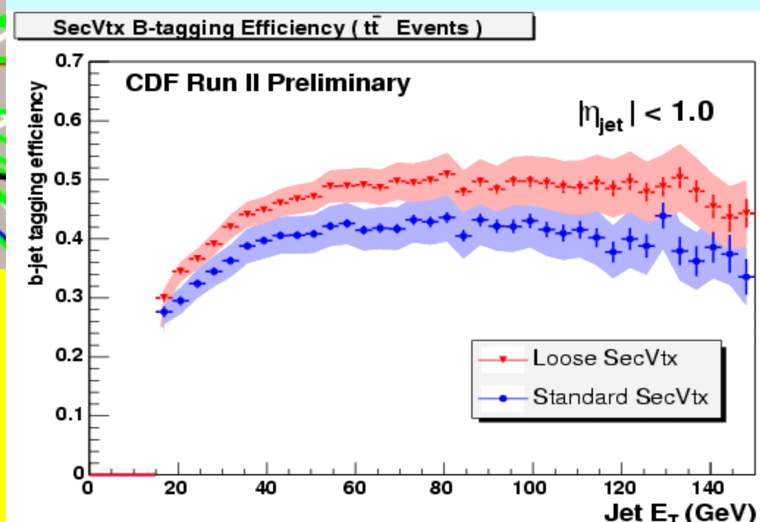
- SeCVTX algorithm developed in run I. Ported to run II in 2000
  - Pass 1: 3 track vertices
  - Pass 2: 2 track vertices

B-tagging timeline at CDF

- **Dec. 2002 SecVtx optimization for 2003 Winter conference:**
  - **SVX alignment and tracking code not optimal**
    - **Tight track selection**
    - **Loose vertex quality cuts**
  - **Run averaged beamline**
- **May 2003:**
  - **Event by event primary vertex with beam line constraint**
  - **Beam width function of z-position**
  - **Account beam variation in a run**



- **Summer 2003: first top and exotic analysis blessed using SecVtx**
- **Improved Tracking and alignment in Fall 2003**
  - **Loosen track selection**
  - **Development Loose SECVTX for double tag analysis (allow larger fake rate)**
  - **First blessing of double tag analysis Summer 2004**



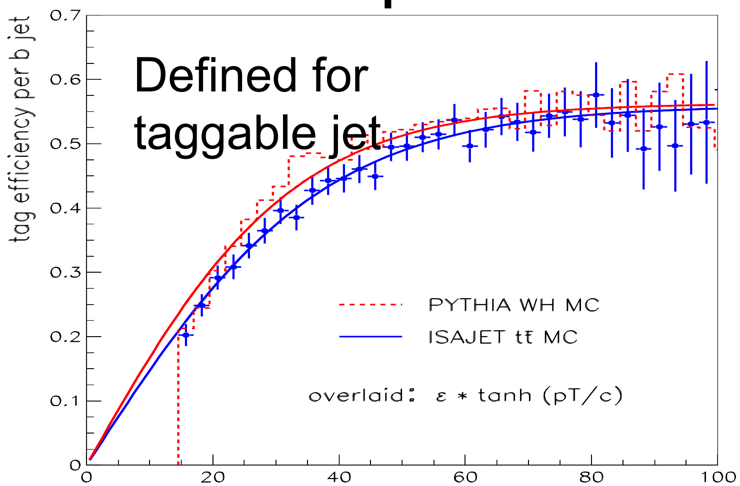
Organizational experience at CDF

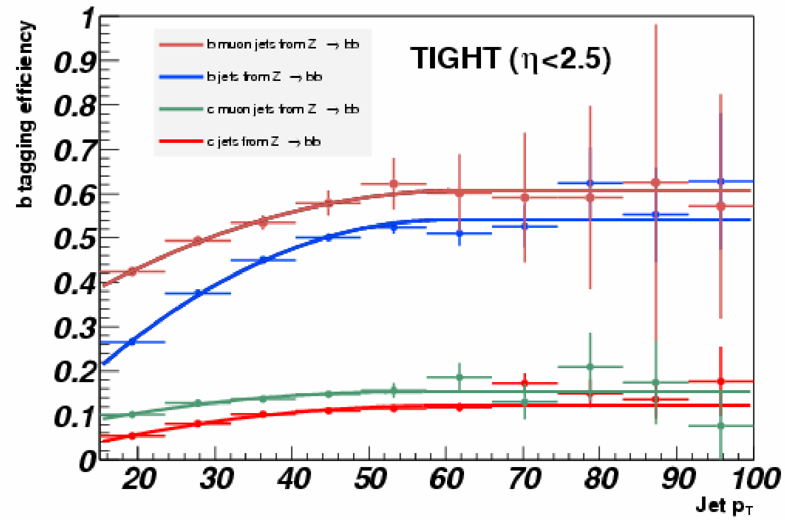
- Current b-tagging improvements:
  - tracking up to $\eta \sim 1.2$ (IO tracks)
  - More realistic MC simulation with new charge deposition model
  - Better alignment in Z.
- **Future: Would like to include forward tracking**
- B-tagging is a high level tool built on lower level objects subjected to change $\Rightarrow$ Maintenance and upgrades are necessary
- Once a b-tagging algorithm is working, it is difficult to motivate people to keep improving it
- Algorithm development at CDF was mostly by top group for top analysis
  - Top mass analysis in all hadronic channel needs very pure b-tagging
- Optimization for searches
  - Improved c-tagging ($t \rightarrow c$ LSP)
  - Or charm rejection
  - Sbottom search largest background is top (which yields b-jets)
    - might need algorithm with high b-tagging efficiency and “sufficient” rejection of light quark jet

Predictions and performance

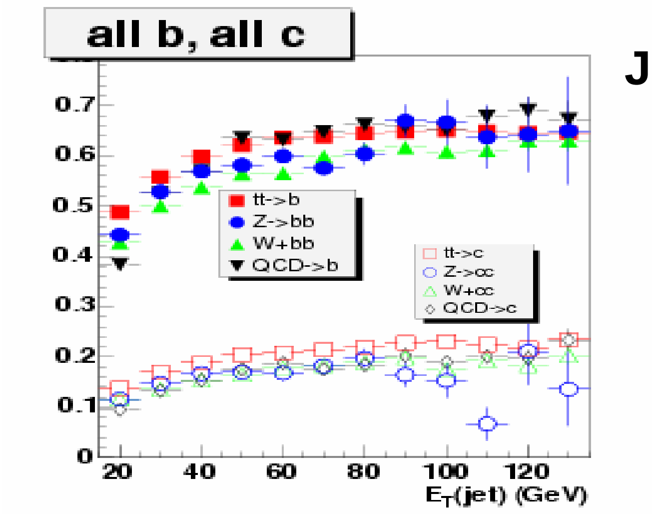
- **D0**

Predictions HEP 2001
Budapest - Chiarelli

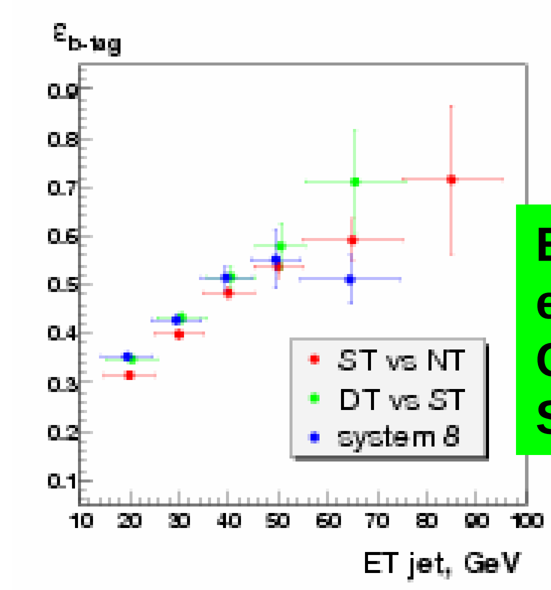




SVT



JLIP

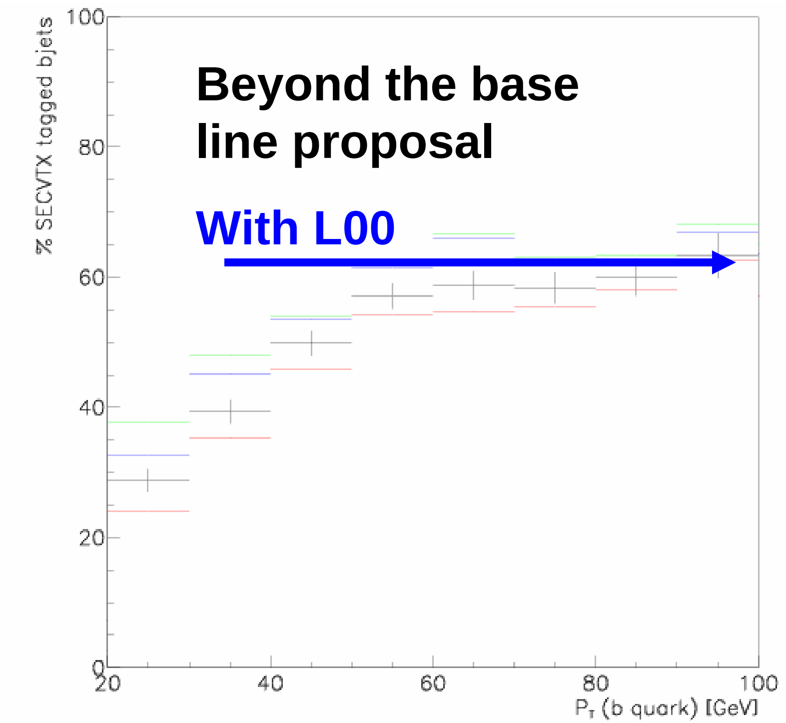


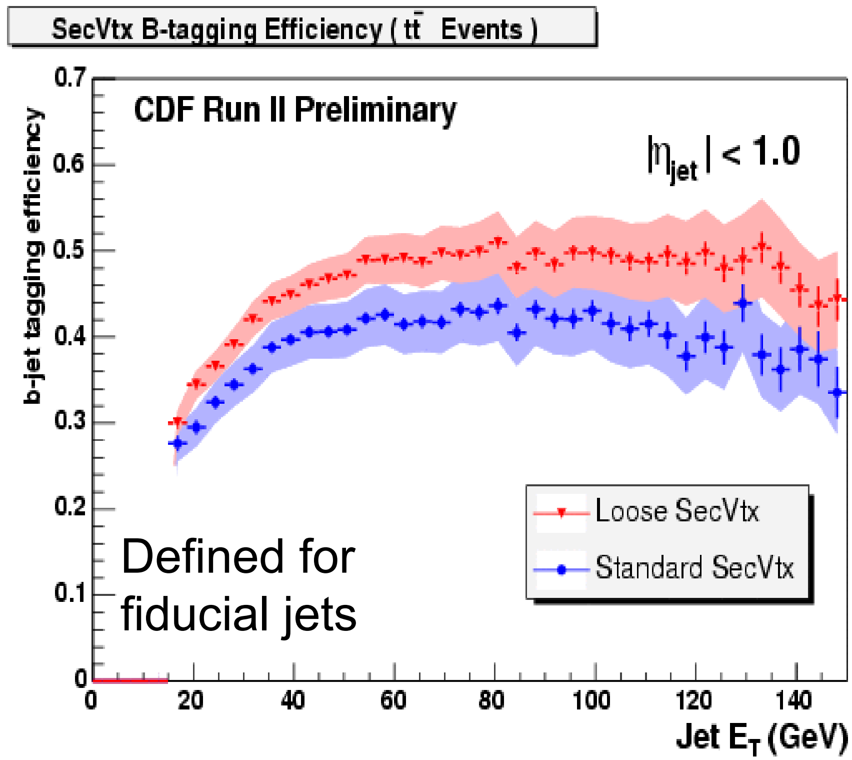
CSIP

Efficiency in top events:
CSIP=61%
SVT=58%

Predictions and performance

- **CDF**



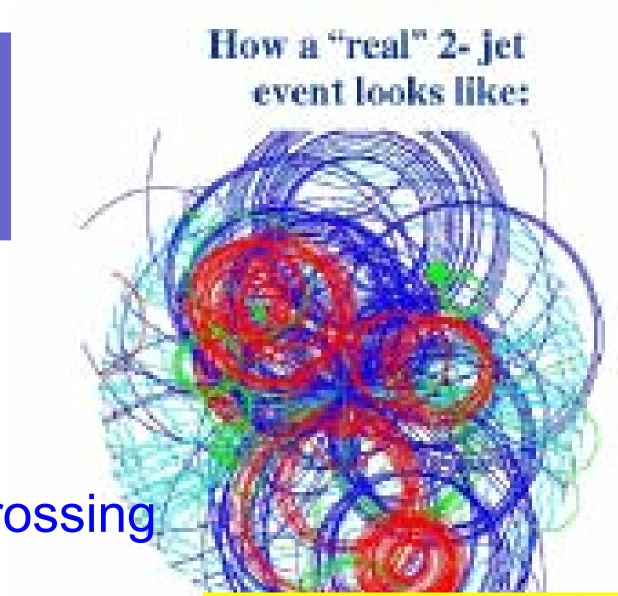


Expected efficiency in top events 65%

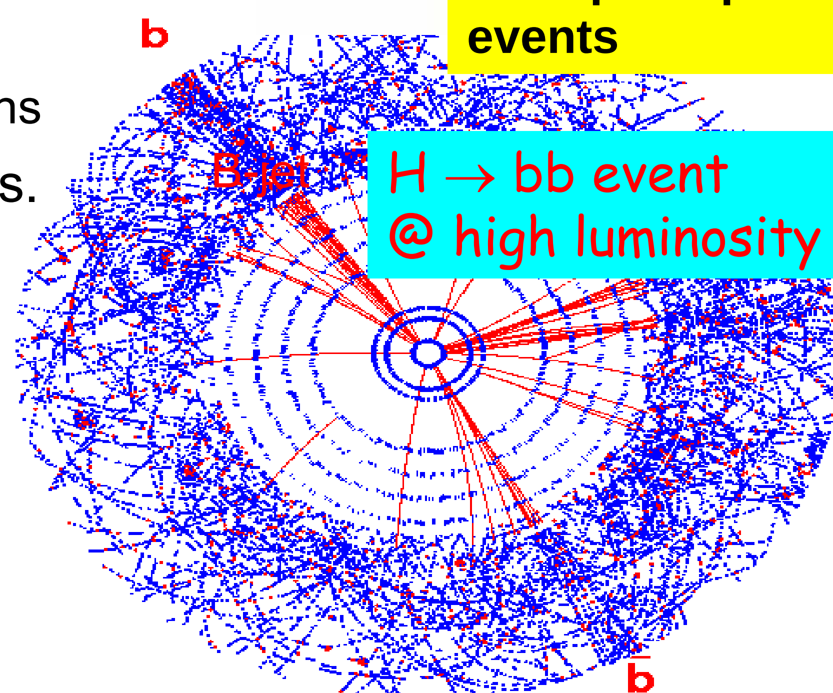
Efficiency in top events:
Winter 03 : 44.3%;
Summer 03: 52.3%;
Summer 04: 58.6% (loose tagger) and still improving

LHC challenges

- **Luminosity**
  - low-luminosity: $10^{33}cm^{-2}s^{-1}$ (first 3 years)
  - high-luminosity: $10^{34}cm^{-2}s^{-1}$
    - ~20 minimum bias events per bunch crossing
    - ~1000 charged tracks per event
  - Radius: 2cm 10cm 25cm
  - N_{Tracks} 10.0 1.0 0.10 /$cm^2$25ns
  - bigger probabilities of jet overlaps.
- **LHC detectors have been built for this environment**
  - Fine granularity
  - Fast response time
  - Excellent IP resolution
  - 90% reconstruction efficiency for high pt tracks inside jets



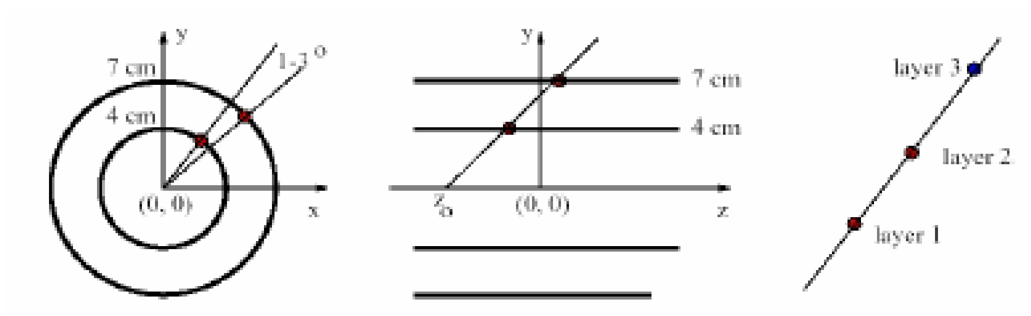
17 superimposed events

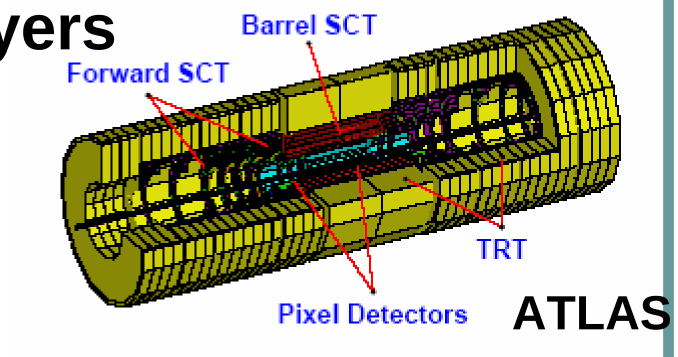


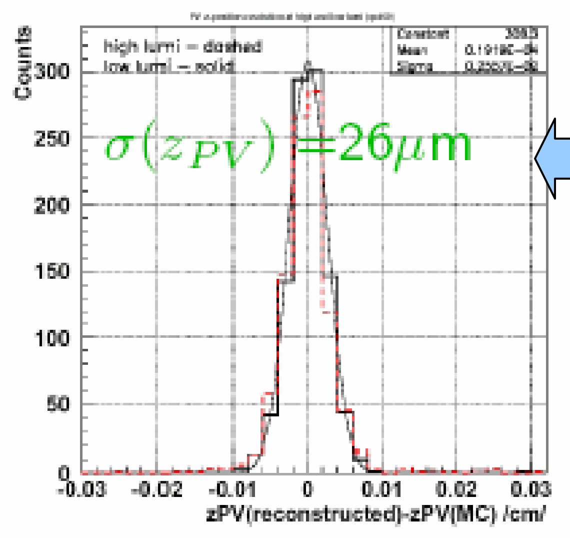
H → bb event
@ high luminosity

LHC challenges

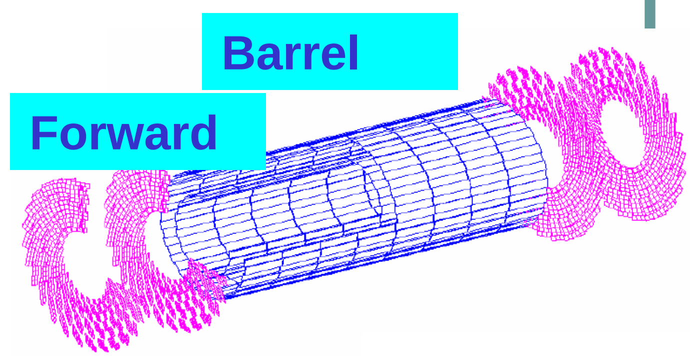
- **Fine pixel sensors close to beam provide excellent and fast primary vertex reconstruction**
- **Track seeding starts from pixel layers**



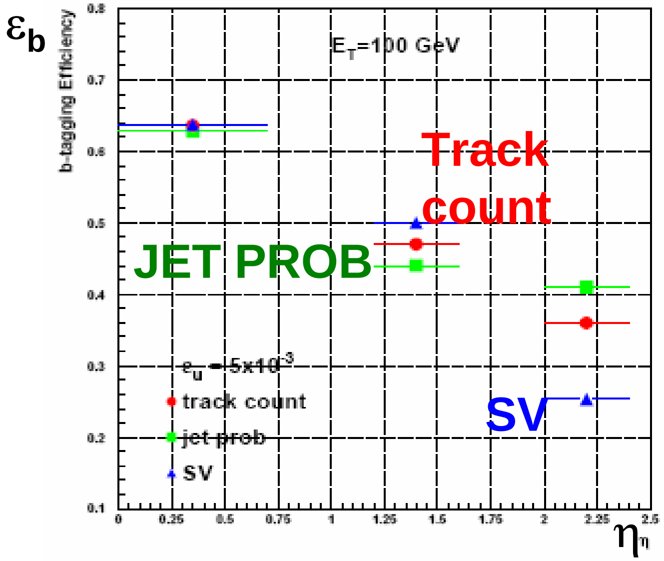


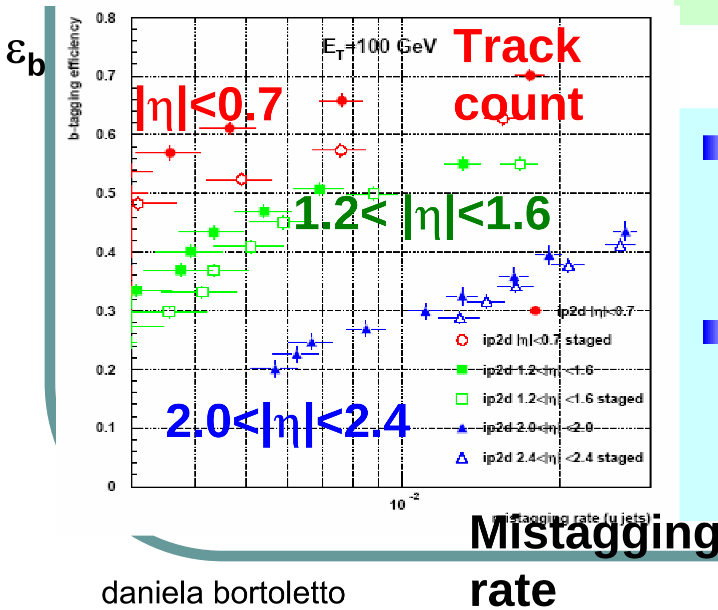


- Select PV with at least 3 tracks that cross the beam axis
- Full tracker resolution 15 μm



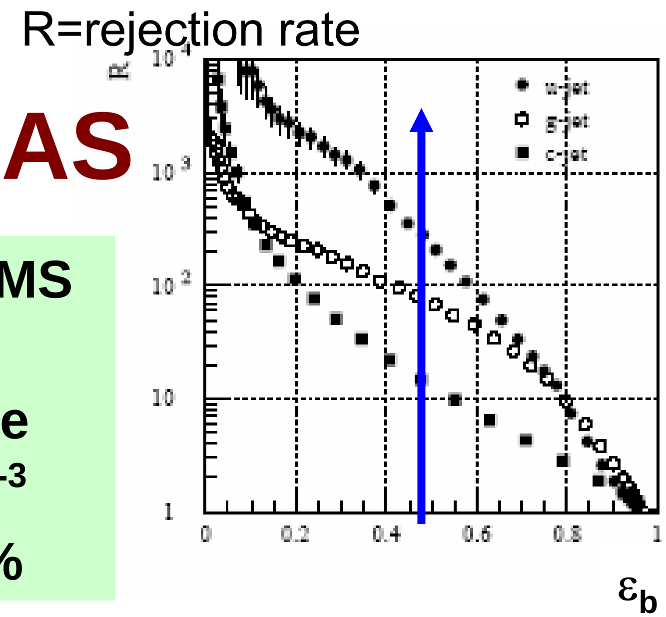
Expected LHC performance





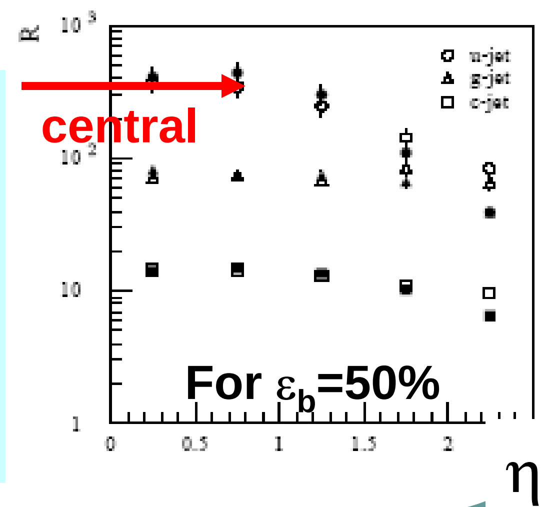
CMS

ATLAS



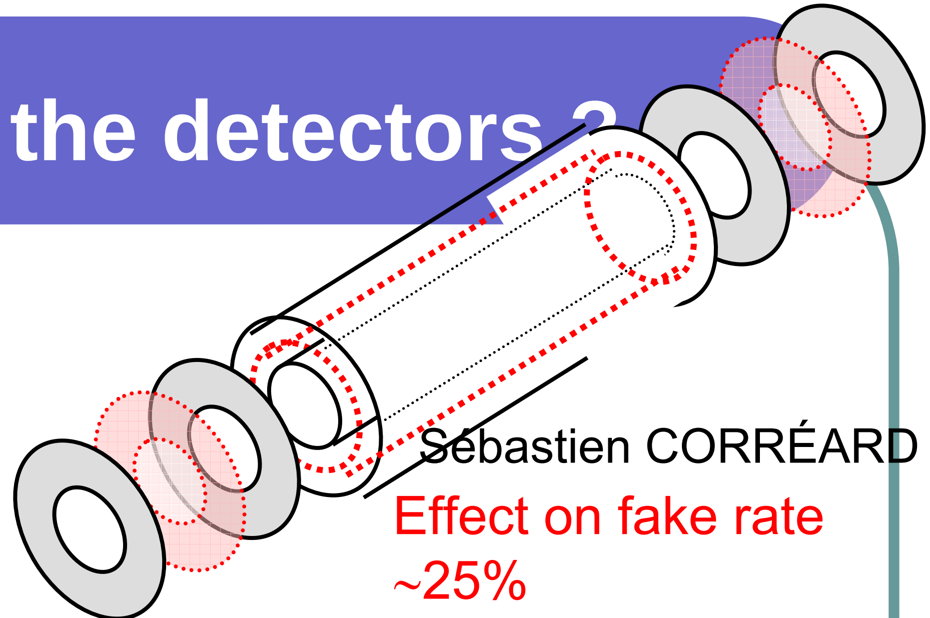
- Both Atlas and CMS achieve:
  - Mistagging rate for u-jet $\sim 5\times10^{-3}$
  - Efficiency~50%

- Staging the pixels: 2 barrels layers + 1 disk
- Loss of 10% average b-tagging efficiency



How well will we know the detectors ?

- Effect of staging in ATLAS
  - no pixel barrel #1
  - no pixel disk #2
  - no CTRT wheels
  - a *b*-layer pitch = 400 μm



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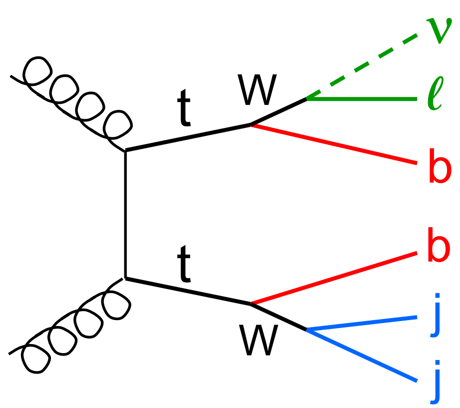
Effect on fake rate ~25%

time	Inefficiency on pixels & SCT		Inefficiency on *b*-layer pixels		Precision on alignment	
	module	**chip**	**module**	**chip**	**pixels**	**SCT**
Period 1 (months 1-2)	4%	3%	2%	1.5%	**100μm**	**300μm**
Period 2 (months 3-4)	2%	2.5%	1%	1.25%	**20 μm**	**60 μm**
Period 3 (months 5-6)	1%	2%	0.5%	1%	**10 μm**	**30 μm**
Period 4 (months 7-8)	1%	2%	0.5%	1%	**5 μm**	**15 μm**
Period 5 (after…?)	1%	2%	0.5%	1%	-	-

Calibration at the LHC

- Large data samples for calibrations:
- Top

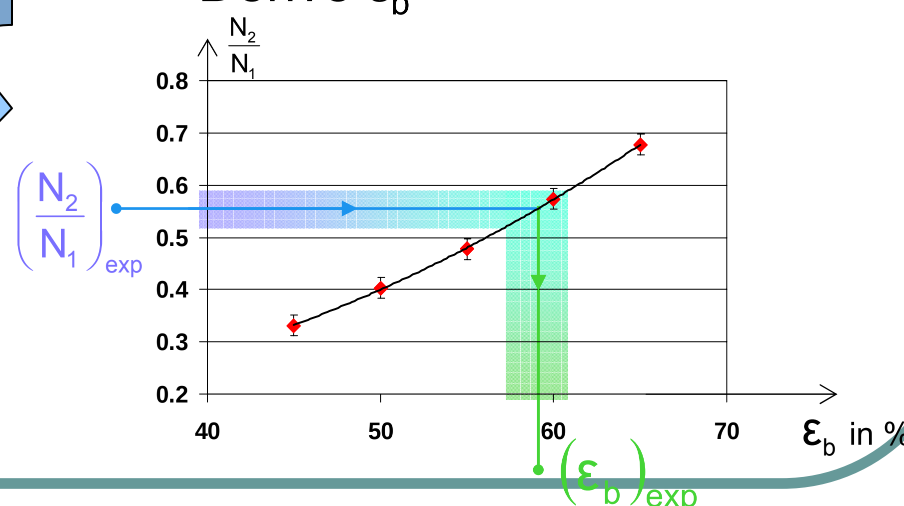


Sébastien CORRÉARD

- $Z \rightarrow \mu\mu \sim 1$ event/s
  - Calibrate absolute momentum scale (B field)

- Calibrate b-tagging efficiency using top ℓ+jet decay?
  - 2 *b*-jets
  - high cross-section: 2.5 M events 1 year at low luminosity
    - Predict the value of N_2/N_1, for different values of ε_b
    - Measure N_2/N_1 in data
    - Derive ε_b

$$\varepsilon_b \propto \frac{N_2}{N_1}$$

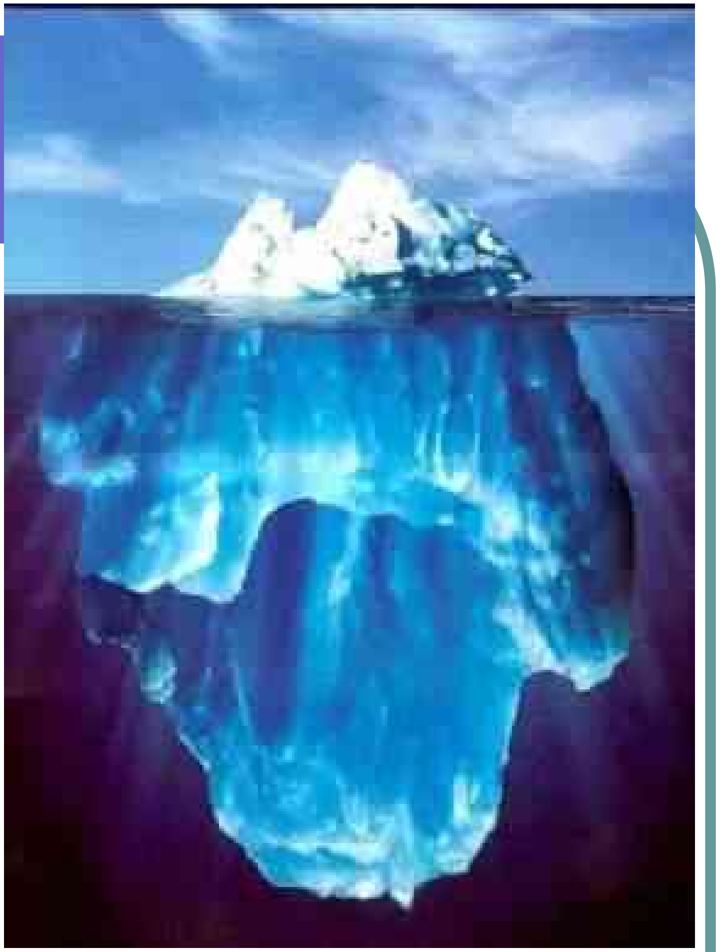


LHC challenges

- **What is the effect of the detector response, physics object definitions, calibration, and alignment procedures on the expected performance?**
- **CMS plans a TDR with feasibility studies of Higgs, SUSY, etc**
  - **Small number of full analyses in the most realistic possible scenarios**
  - **Analyses will include backgrounds, misalignment, and miscalibration**
- **Alignment**
  - **State of the art techniques ala SLD with 96 pixel elements:**
    - **Determine 578 corrections x from 2108 coefficients from residual fits C**
    - **Ax=C where is the A design matrix**
    - **Find A^+ such that $x=A^+c$ minimizes |Ax-C|**
  - **CMS has 20,000 independent silicon sensors…..**

Outlook

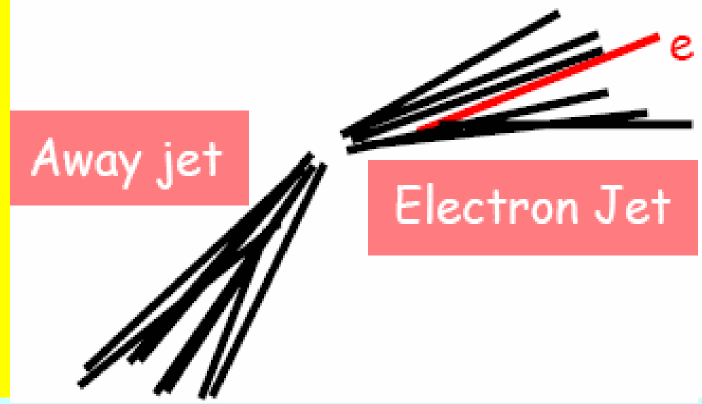
- We might find SUSY at the Tevatron ⇒ would give insight for LHC.
- Implementation of TeV analysis in LHC framework, validation of LHC techniques on TeV data might facilitate preparation for discovery
- Questions/ requests:
  - Was the simulation different from the real life at the TeV startup ?
  - Do the b-tagging efficiency and fake rate change with luminosity and # of primary vertices?
  - Micro-DST of the good TeV events with and without b-jets to tests LHC software
  - How much the mis-alignment detector affect the results?

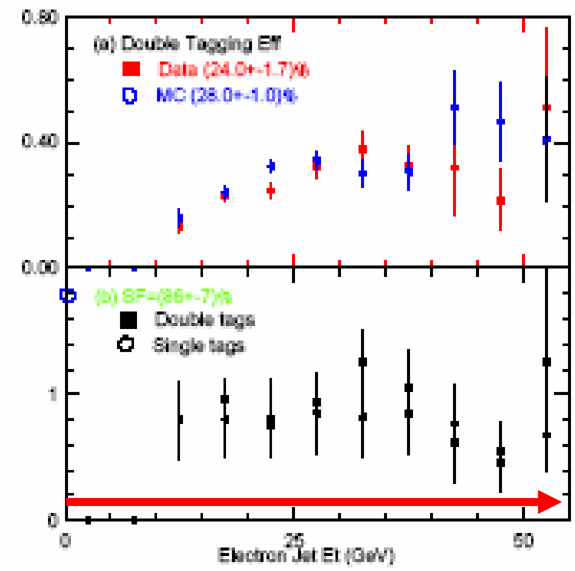


  - How do you calibrate the results.. using MC generators, which ones?
- As usual: Hard work is necessary

B-tagging efficiency

- **B-tag efficiency depends on**
  - **b- momentum and lifetime**
  - **Decay Charge multiplicity**
  - **Tracking performance (efficiency, resolution, material)**





- **Measurement**
  - **Use high statistics, high purity b-jets sample such as electron data**
  - **Both Jets with E_T>15 GeV**
  - **Tag away jet to increase purity**
  - **Measure efficiency in data and MC and correct with a scale factor**
  - **Aim: scale factor S=1**

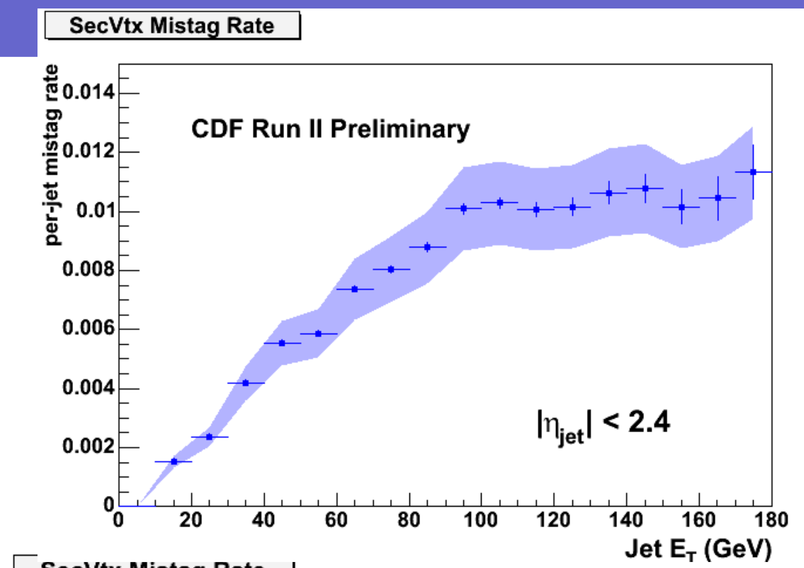
Not a great match to top and exotic physics

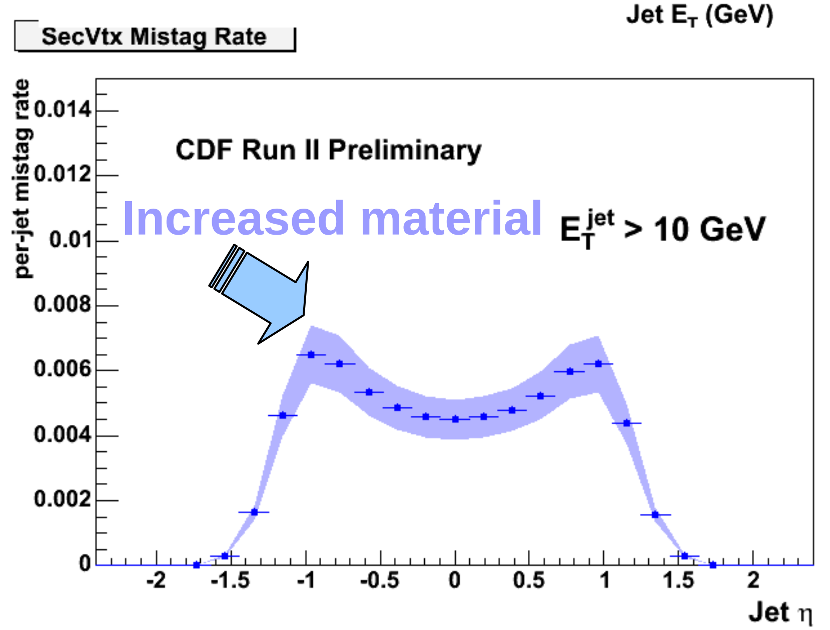
- **Scale factor**

$$\mathbf{S = 0.82 \pm 0.06}$$

Mistagging

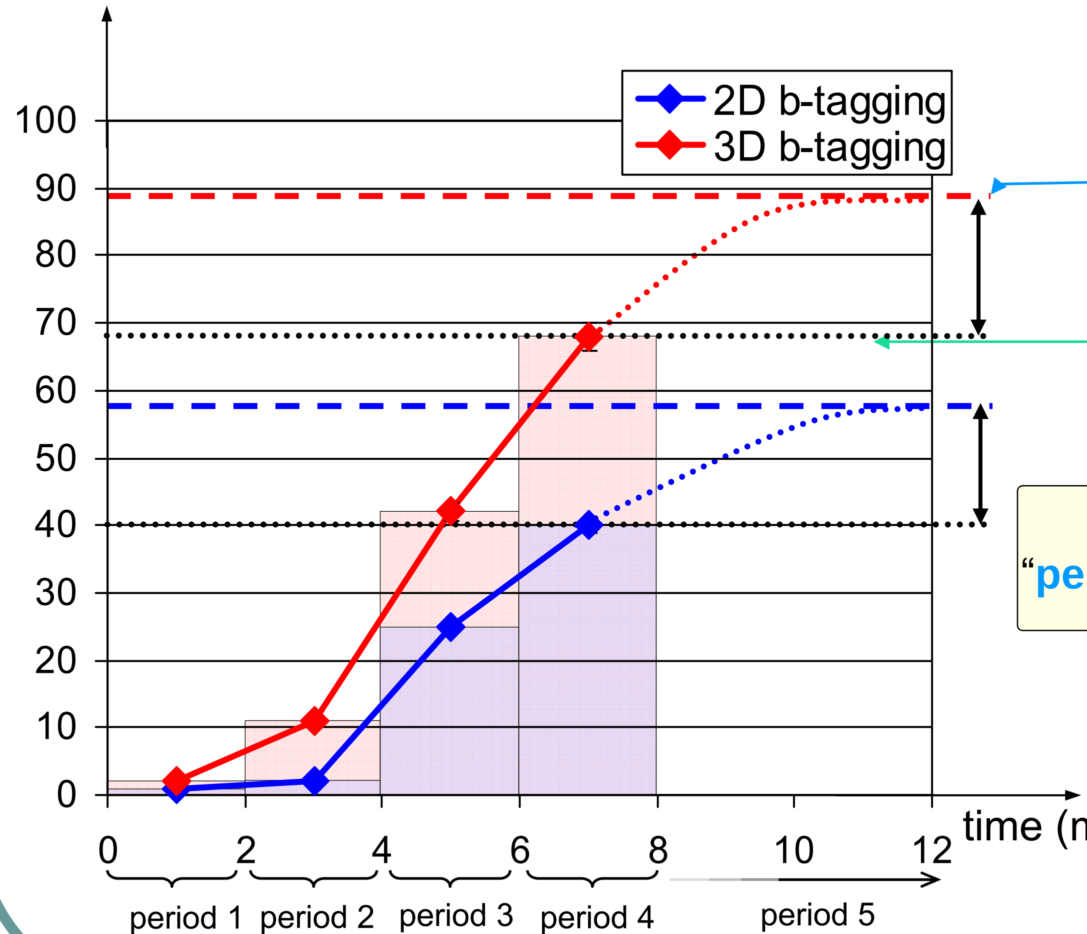
- Mis-tagging probability depends on :
  - Jet E_T
  - Jet η and ϕ
  - # of tracks in jet
  - Energy in the event
- Determined from the negative rate ($-L_{xy}$) in jet data. Corrected for material effects and long lived particles
- Build fake matrix
  - Use jet sample collected with different thresholds (20, 50, 70, 100 GeV)
  - Test on 4 jets sample and ΣE_T >100 GeV
- Correlation with MET not explored. But is important for searches





Effect on performance

R_u : light jet rejection for ε_b=60%



ATLAS

Athen's meeting 2003

Large difference between "**perfect**" and "**nominal**" alignment:

about 25% !

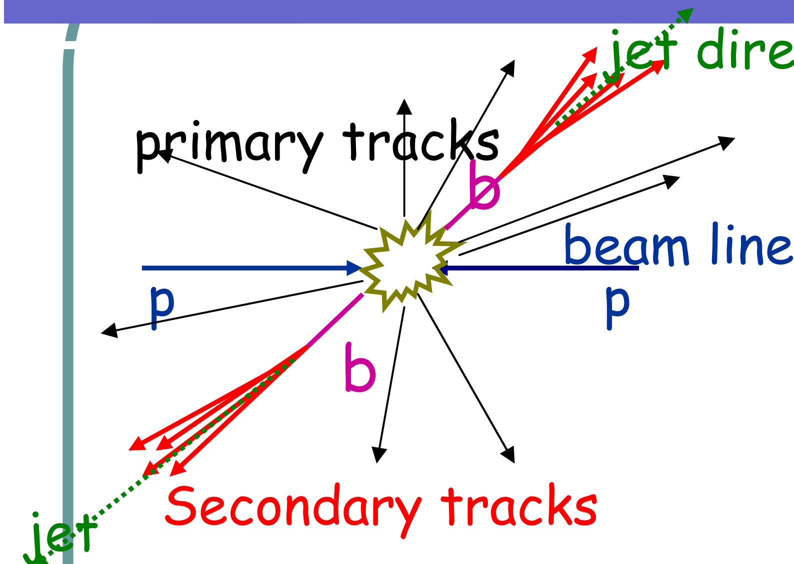
Sébastien CORRÉARD

Alignment at Atlas

- Alignment must not degrade any track parameters by 20%
- Precision placement during building: pixels (10/100 μm), strips (50/250 μm
- X-ray survey determine actual position 10/50 μm
- Continuous monitoring of deformation (scanning interferometer)
- Track alignment gives better local precision
- M(w) <15 MeV ,
  - 1 μm in r-Φ
  - B field to 0.02%
  - Detector Material known to 1%
  - P_T resolution to 1%
- Calibration with large sample of $Z \rightarrow \mu\mu$ possible

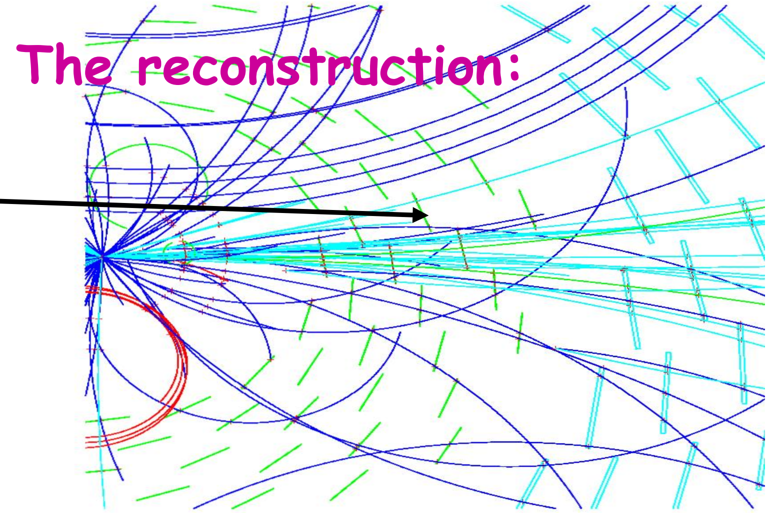
- Alignment algorithms under development:
  - χ^2 minimization (ALEPH and SLD)
    - Huge 30,000$\times$30,000 symmetric matrix
  - Iterative track fitting
    - Fit track
    - Plot hit residuals/module
    - Move module

CMS Trigger a b Jet with HLT



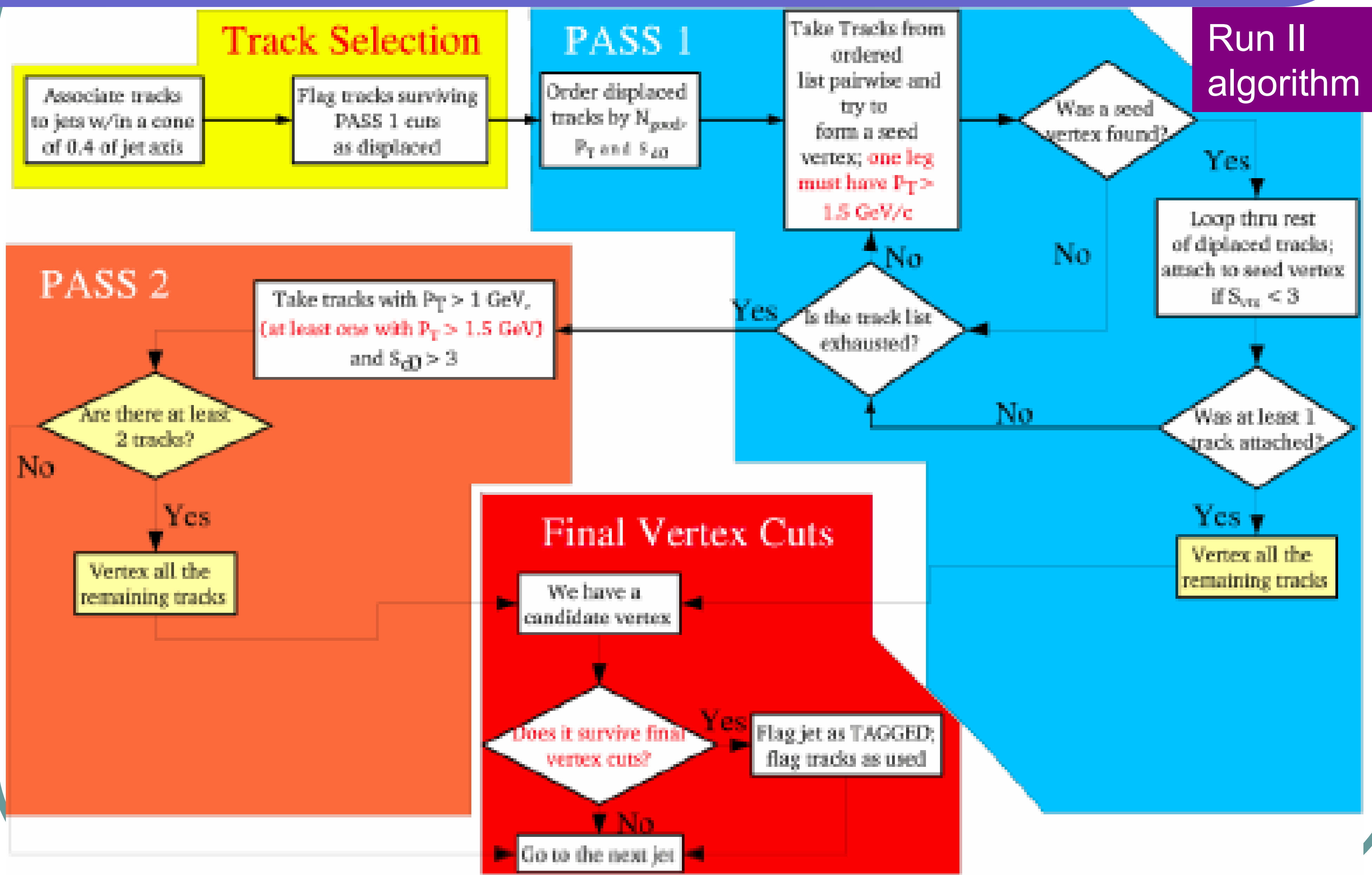
Sensible layers: where the "hit" is recorded

From hits the track is reconstructed



- From pixel hits and calorimeters:
  - The seed for tracks reconstruction is created around the LVL1 jet direction
  - Primary vertex is calculated
- Tracks are reconstructed in a cone of $\Delta R>0.15$ around the jet direction
- Tracks are conditionally reconstructed
- The Jet direction is refined using the reconstructed tracks

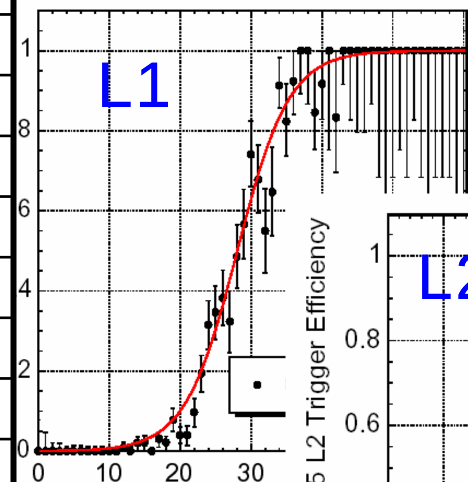
SECVTX ALGORITHM

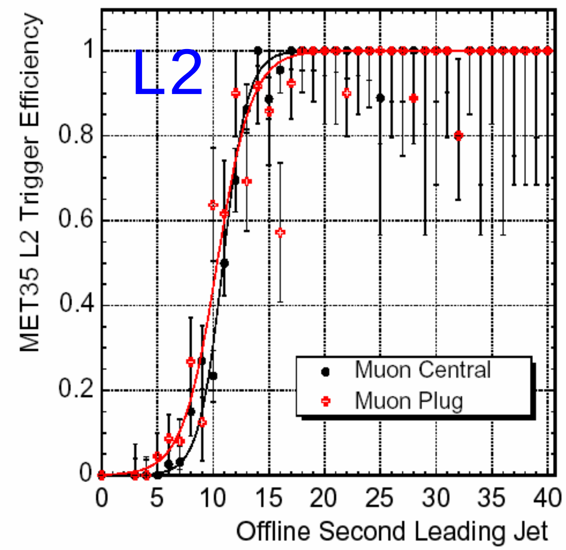


Trigger and systematics

Signal acceptance Systematic Uncertainties	Exclusive Single b-tag	Inclusive Double b-tag
	10.0%	10.0%
	7.5%	5.0%
	3.0%	3.0%
	2.0%	2.0%
	6.0%	6.0%
	2.0%	2.0%
	7.0%	14.0%
	2.5%	2.5%
	0.5%	0.5%
	0.5%	0.5%
Total	**16.5%**	**19.5%**

- L1: $\not{E}_{T\,trg} \geq 25$ GeV
- L2: Two clusters $E_T \geq 10$ GeV $,\eta = (0, 3.6)$
- L3: $\not{E}_{T\,off} \geq 35$ GeV





Backgrounds

Process	Exclusive Single B-Tag	Inclusive Double B-Tag
EWK	$5.66 \pm 0.76(stat) \pm 1.72(sys)$	$0.61 \pm 0.21(stat) \pm 0.19(sys)$
TOP	$6.18 \pm 0.12(stat) \pm 1.42(sys)$	$1.84 \pm 0.06(stat) \pm 0.46(sys)$
QCD	$4.57 \pm 1.64(stat) \pm 0.57(sys)$	$0.18 \pm 0.08(stat) \pm 0.05(sys)$
Total Predicted	$16.41 \pm 1.81(stat) \pm 3.15(sys)$	$2.63 \pm 0.23(stat) \pm 0.66(sys)$

$Wjj \rightarrow e\nu jj$
$Wjj \rightarrow \mu\nu jj$
$Wjj \rightarrow \tau\nu jj$
$Zjj \rightarrow eejj$
$Zjj \rightarrow \mu\mu jj$
$Zjj \rightarrow \tau\tau jj$
$Zjj \rightarrow \nu\nu jj$
$Zjj \rightarrow b\bar{b}jj$
ZZ
WZ
WW

EWK backgrounds estimated using ALPGEN + HERWIG MC samples

- QCD-multijet
  - HF QCD MC
  - fake b-tags

Fake b-tags are estimated using parameterization of the neg. tag rates obtained from data

- QCD uncertainty dominated by jet energy scale uncertainty