Top Phys. @ the LHC

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Outline

Introduction, top uniqueness.

Precision tests & conservation laws:

(i) Low p_T region.

(ii) High p_T region.

Hunting resonances, the t-jets challenge.

Top FCNC & flavor @ LHC.

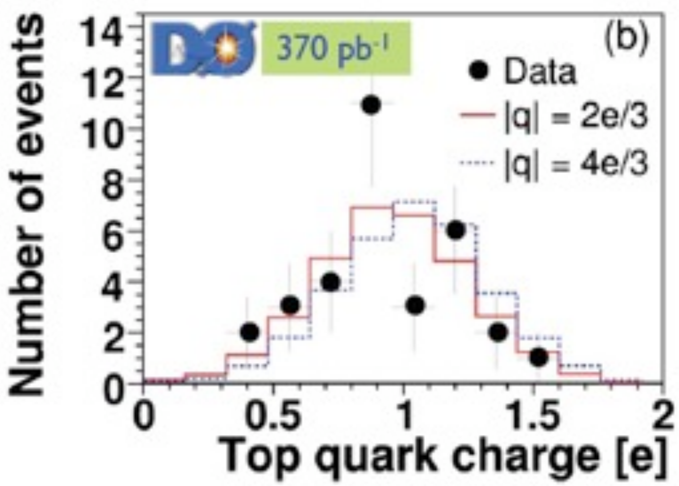
Conclusions.

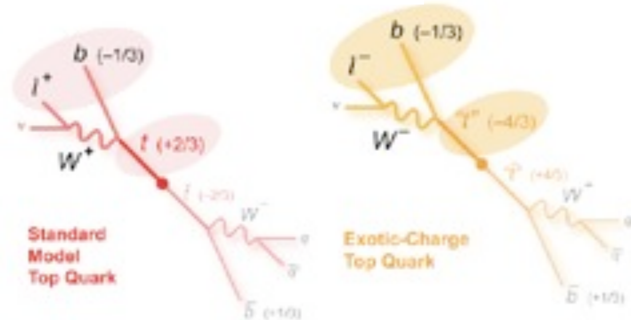
Introduction

- In the SM (& beyond) top is unique:
  only ultra heavy quark, $m_t \sim \langle H \rangle$;
  induce most severe fine tuning;
  controls flavor & custodial violation;
  linked to EW breaking in natural models.
- Direct info' is limited [Tevatron, $O(10^3)$].
- At the LHC: 10^7 tops/yr (eventually).
- SM: more than 10^4 tops/yr with $\gamma_t \geq 5.$

t-sector what's known (conservation laws)?

- Top charge: |q|=4e/3 excluded at 92% C.L.





Requires b-quark charge from jet charge

Recently confirmed by CDF, excluded by 82%.

- $t-\bar{t}$ mass difference (test of CPT & systematic):

D0 (1 fb^{-1}):
Δm_t=3.8 ± 3.7 GeV

Consistency "sanity" checks

- Top coupling, V_{tb} (single top):
  - In March 2009 the Tevatron experiments reported observation of with about **5** σ significance (to be published in PRL this week)
  - CDF and D0 combined their results using a Bayesian approach:

Tevatron (3.2 fb^{-1}):
$\sigma_t = 2.76^{+0.58}_{-0.47}$ (stat+syst) pb

LP09

Tevatron (3.2 fb^{-1}), PRD66 054024, 2002:
$|V_{tb}| = 0.91 \pm 0.08$ (stat+syst)

SM: $0.999133^{+0.000044}_{-0.000043}$

- Top width:

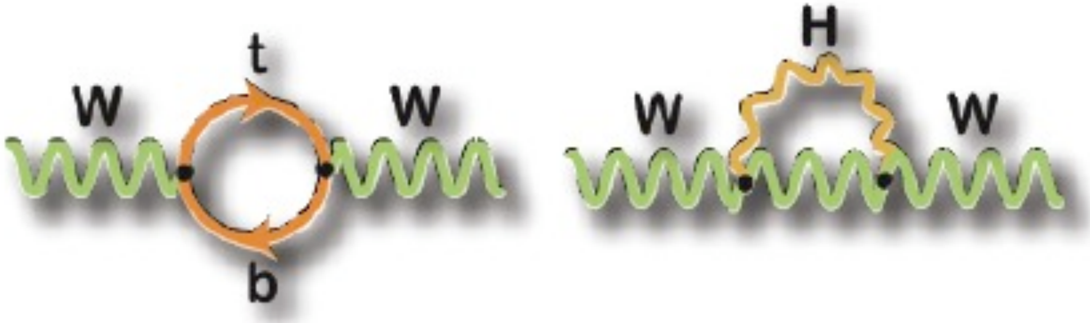
$$\Gamma_t \;<\; 13.1 \text{ GeV at } 95\% \text{ C.L.}$$

SM (weakly coupled): 1.5 GeV

Precision tests

- Top mass:

Tevatron (Winter 09):
m_t=173.1 ± 0.6 (stat) ± 1.1 (syst) GeV
m_t=173.1 ± 1.3 (stat+syst) GeV



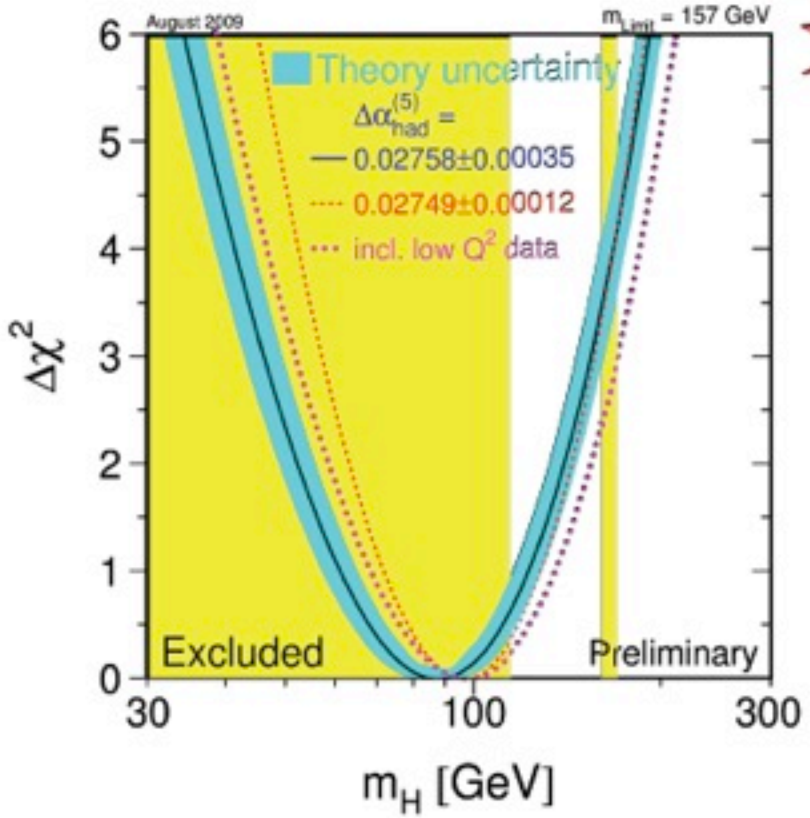
$\Delta r \propto m_t^2$ $\Delta r \propto \log m_H$

Precision tests

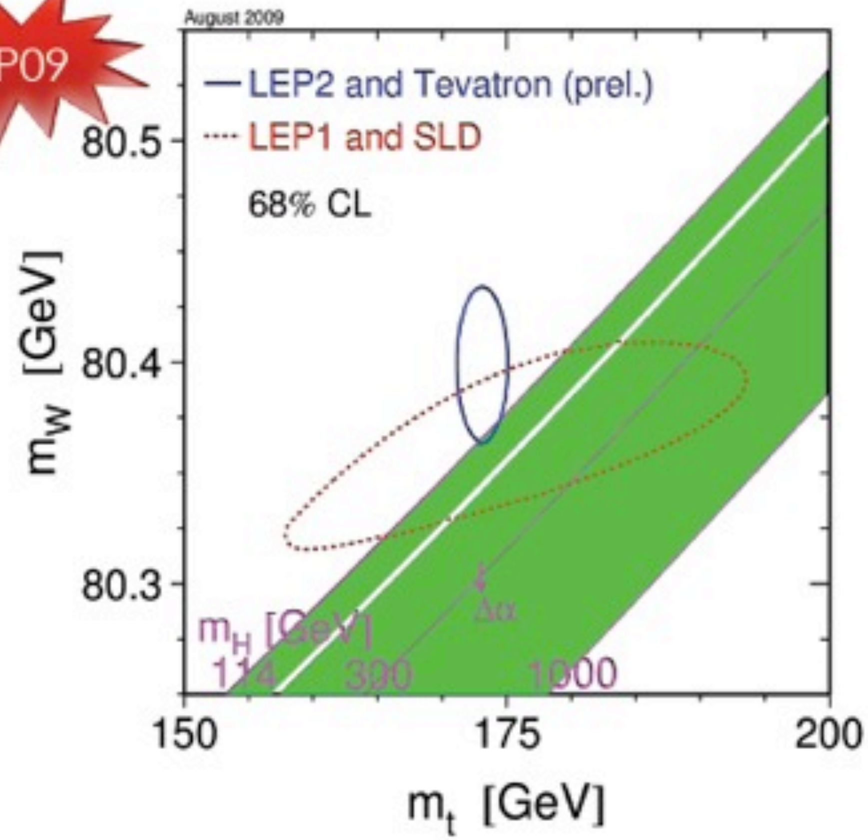
- Top mass:

Tevatron (Winter 09):
m_t=173.1 ± 0.6 (stat) ± 1.1 (syst) GeV
m_t=173.1 ± 1.3 (stat+syst) GeV

- m_H = 87+35-26 GeV
- m_H < 157 GeV (95% CL)
- m_H < 186 GeV (when LEP limit included)

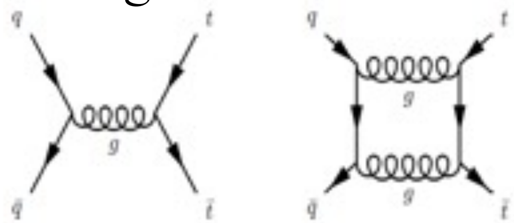


LP09



Precision tests

- **Forward Backward asym':** $A_{fb} = \frac{N_+ - N_-}{N_+ + N_-}$
  - N_+ is number tops has with larger rapidity than anti-tops.
  - At tree level requires both axial & vector couplings @ production & decay.
  - Very small at the SM, generated dominantly via NLO QCD.



$$A_{FB}^{p\bar{p}} = 0.193 \pm 0.065\ (\text{stat.}) \pm 0.024 (\text{syst.})$$

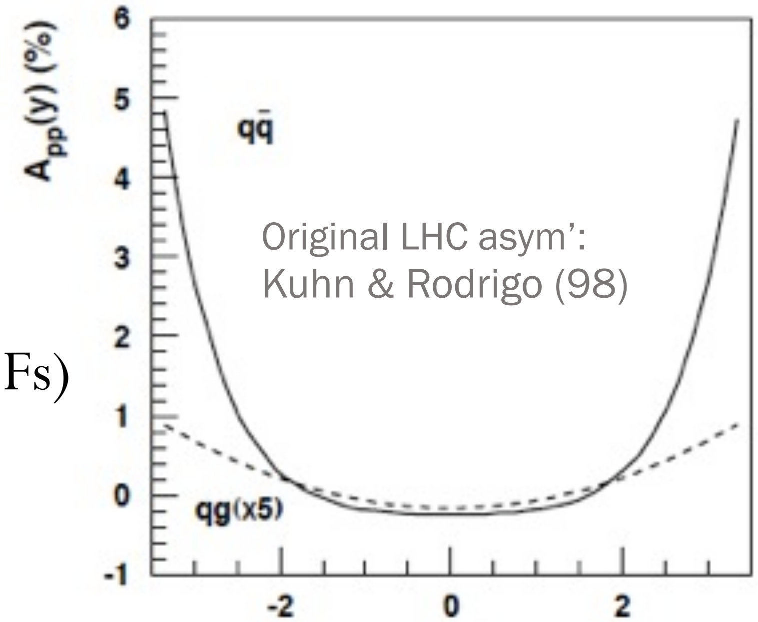
$$\text{SM: } 0.05 \pm 0.015\ (\text{inclusive})$$

O. Antunano, J.H. Kuhn and G. Rodrigo, Phys. Rev. D 77, 014003 (2008); M.T. Bowen, S. Ellis and D. Rainwater, Phys. Rev. D 73, 014008 (2006); S. Dittmaier, P. Uwer, S. Weinzierl, Phys. Rev. Lett. 98, 262002.

A_{FB} @ the LHC?

♦ 2 problems:

- Xsec' dominated by gluons => no asym'.
- How to define forward & backward? Boost (PDFs)



New phys. (NP) could yield large effects but at higher q^2 (for instance due to resonances).

For ex.: Frederix and F. Maltoni (08) axigluon and also Z' models.

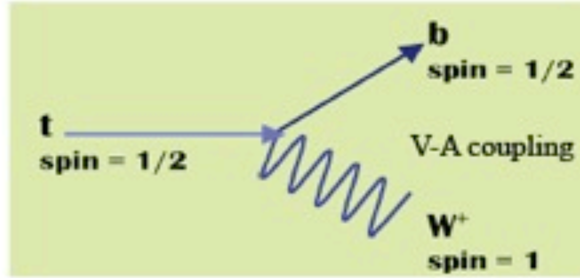
Effect could be induce due to NLO interference with vector resonance, sensitive to qqbar production (KK gluon).

Meade, Perez, Randall, unpublished.

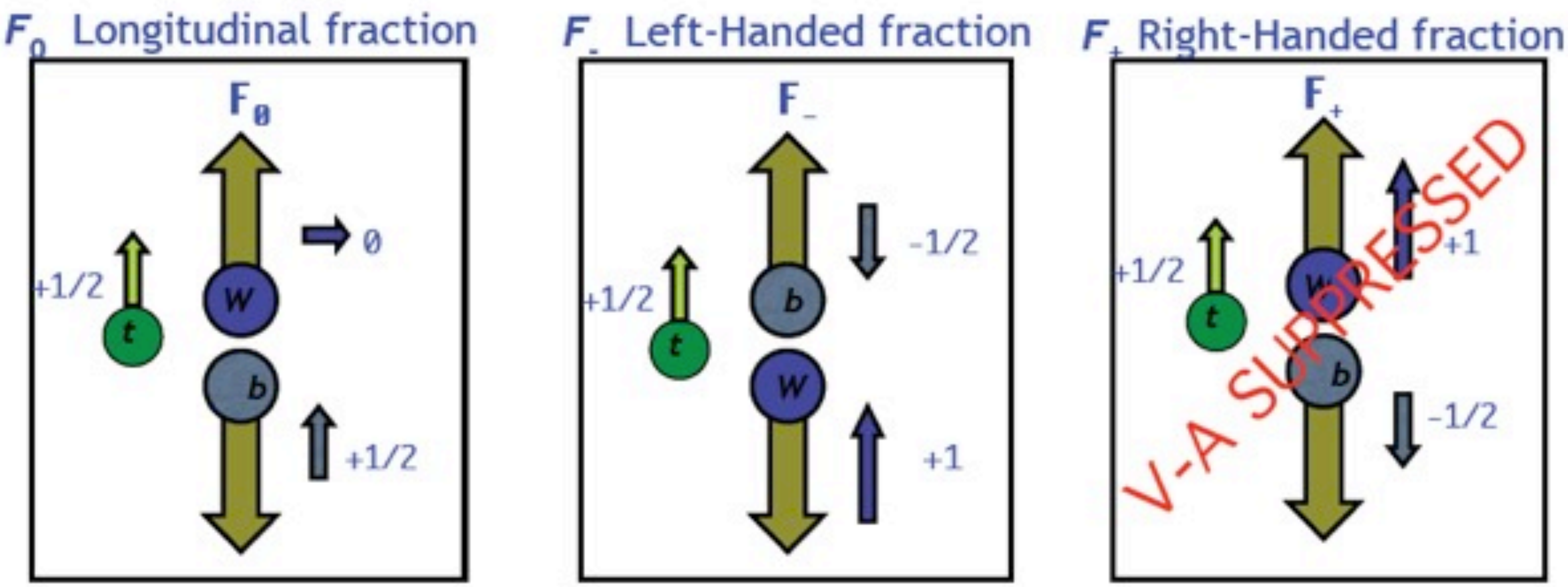
W polarization

Are there new interactions in top quark decay ?

- Positive helicity F_+ suppressed by chiral factors $\sim M_b^2 / M_W^2$
- Relative fraction of F_0 is:



$$F_0 = \frac{M_t^2 / 2M_W^2}{1 + M_t^2 / 2M_W^2} \cong 0.7$$



F_0 - CDF: 0.62 ± 0.11 D0: 0.490 ±0.106 (stat) ±0.085 (syst); SM: 0.7

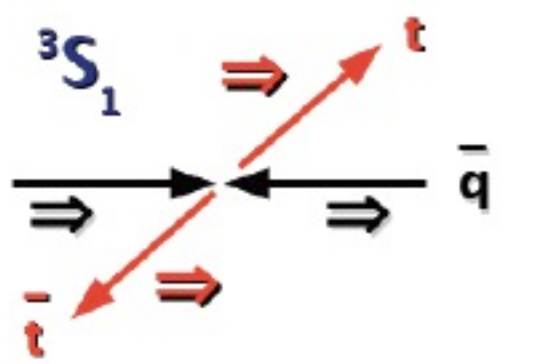
F_+ - CDF: -0.04 ± 0.05 D0: 0.110 ±0.059 (stat) ±0.052 (syst); SM: 0

Interesting NP model/model indep study?

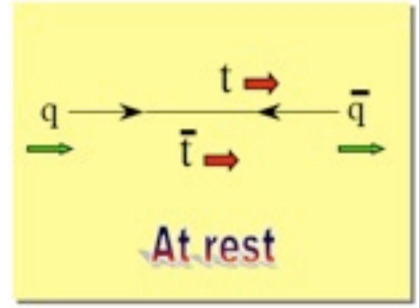
Spin-Spin Correlation

Near theshold!

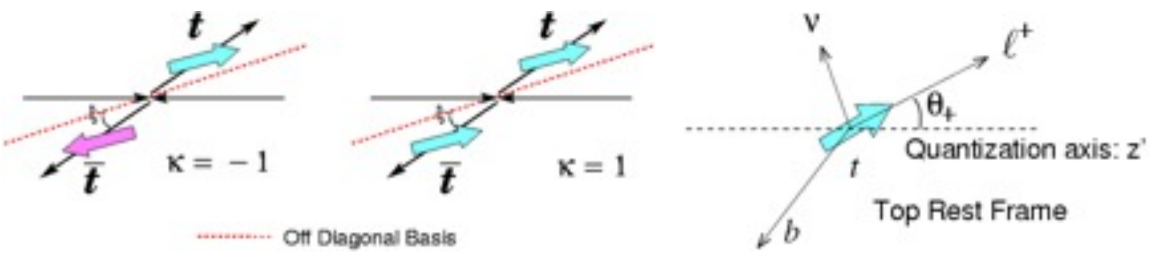
Tevatron



LHC is via gluons.



- Production, Spin-Spin correlation:



$$\frac{1}{\sigma}\frac{d^2\sigma}{d\cos\theta_+ d\cos\theta_-} = \frac{1+\kappa\cos\theta_+\cos\theta_-}{4}$$

$$\kappa = \frac{N(\uparrow\uparrow)+N(\downarrow\downarrow)-N(\uparrow\downarrow)-N(\uparrow\downarrow)}{N(\uparrow\uparrow)+N(\downarrow\downarrow)+N(\uparrow\downarrow)+N(\uparrow\downarrow)}$$

Tevatron: SM predicts κ=0.78

LHC improve by O(10)

D0 (4 fb^{-1}):
$\kappa = -0.17^{+0.64}_{-0.53}$

Beam axis

CDF (2.8 fb^{-1}):
$\kappa = 0.32^{+0.55}_{-0.78}$

Ultra relatistic limit, LHC

Polarization asym'

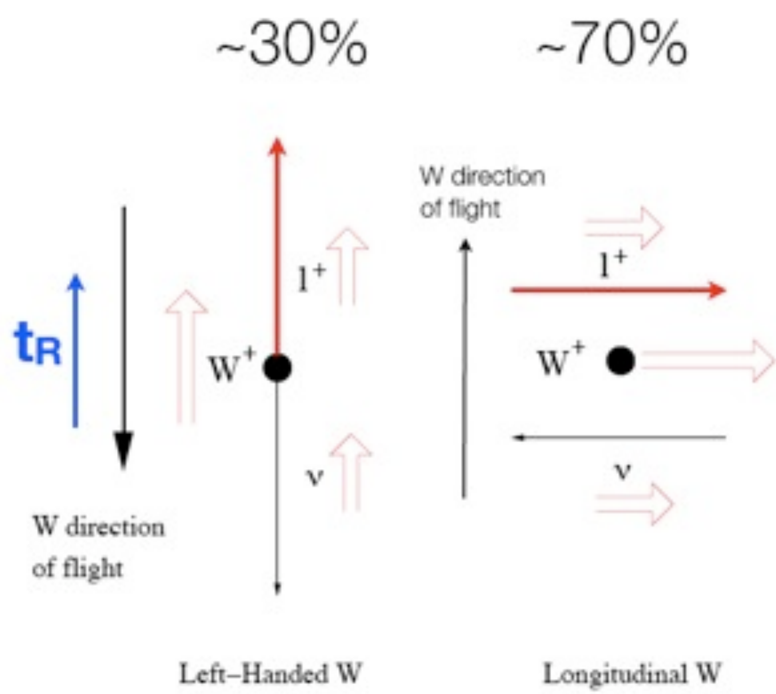
♦ For $m_{t\bar{t}}^2 \gg 4m_t^2$ helicity=chirality;

For t_R we expect more forward leptons:

$$P_{LR} \equiv 2 \times \frac{N_+ - N_-}{N_+ + N_-}$$

Top Polarization

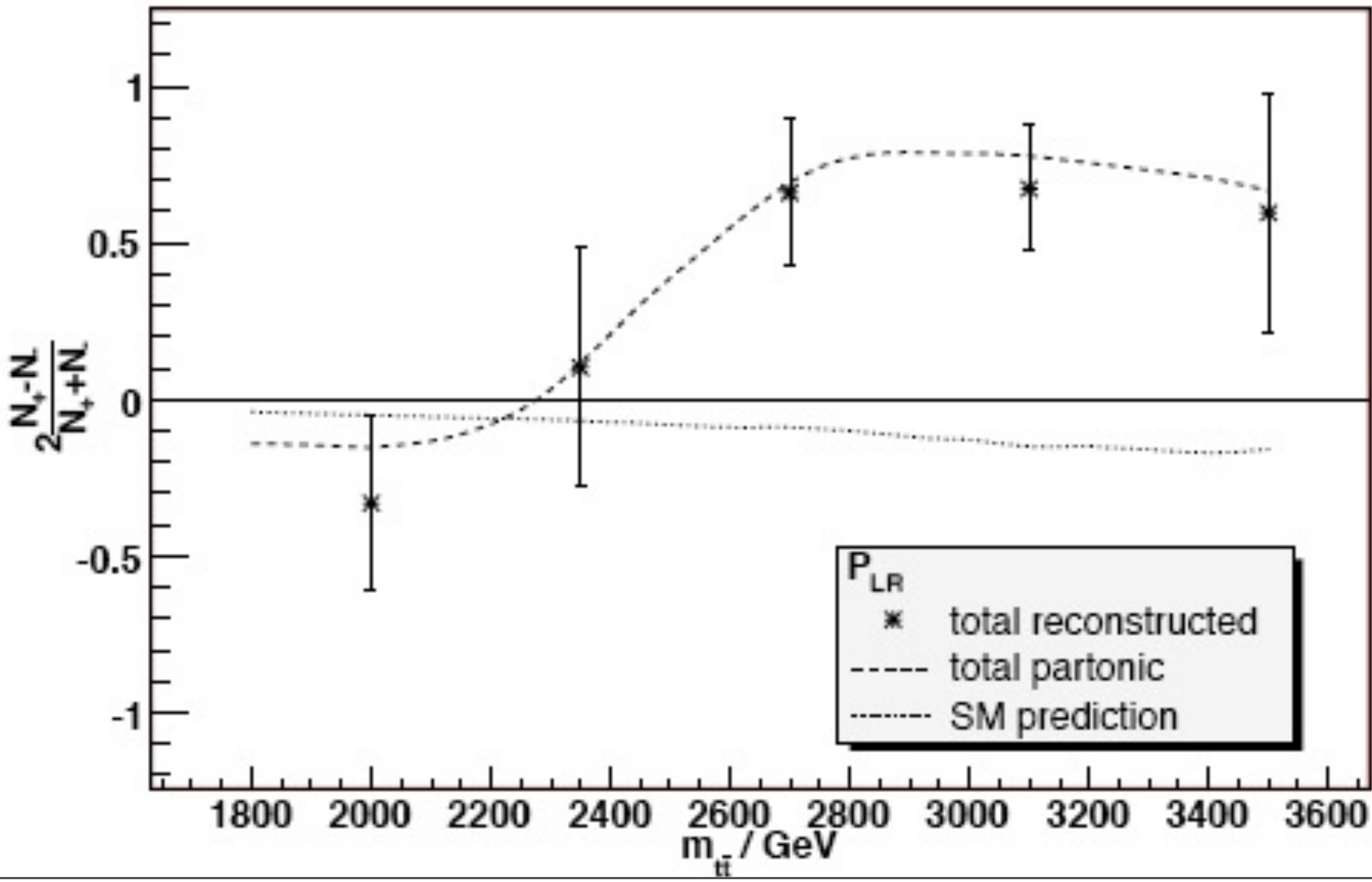
- lepton:forwarded for t_R
  back-warded for t_L



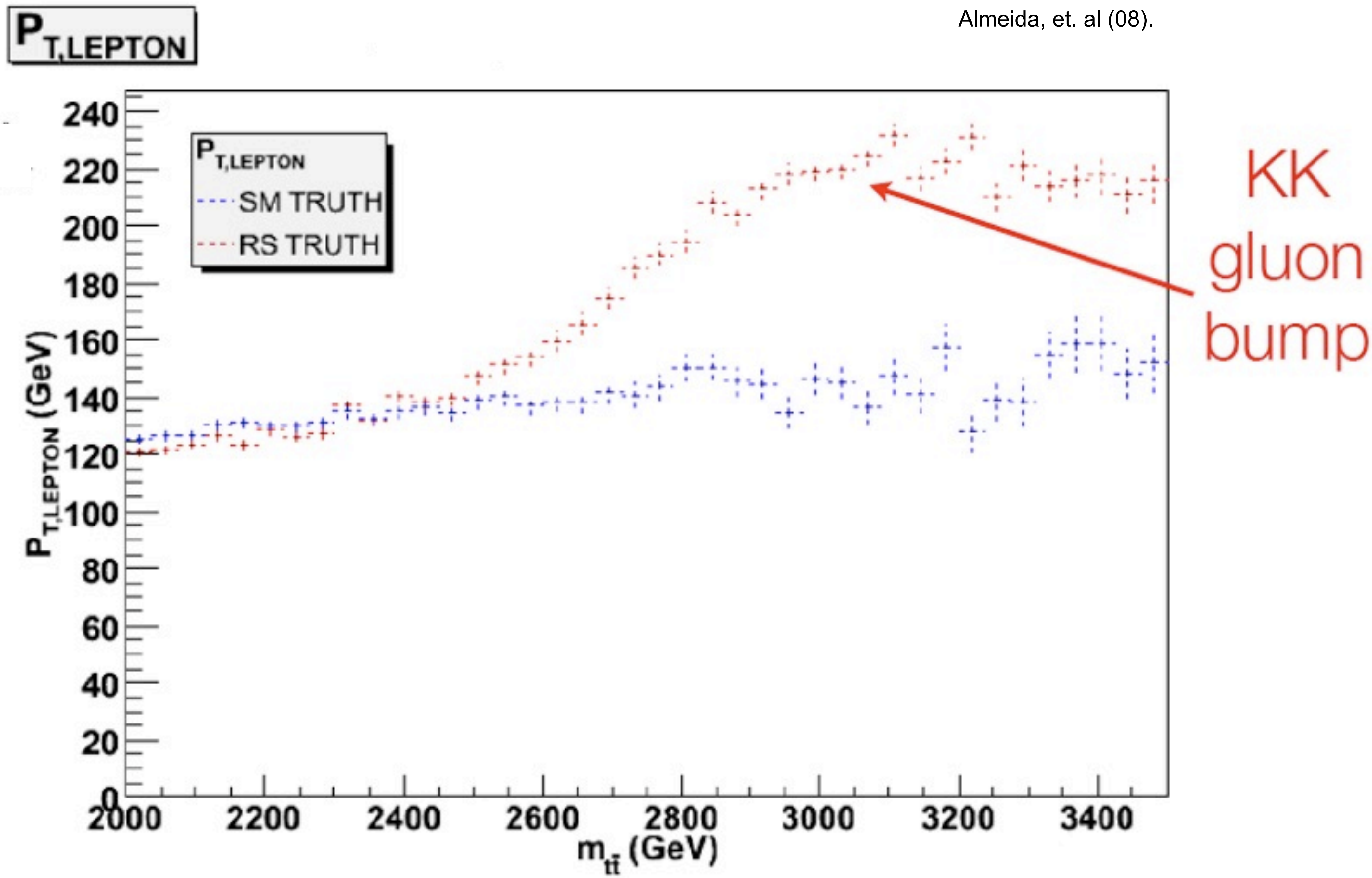
Measu' of diff' pol' asym, ex. KK gluon

Within the SM => 0!

Agashe, et. al (06).

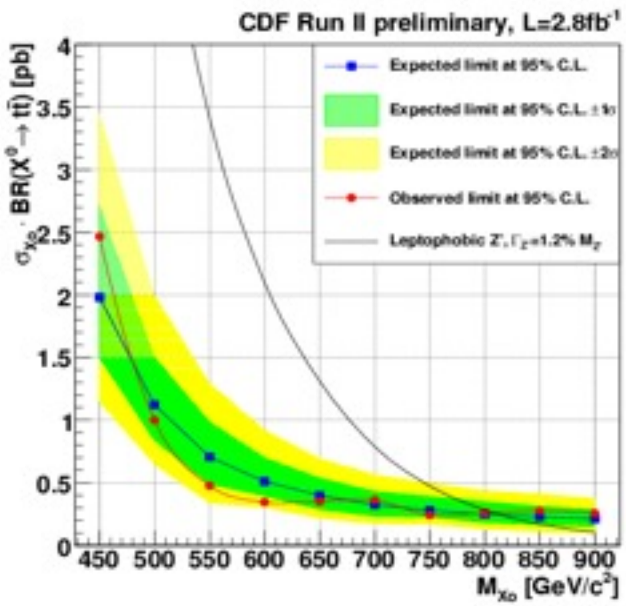


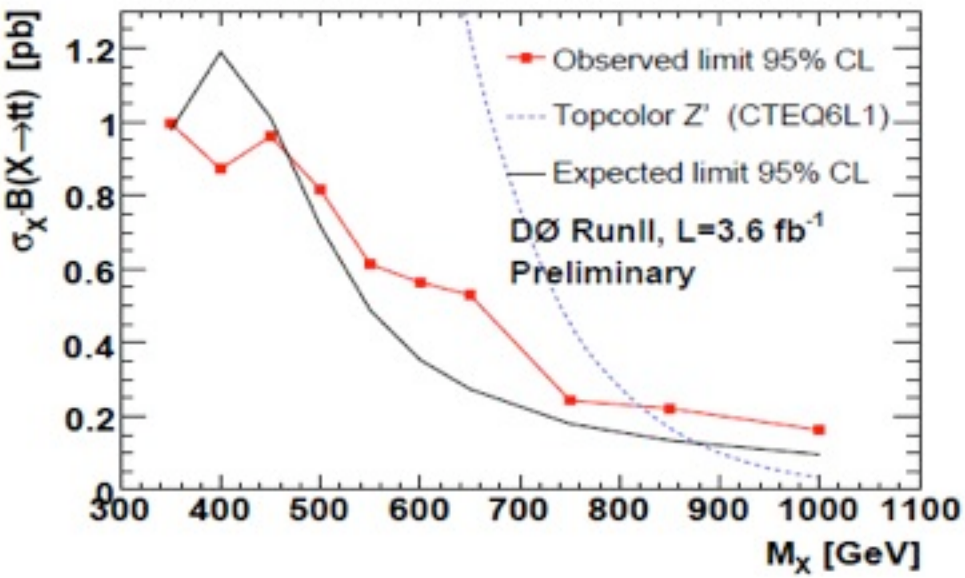
polar' without derived quantities?



Bounds on resonances from ttbar

- The limit is set using M_{tt} distributions



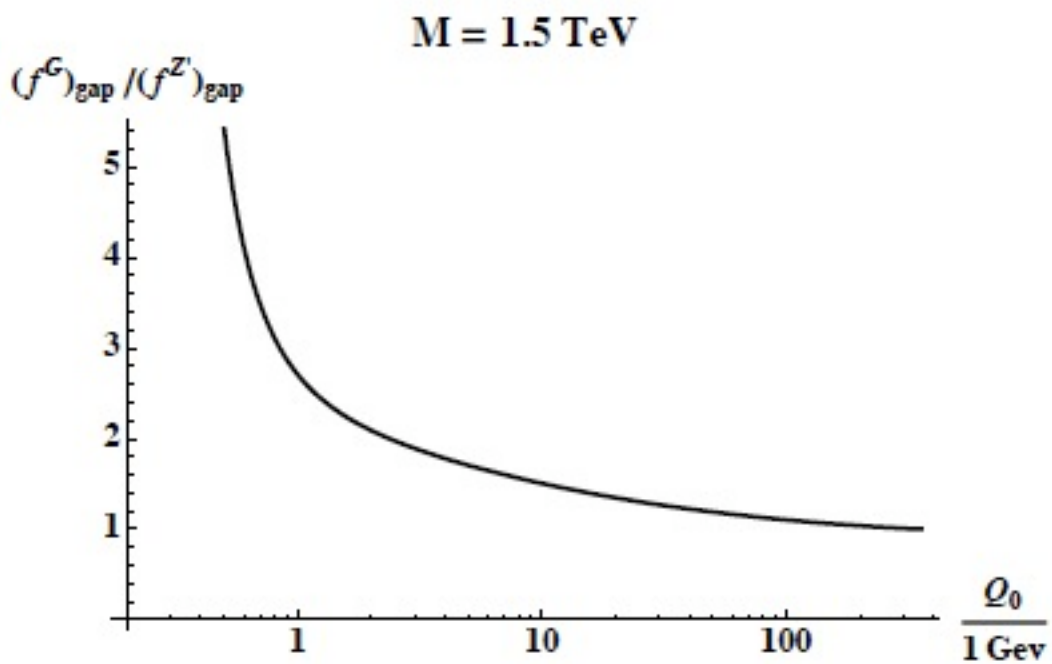


For topcolor-assisted technicolor $M_{Z'}$ > 820 GeV (D0) and $M_{Z'}$ > 805 GeV (CDF)

Color singlet vs Octet?

Sung (09)

Radiation into rapidity gap is an indicator!

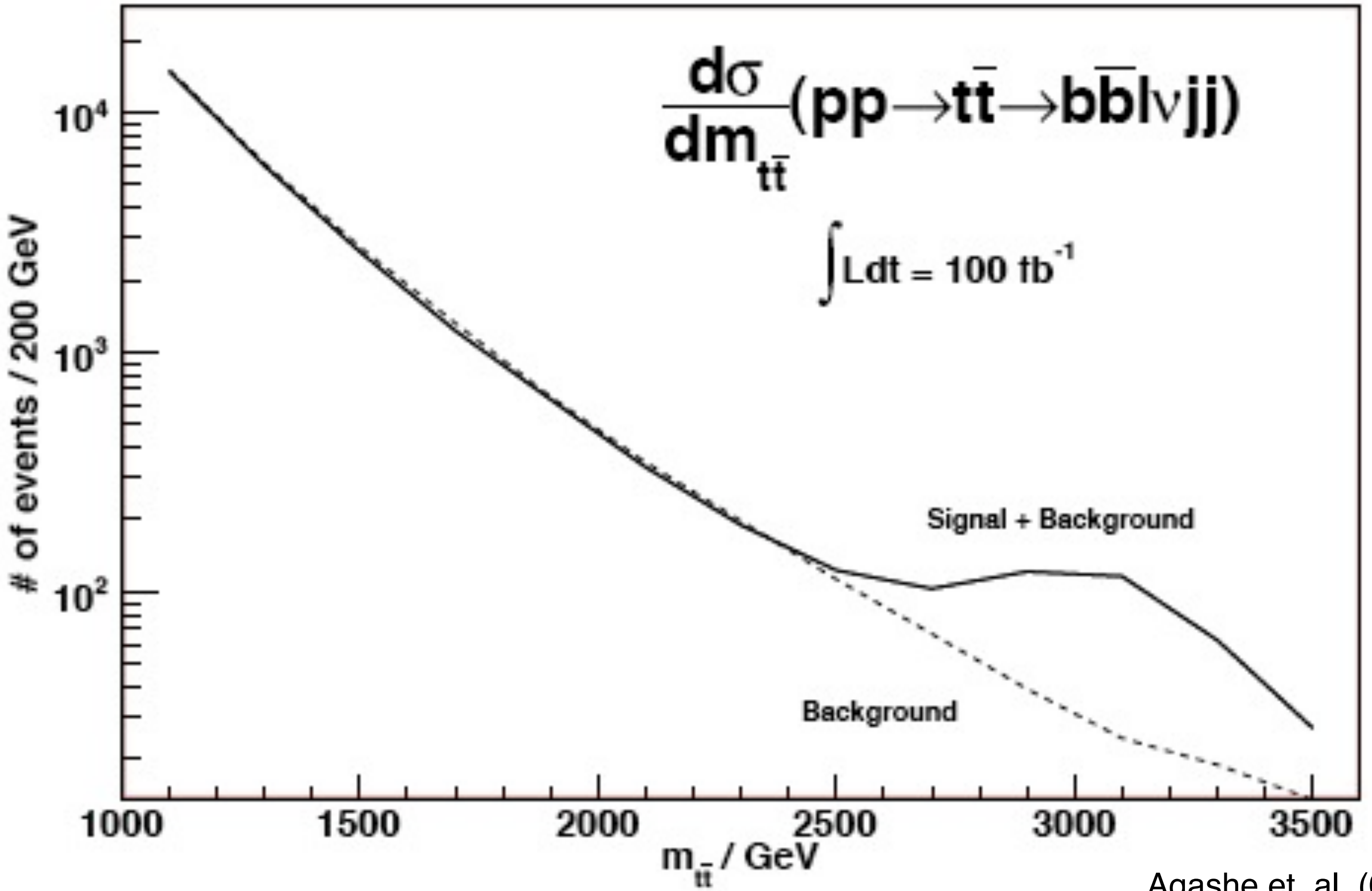


(b)

High p_t tops, might be crucial signal for various NP models

Z': Butterworth, Cox & Forshaw; KK gluon: Agashe, Belyaev, Krupovnickas, GP & Virzi (06); Lillie, Randall & Wang (07); KK graviton: Fitzpatrick, Kaplan, Randall & Wang (07); Agashe, Davoudiasl, GP & Soni (07).

$M_{KKG} = 3\,\text{TeV}$



Agashe et. al, (06)

The challenge of highly boosted tops

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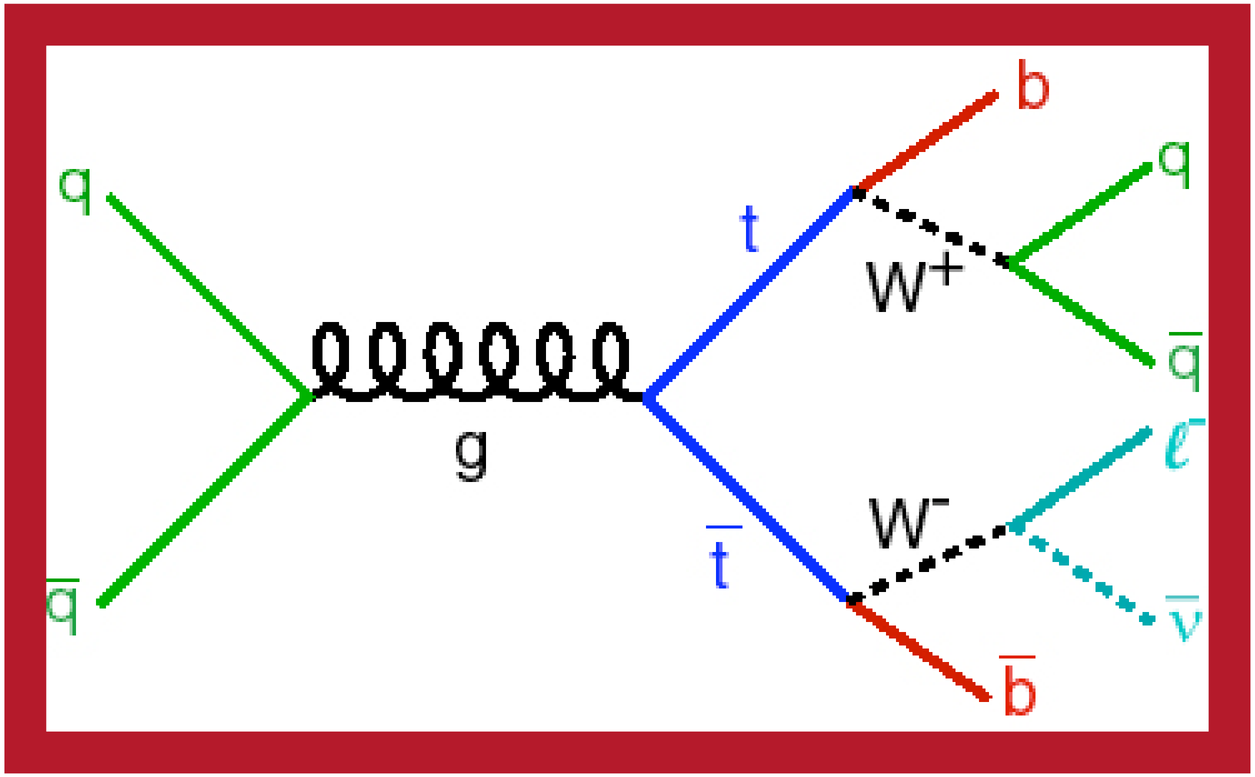
- Above a TeV, due to collimation, top's similar to light jet, efficiency & fake rate worsen.



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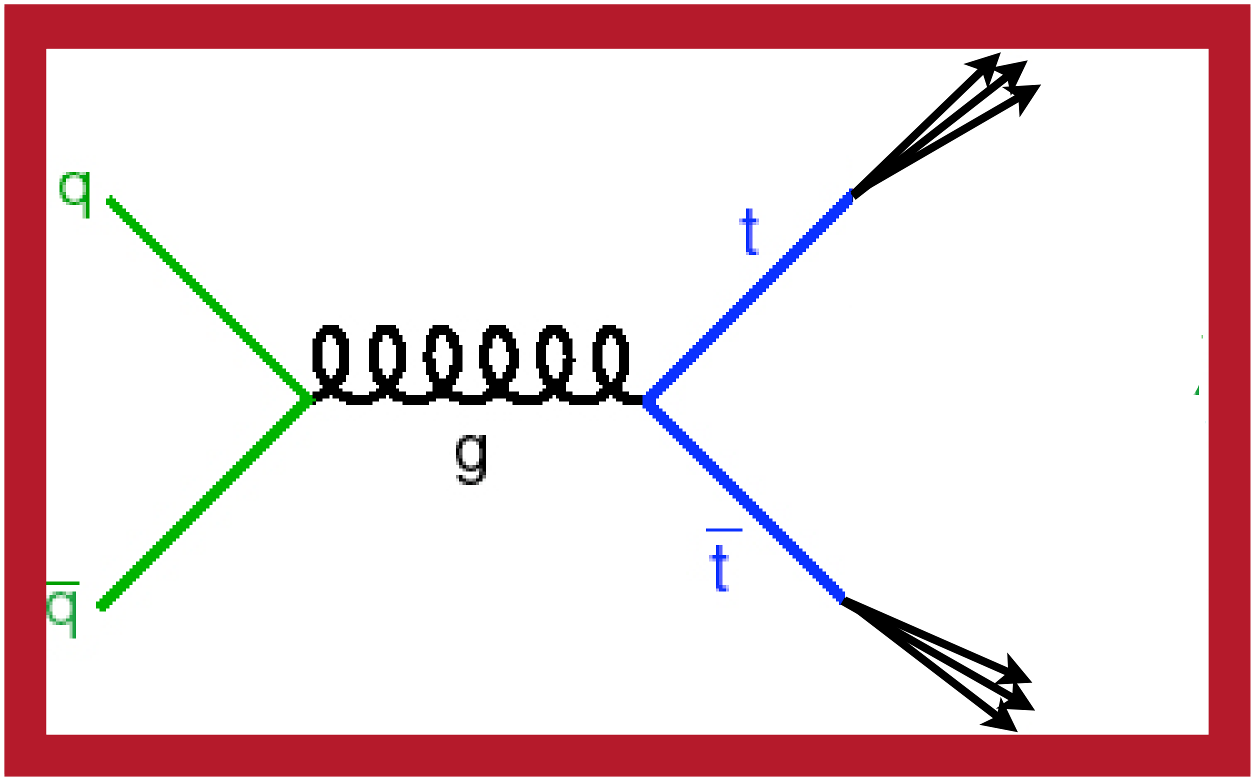


- The concept of top jet emerges (Seung's talk).

Up sector flavor violation

Look Down

Look Up

Top-FCNC: 2 questions

- $BR(t \to qZ\gamma) \sim 10^{-5}$ $\Leftrightarrow$ B phys

Requires model indep' study.

(Han & Hewett (98); Larios, Martinez & Perez (04); Fox, *et. al* (05))

- Can NP naturally yield enhancement?

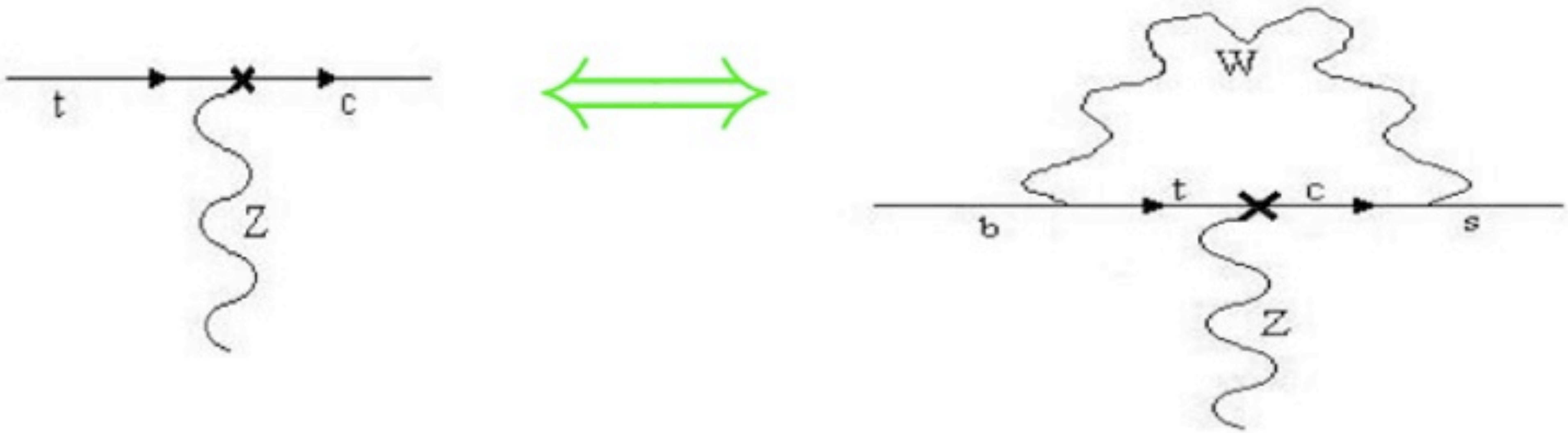
ex.: RS (Del Aguila & Santiago (00), Agashe, GP & Soni (06))

Is the LHC/ILC window closed?

- $t \to c\gamma, Z$: SM + Dim' 6 Op' @ m_t:

$$(LL^u)_{23} \leftrightarrow \bar{Q}_3 H^\dagger \not{D} H Q_2,\ (LR^u)_{23}, (RL^u)_{23}, (RR^u)_{23}.$$

- Confront with $b \to s, c$ data.



Is the window closed?

(Fox, *et. al.*)

	C^u_{LL}	C^h_{LL}	C^w_{RL}	C^b_{RL}	C^w_{LR}	C^b_{LR}	C^u_{RR}
direct bound	9.0	9.0	6.3	6.3	6.3	6.3	9.0
LHC sensitivity	0.20	0.20	0.15	0.15	0.15	0.15	0.20
$B \to X_s\gamma,\ X_s\ell^+\ell^-$	$[-0.07,\ 0.036]$	$[-0.017,\ -0.01]$ $[-0.005,\ 0.003]$	$[-0.09, 0.18]$	$[-0.12, 0.24]$	$[-14, 7]$	$[-10, 19]$	—
$\Delta F = 2$	0.07	0.014	0.14	—	—	—	—
semileptonic	—	—	—	—	$[0.3, 1.7]$	—	—
best bound	0.07	0.014	0.15	0.24	1.7	6.3	9.0
Λ for $C_i = 1$ (min)	3.9 TeV	8.3 TeV	2.6 TeV	2.0 TeV	0.8 TeV	0.4 TeV	0.3 TeV
$\mathcal{B}(t \to cZ)$ (max)	7.1×10^{-6}	3.5×10^{-7}	3.4×10^{-5}	8.4×10^{-6}	4.5×10^{-3}	5.6×10^{-3}	0.14
$\mathcal{B}(t \to c\gamma)$ (max)	—	—	1.8×10^{-5}	4.8×10^{-5}	2.3×10^{-3}	3.2×10^{-2}	—
LHC Window	Closed*	Closed*	Ajar	Ajar	Open	Open	Open

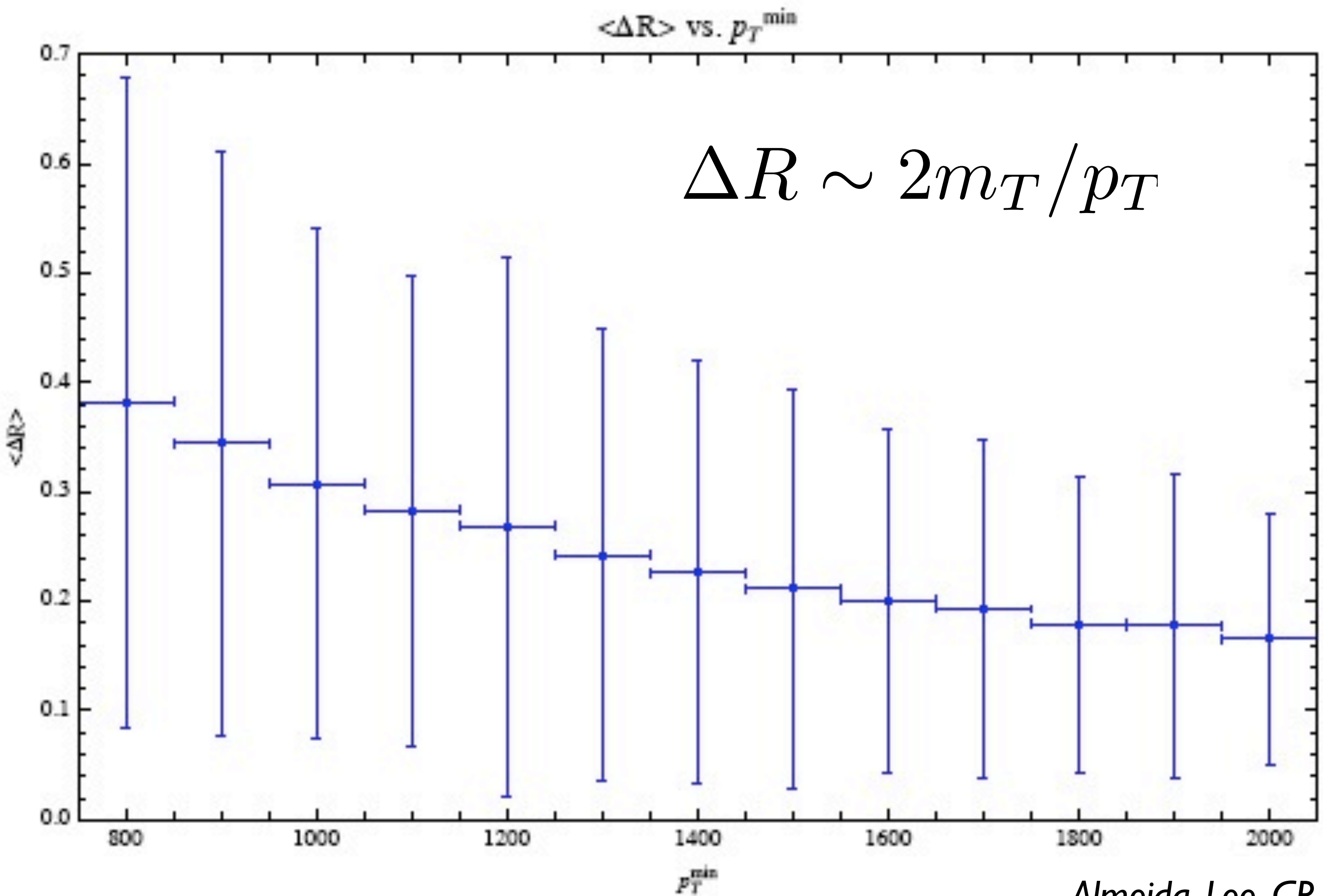
Partially (for $t \to c_L\gamma, Z$.)

Similar conclusion for $t \to uZ, \gamma$. ($\Delta F = 2$)

Conclusions

The t-future is bright!

Boosted top jets & collimation



Almeida, Lee, GP, Sung & Virzi (08).

Shower size of a single 100 GeV pion

E% vs. size of section

- Ave' cone of 20 cm is

required to contain
 95% of the energy;
a full cell size!

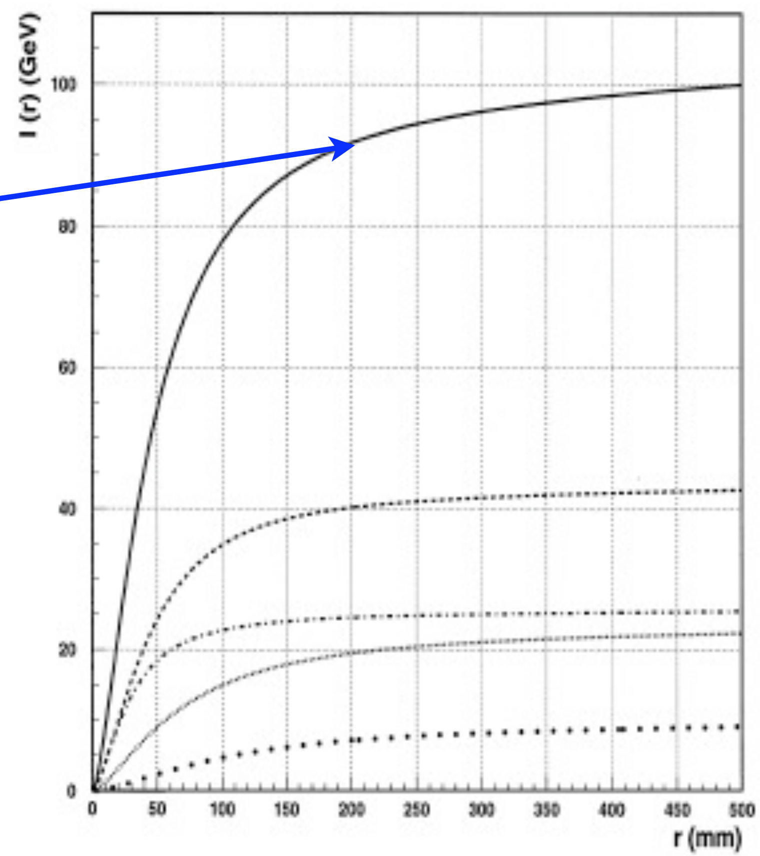


Fig. 14. Containment of shower $I(r)$ (the solid line) as a function of radius for the entire Tile Calorimeter. The dash-dotted line is the contribution from the first depth segment, the dashed line is the contribution from the second depth segment, the thin dotted line is the contribution from the third depth segment, the thick dotted line is the contribution from the fourth depth segment.

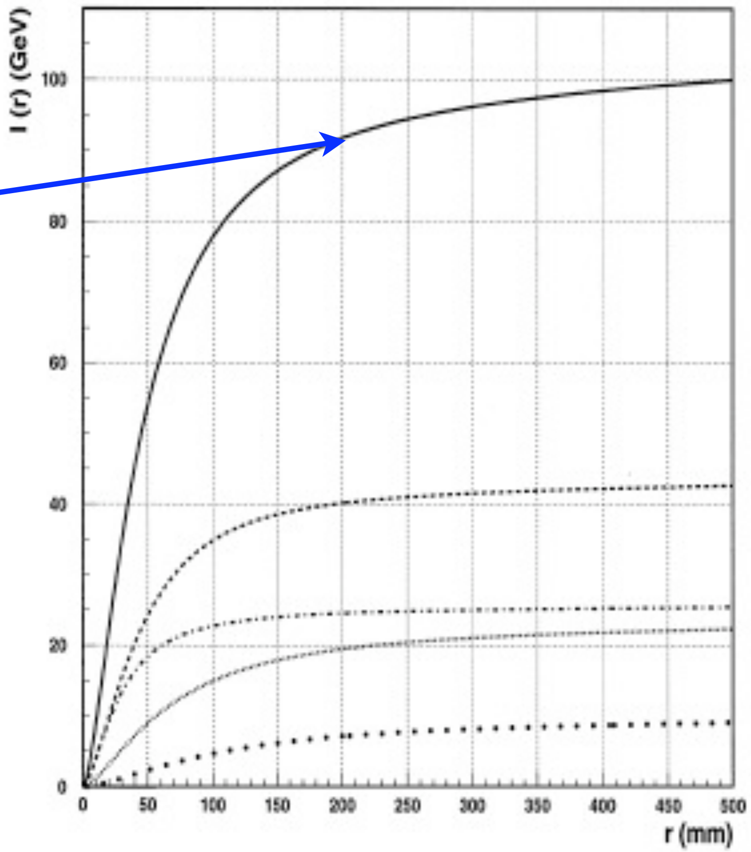
ATLAS, NIM A 443 (2000)

Shower size of a single 100 GeV pion

E% vs. size of section

- Ave' cone of 20 cm is required to contain 95% of the energy; a full cell size!

- R=0.4 smallest cone used so far. A careful th'+exp' effort required to go beyond that.



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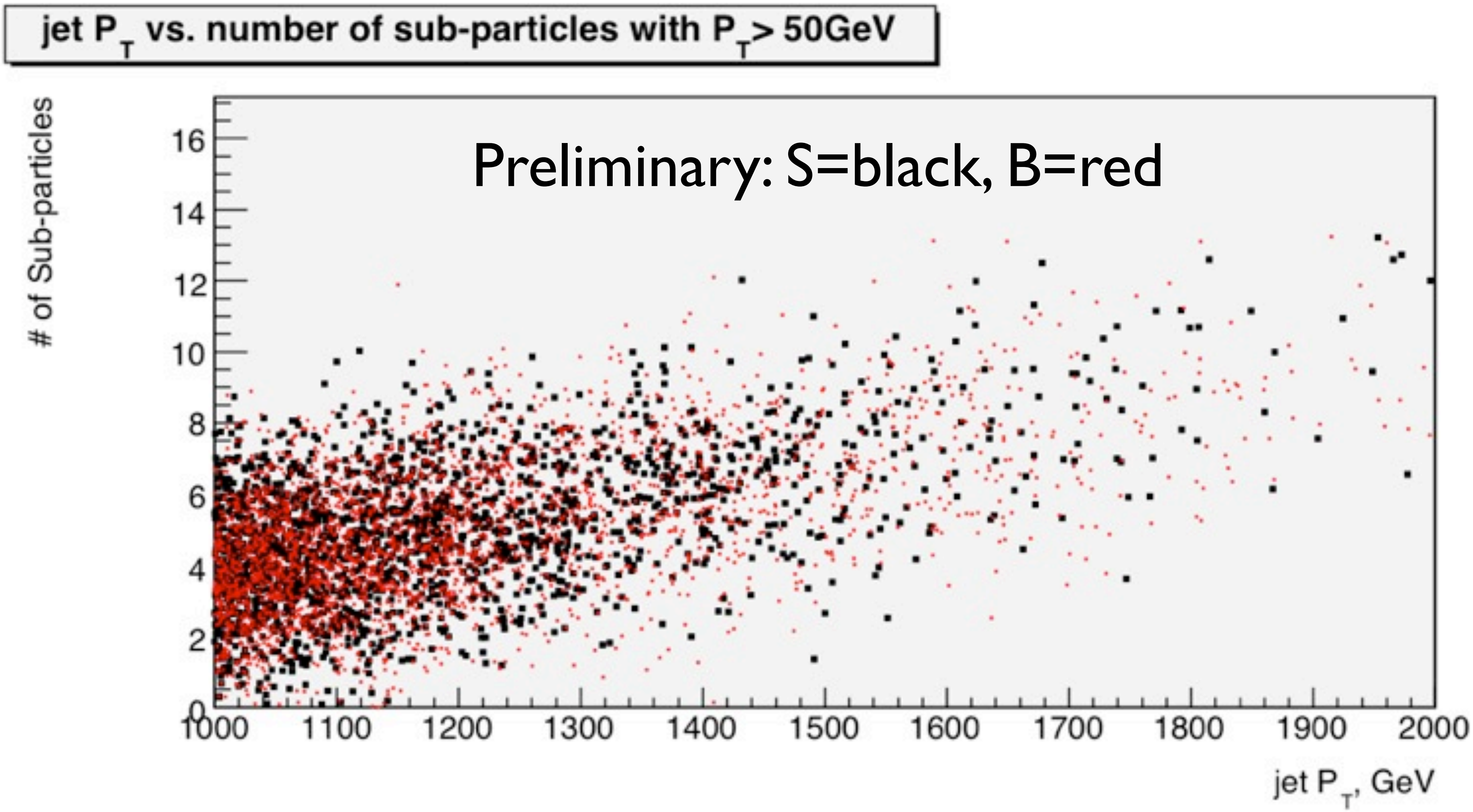

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