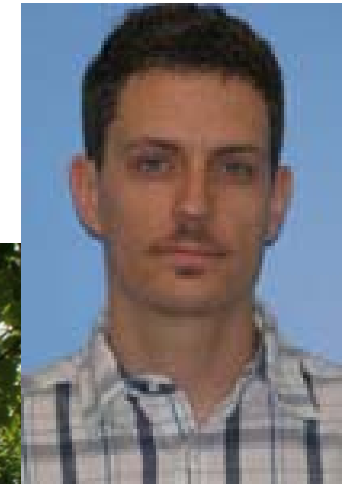



# THEP @ UU [www.isv.uu.se/thep](http://www.isv.uu.se/thep)

Staff	<b>Gunnar Ingelman, Johan Rathsman</b>
Postdoc	<b>Nazila Mahmoudi</b> → staff @ Clermont Ferrand
Ass.lecturer	<b>Rikard Enberg</b> ← postdoc Paris, Berkeley, Tuscon
Grad. stud.	<b>David Eriksson, Oscar Stål</b>
Master stud.	Tim Stefaniak, Lisa Zeune ← Göttingen
Guests	Alexandre Arbey, Emidio Gabrielli



# Main activities

- 
- QCD – interplay soft-hard
  - QCD and signals for new physics
  - Beyond the Standard Model
  
  - Astroparticle physics
  
  - Tools: Monte Carlo, SuperIso

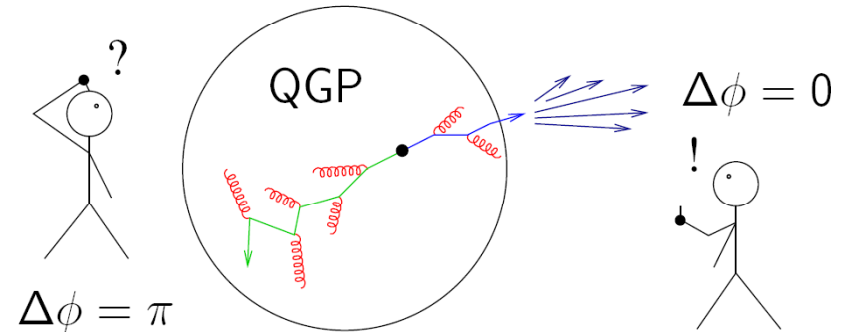
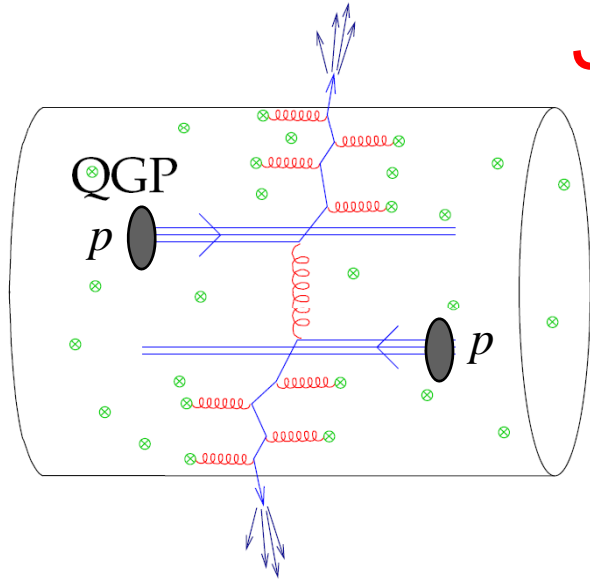
## Some papers in 2007-08: Beyond SM

- **Charged Higgs bosons in Minimal Supersymmetry: Updated constraints and experimental prospects**  
D. Eriksson, F. Mahmoudi and O. Stål, [arXiv:0808.3551](#)
- **SuperIso v2.3: A program to calculate flavor physics observables in SUSY**  
F. Mahmoudi, [arXiv:0808.3144](#)
- **Neutralino annihilation processes in the minimal supergravity model**  
T. Stefaniak, [arXiv:0806.2214](#)
- **SUSY constraints from relic density: High sensitivity to pre-BBN expansion rate**  
A. Arbey, F. Mahmoudi, [arXiv:0803.0741](#)
- **New angles on top quark decay to a charged Higgs**  
D. Eriksson, G. Ingelman, J. Rathsman, O. Stål, [arXiv:0710.5906](#)
- **New constraints on supersymmetric models from  $b \rightarrow s$  gamma**  
F. Mahmoudi, [arXiv:0710.3791](#)
- **Associated production of a Kaluza-Klein excitation of a gluon with a  $t$  anti- $t$  pair at the LHC**  
M. Guchait, F. Mahmoudi, K. Sridhar, [arXiv:0710.2234](#)

## Some papers in 2007-08: Quark-Gluon-Plasma & astroparticle

- **Parton Energy Loss Without Transverse Momentum Broadening**  
K. Zapp, G. Ingelman, J. Rathsman, J. Stachel and U. Wiedemann  
arXiv:0805.4759
- **A Monte Carlo model for 'jet quenching'**  
K. Zapp, G. Ingelman, J. Rathsman, J. Stachel, U. Wiedemann,  
arXiv:0804.3568
- **QCD evolution of jets in the quark-gluon plasma**  
S. Domdey, G. Ingelman, H.J. Pirner, J. Rathsman, J. Stachel, K. Zapp  
arXiv:0802.3282
- **Heavy quark energy loss through soft QCD scattering in the QGP**  
K. Zapp, G. Ingelman, J. Rathsman and J. Stachel, hep-ph/0702201
- **Prospects for GMRT to Observe Radio Waves from UHE Particles Interacting with the Moon**  
S. Panda, S. Mohanty, P. Janardhan, O. Stål, arXiv:0708.1683
- **Prospects for Lunar Satellite Detection of Radio Pulses from Ultrahigh Energy Neutrinos Interacting with the Moon**  
O. Stål, J. Bergman, B. Thide, L. Daldorff, G. Ingelman, astro-ph/0604199

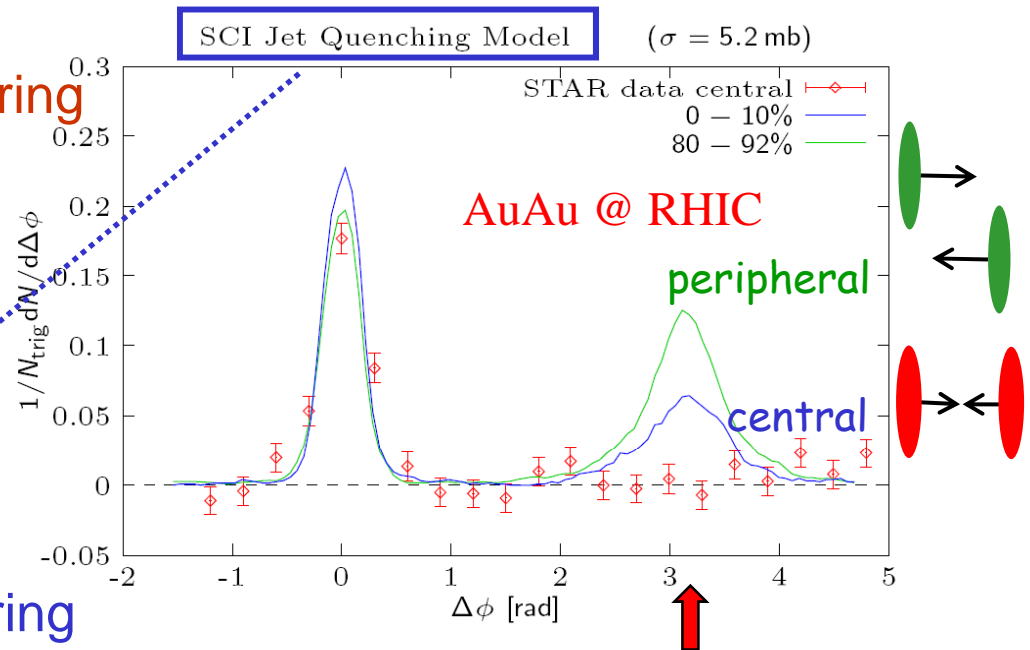
# Jet quenching



Hadron flow in azimuth  $\Delta\phi$  vs trigger particle/jet

Quark/gluon from hard QCD-scattering  
multiple scattered in plasma  
⇒ energy loss  
⇒ hadron/jet energy reduced

Uppsala-Heidelberg:  
“Soft Colour Interaction” model  
with non-perturbative elastic scattering  
→ ≈ half observed effect @ RHIC

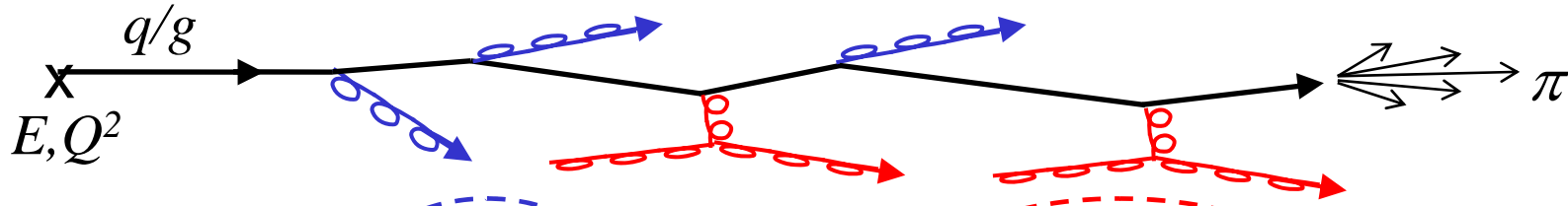


back-to-back jet  
disappears!

# QCD evolution of jets in plasma

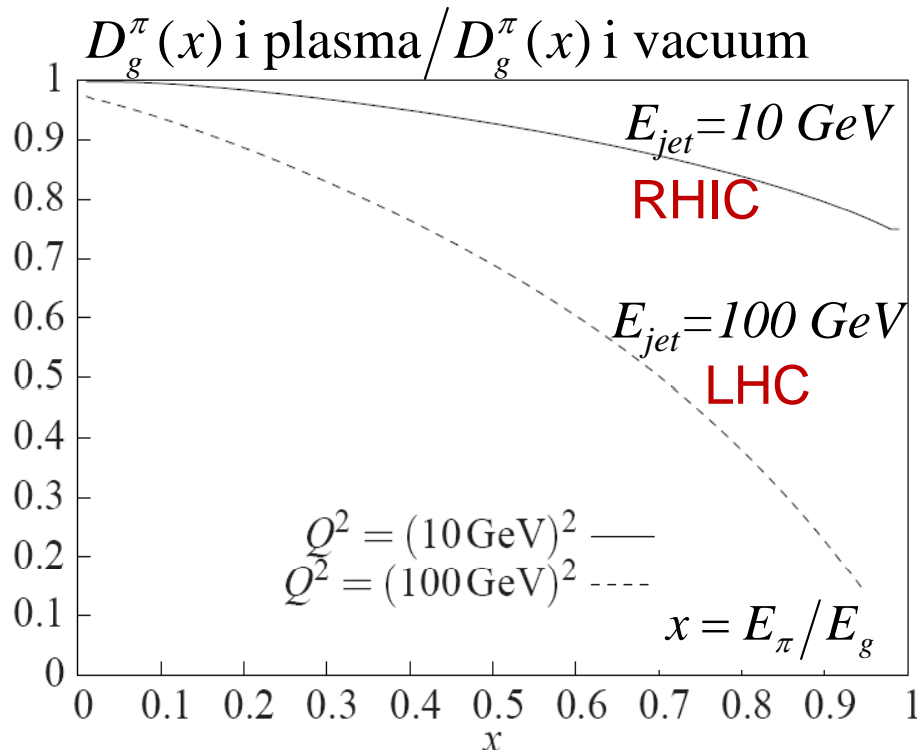
Domdey, Ingelman, Pirner, Rathsman, Stachel, Zapp, arXiv:0802.3282

Time dilation → gluon emission simultaneous with scattering in plasma



$$\frac{\partial D_g^\pi(x, Q^2)}{\partial \ln Q^2} = \int_x^1 \frac{dy}{y} \left\{ \alpha_s(Q^2) P(y) D\left(\frac{x}{y}, Q^2\right) + n_g(T) d\sigma(gg \rightarrow gg) D\left(\frac{x}{y}, Q^2\right) \right\}$$

$$\propto \frac{\alpha_s^2}{(|t| + m_D^2)^2} \quad \text{Debye mass}$$



Higher energy scale ( $E, Q^2$ )

→ longer  $\ln Q^2$  evolution

→ longer life time for parton

& plasma

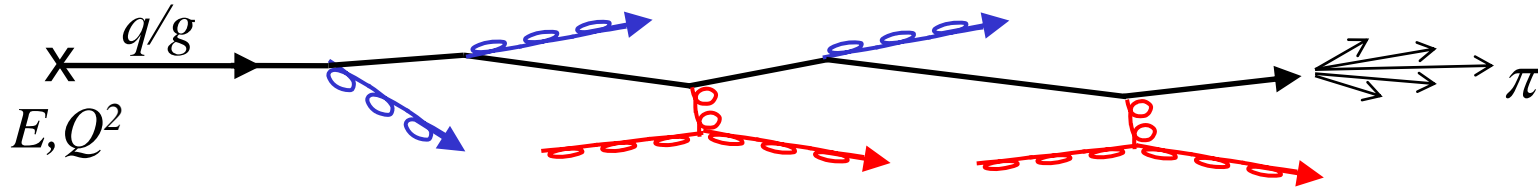
→ more multiple scattering

Quenching @ LHC > @ RHIC !?



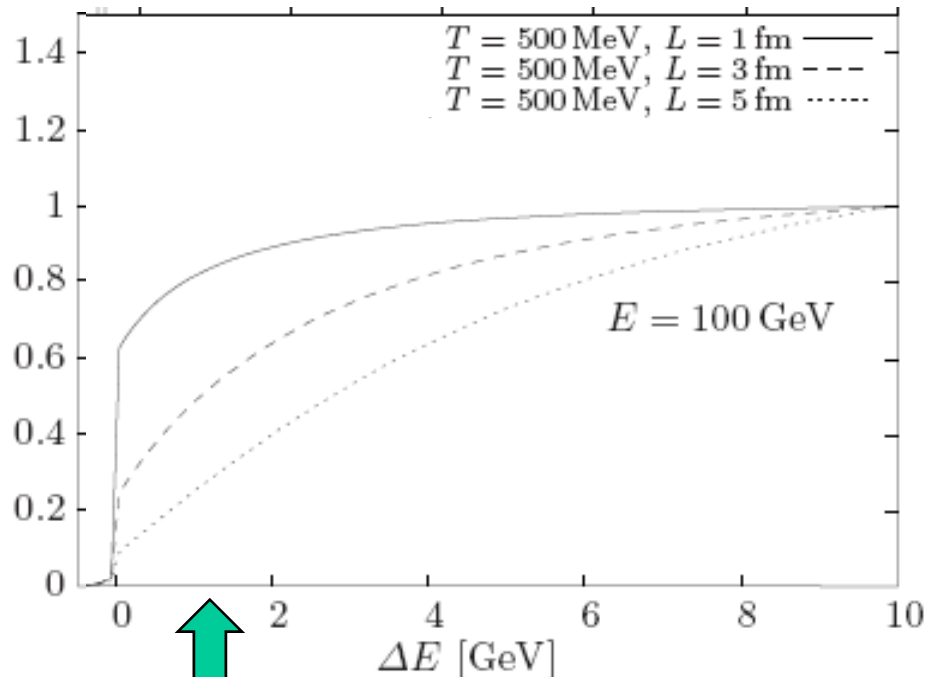
# Monte Carlo JEWEL (Jet Evolution With Energy Loss)

K. Zapp, Ingelman, Rathsman, Stachel, Wiedemann, arXiv:0804.3568



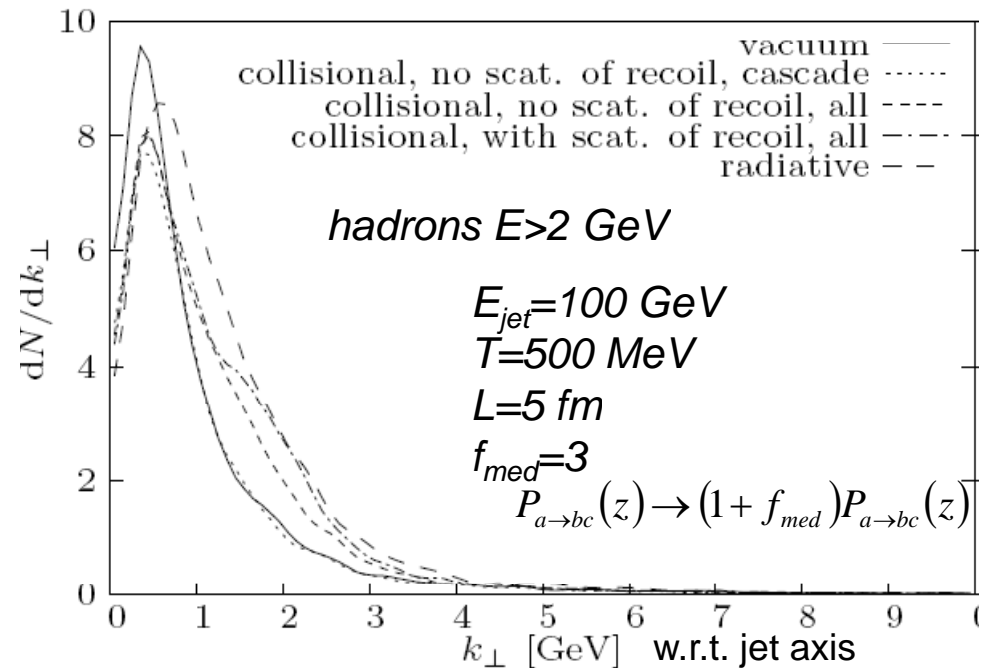
Parton shower + scattering → medium modifies jet & jet modifies medium  
Modified jet properties observable above soft background !

Fraction of quarks with energy loss below  $\Delta E$



small  $\theta$  elastic scattering dominates

Energy loss without sizeable  $p_{\perp}$  broadening !



$E, p$  conservation important

# Summary / outlook

## LHC phenomenology

- BSM & QCD  $\leftrightarrow$  ATLAS
- QGP  $\leftrightarrow$  ALICE

## Connection to astroparticle/cosmology

- constraints on new physics
- dark matter  $\leftrightarrow$  SUSY
- neutrino fluxes  $\leftrightarrow$  IceCube

## UU evaluation KoF 07:

- “note outstanding theoretical work on high-energy phenomenology”
- “recommends upcoming hires to open up directions related to phenomenology”



# Extra material

## SuperIso: C-program for calculating observables in SUSY

- Automatic calculation in mSUGRA, NUHM, AMSB, GMSB
- Compatible with SUSY Les Houches Accord format

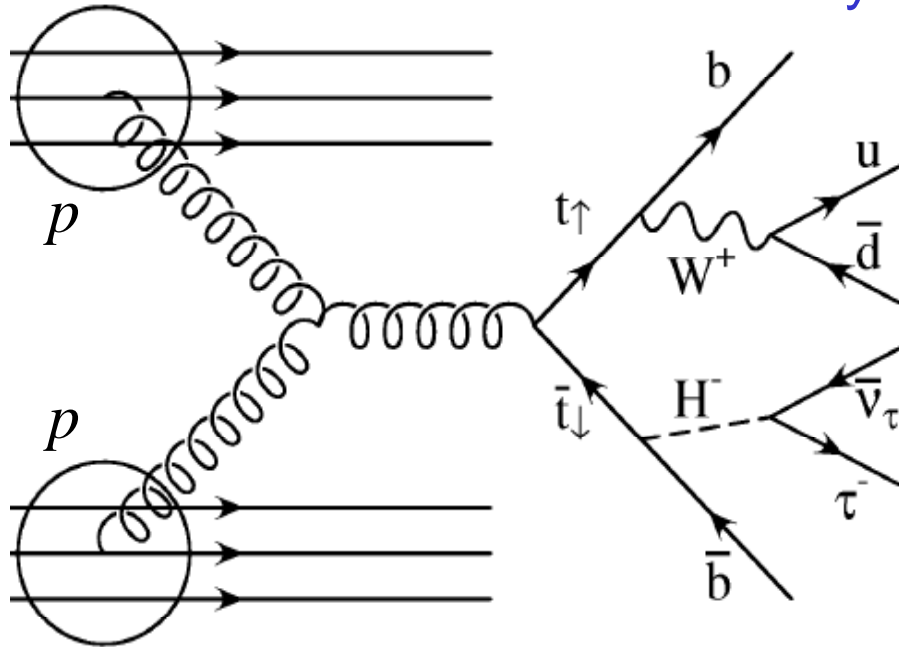
Observables:

- isospin asymmetry of  $B \rightarrow K^* \gamma$  at NLO
- inclusive branching ratio of  $B \rightarrow X_s \gamma$  at NNLO
- branching ratio of  $BR(B_s \rightarrow \mu^+ \mu^-)$
- branching ratio of  $BR(B \rightarrow \tau \nu)$
- branching ratio of  $BR(B^- \rightarrow D^0 \tau^- \nu)$  and  $\frac{BR(B^- \rightarrow D^0 \tau^- \nu)}{BR(B^- \rightarrow D^0 e^- \nu)}$
- $\frac{BR(K \rightarrow \mu \nu)}{BR(\pi \rightarrow \mu \nu)}$  and  $R_{\ell 23}$
- anomalous magnetic moment of muon ( $g - 2$ )

# New angles on top quark decay to a charged Higgs

David Eriksson, GI, Johan Rathsman, Oscar Stål, JHEP 0801:024, 2008

LHC  $\rightarrow >10^7$   $t\bar{t}$ bar/year with correlated spins (jfr EPR)



SM:  $t \rightarrow Wb \rightarrow b\ell^+\nu$  alt.  $bq\bar{q}'$

If  $m_t > m_{H^\pm}$  also

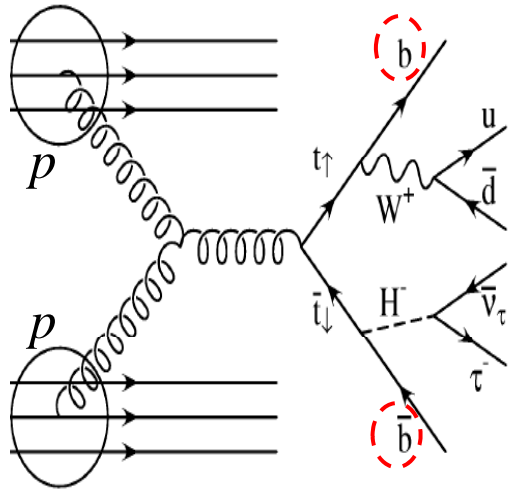
$t \rightarrow H^+b \rightarrow b\ell^+\nu$  alt.  $bq\bar{q}'$

Charged Higgs  $H^\pm \Leftrightarrow$  new physics

$\left. \begin{array}{l} W^\pm \text{ spin}=1 \\ H^\pm \text{ spin}=0 \end{array} \right\} \Rightarrow$  different angular distributions

Korrelations between jets and/or leptons  $\rightarrow$  many theoretical possibilities  
but few experimentally useful to measure **spin of  $H^\pm$**

Monte Carlo simulation  $\rightarrow$  detailed & realistic study



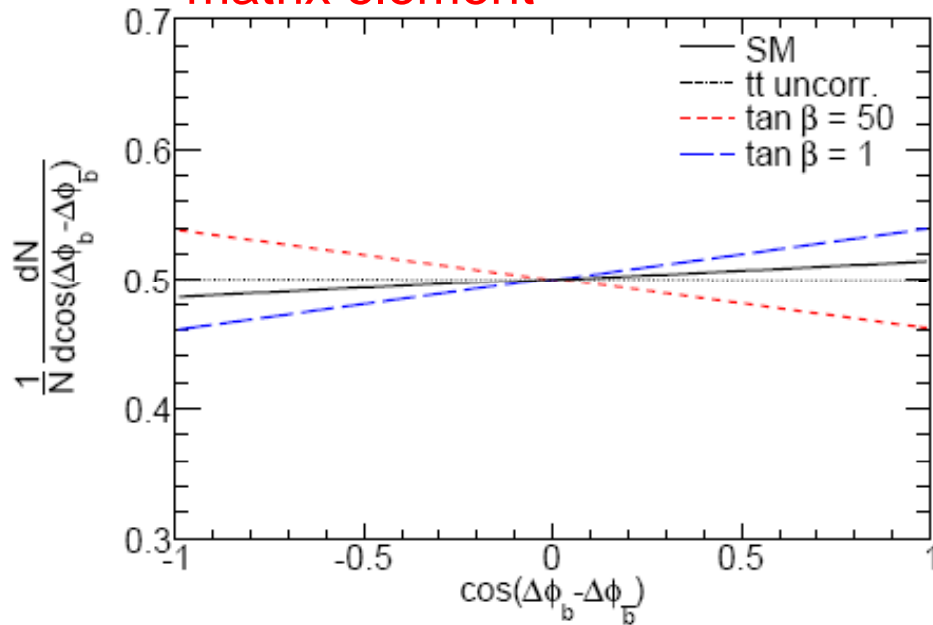
## Example of observable angular correlation:

→ transverse rest system of top (anti-top)

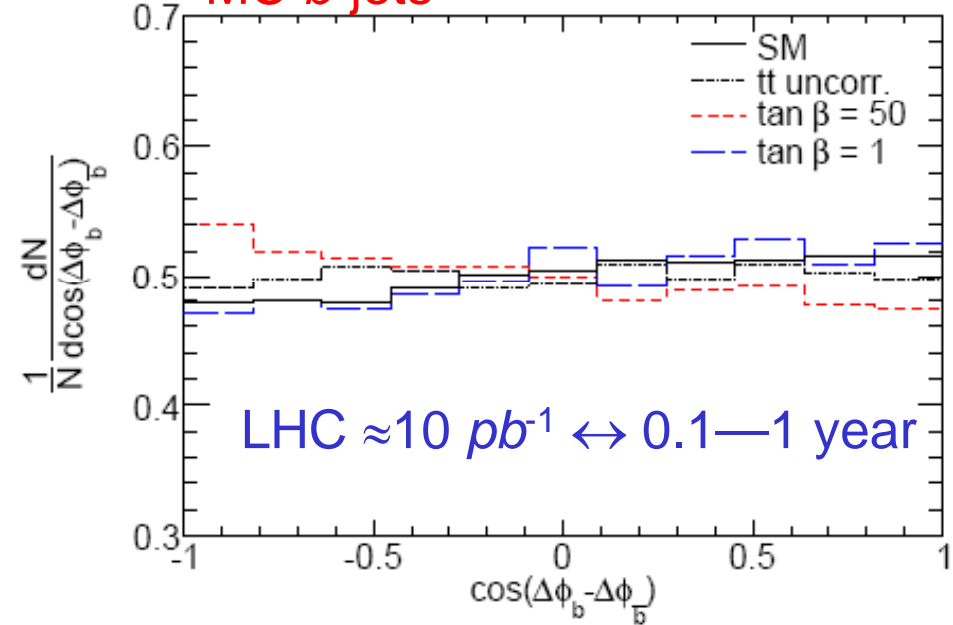
→ azimuthal angle  $\Delta\phi_b$  ( $\Delta\phi_{\bar{b}}$ ) of  $b$ -jet ( $\bar{b}$ ) vs  $p_{\perp}$  of  $t$  ( $\bar{t}$ )

$$\Rightarrow \frac{1}{N} \frac{dN}{d \cos(\Delta\phi_b - \Delta\phi_{\bar{b}})} = \frac{1}{2} \left[ 1 + D \alpha_b \alpha_{\bar{b}} \cos(\Delta\phi_b - \Delta\phi_{\bar{b}}) \right]$$

matrix element



MC  $b$ -jets



Non-trivial but possible measurement  $\Rightarrow$  spin of  $H^{\pm}$