

THEORY SHAPING EXPERIMENT

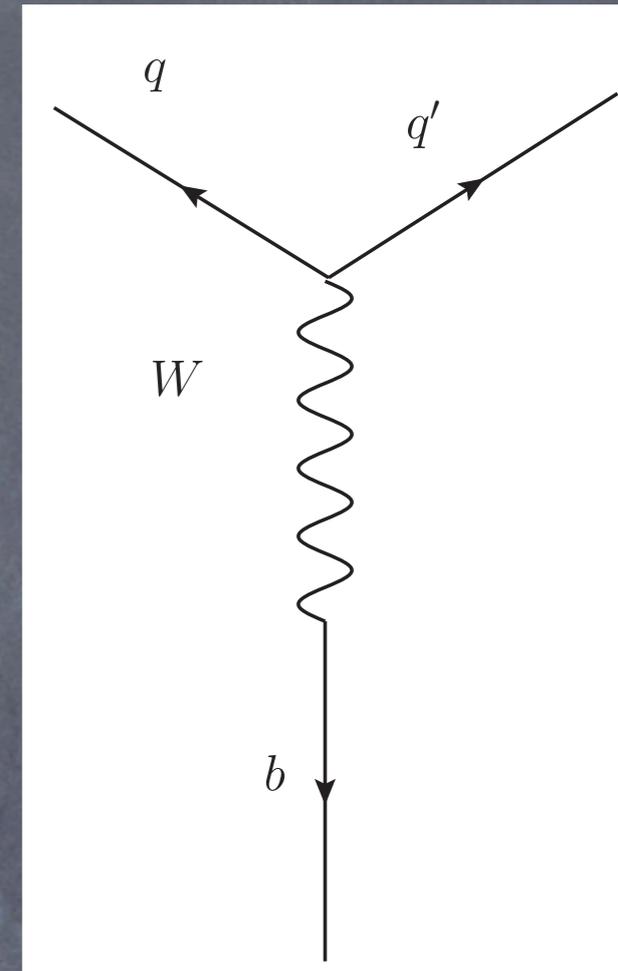
Kaustubh Agashe (University of Maryland)



BOOSTED TOP QUARKS

Who ordered them? LHC now...

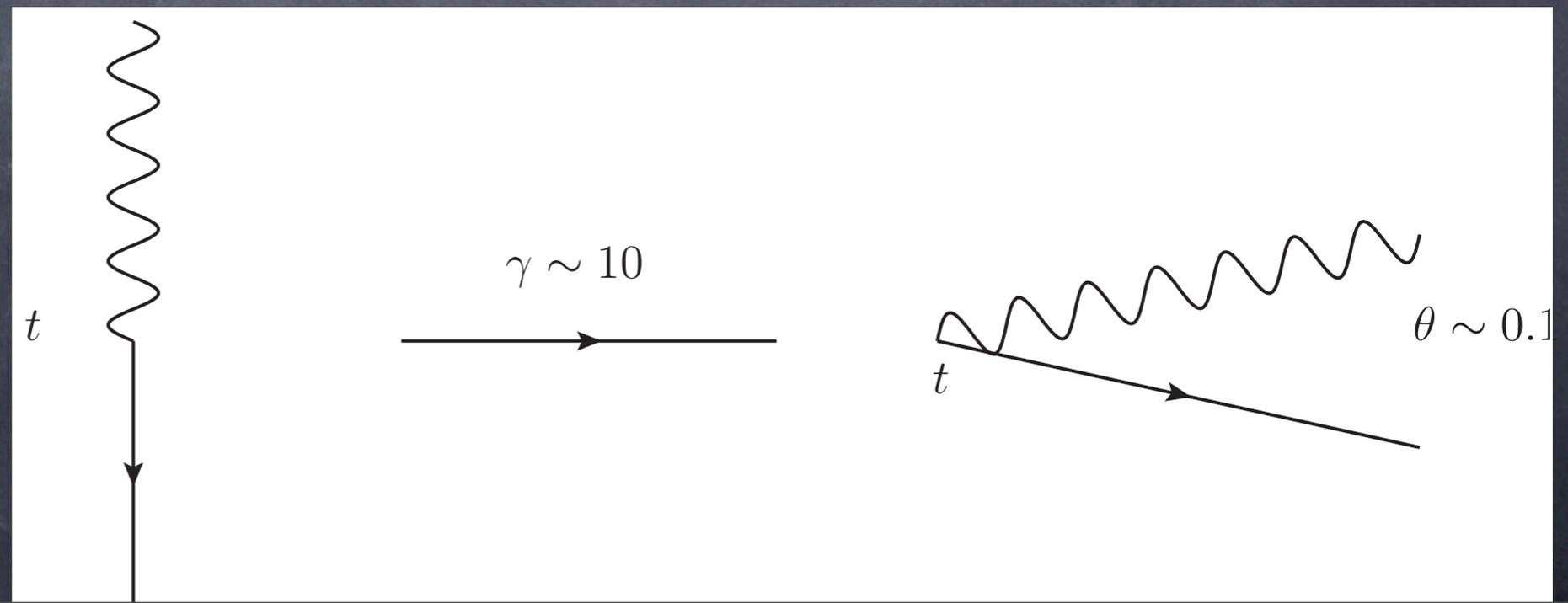
- has become an **industry** (experimental and phenomenological), e.g., BOOST conferences
- Most tops from SM ~ **at rest** (in lab frame)
 - b and W decay products **well-separated**
- Tops from **new** particle (NP)...**heavy** (says **LHC**):



NP mass

$\gamma_{top} \sim E_{top}/m_{top} \sim 1.5 \text{ TeV}/170 \text{ GeV} \sim 10$
opening angle between b and $W \sim 1/\gamma_{top} \sim 0.1$

- b and W (and W decay products) **merge: top-jet** special techniques (e.g., jet-substructure)



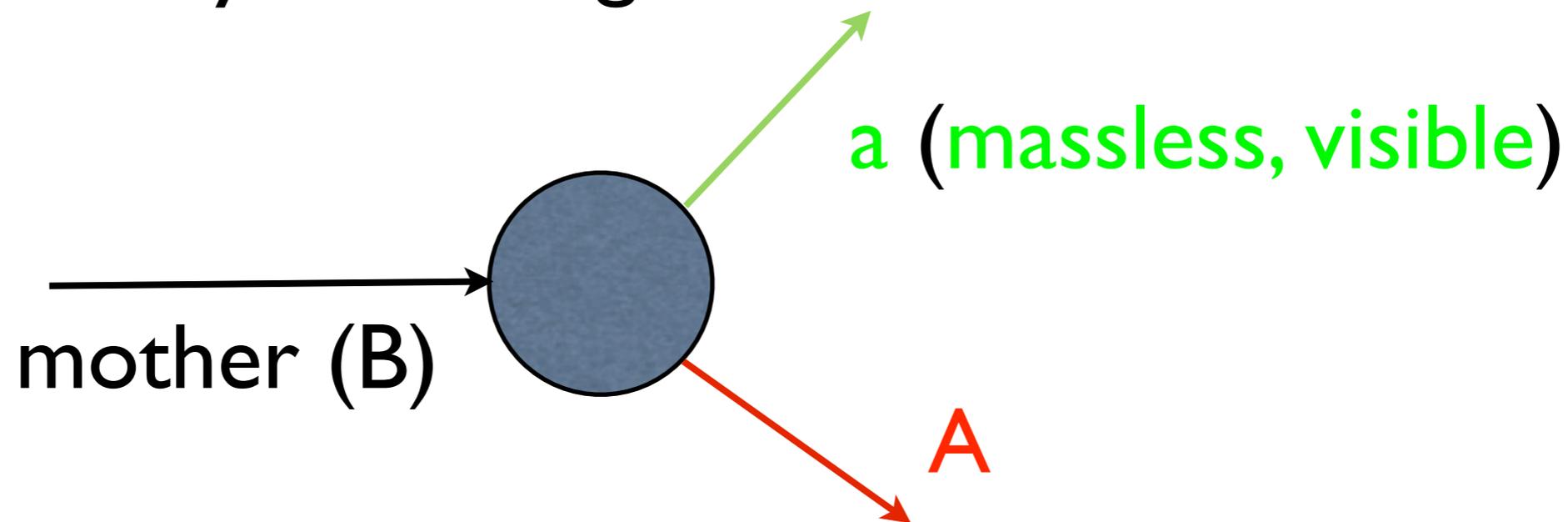
Theorists ordered them before...

- NP “already” heavy due to **precision tests**: e.g., Kaluza-Klein gluon (>3 TeV) in warped extra dimension (KA, Belyaev, Krupovnickas, Perez, Virzi: hep-ph/0612015 and Lillie, Randall, Wang: hep-ph/0701166) dominant decay/discovery mode
- **Searches** using boosted top techniques: CMS-PAS-B2G-12-005, ATLAS-CONF-2012-102

ENERGY-PEAK

Basic goal/assumptions

- 2-body decay: one daughter **visible, massless**:



- determine mass of mother using visible only
- ...other (A) **don't** care (almost)!

Energy (**not** invariant) of daughter

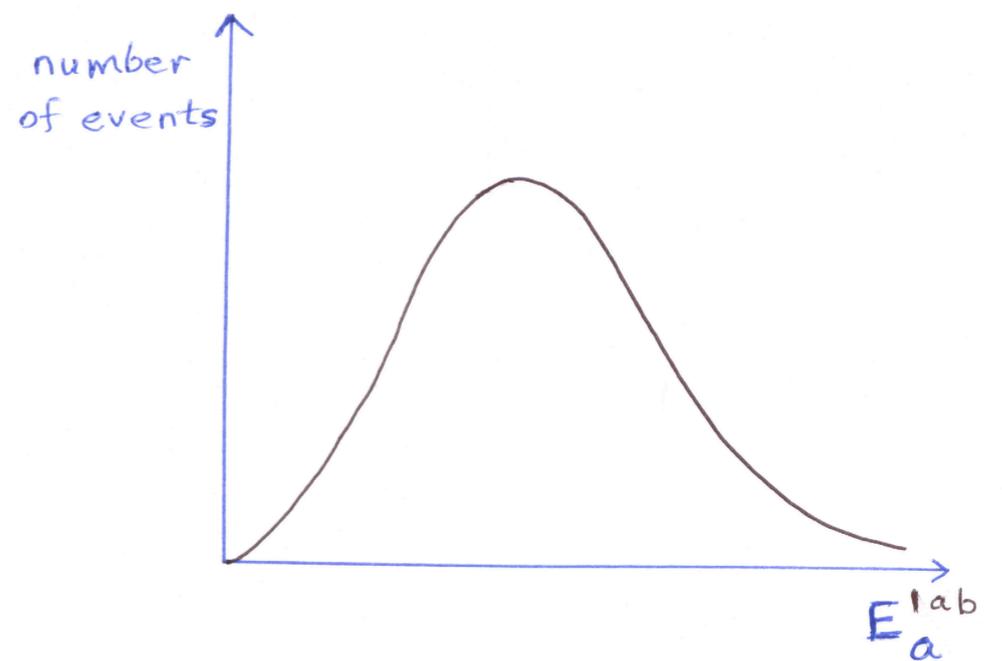
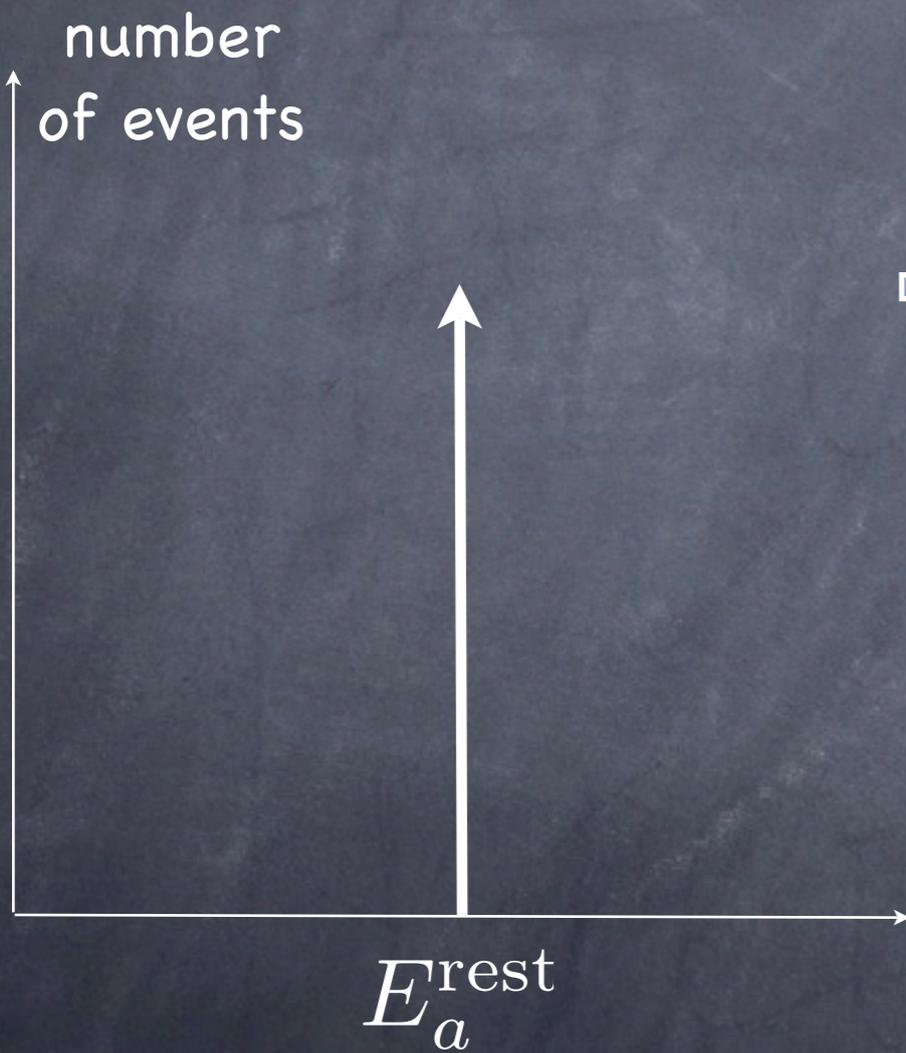
- **simple** function of masses in **rest** frame of mother:

$$E_a^{\text{rest}} = \frac{M_B^2 - M_A^2}{2M_B}$$

- **determine** M_B if M_A known and E_a^{rest} measured

...**too** simple to be practical/useful?!

- hadron collider: mother has **unknown boost**;
varies event to event \rightarrow **distribution** in E_a^{lab}



- lose** rest-frame information?!

New "invariance": Energy-peak

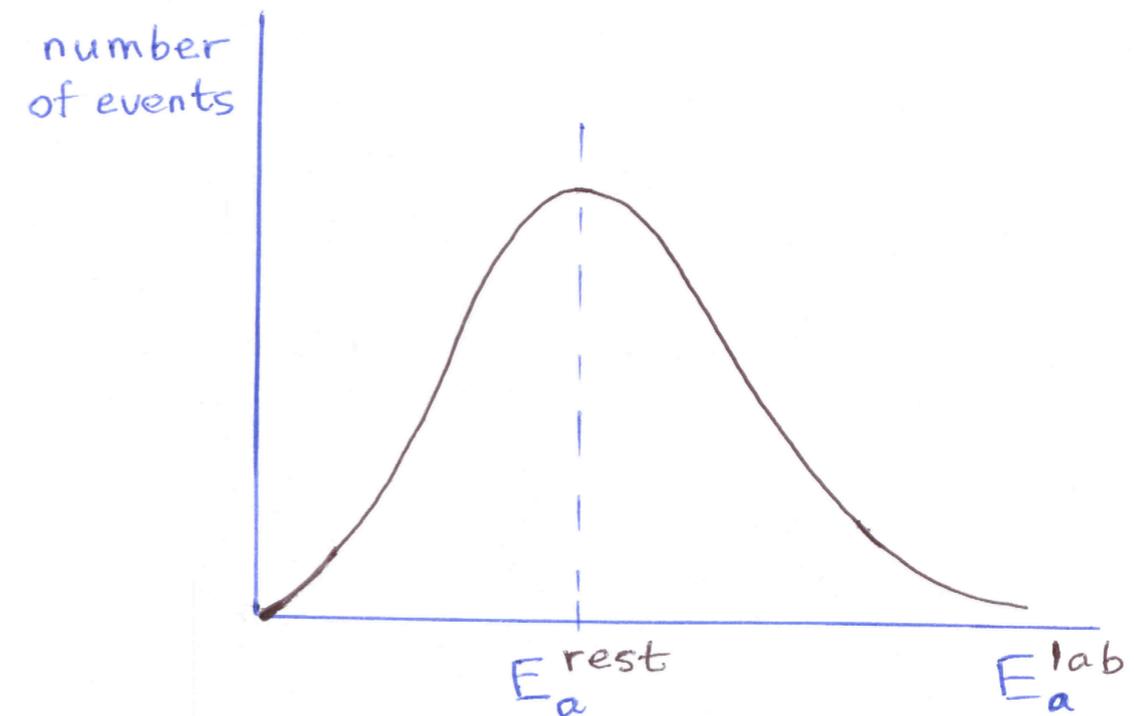
(KA, Franceschini, Kim: 1209.0772)

LHC-TI (NSF) fellow

Location of **peak** (of lab. distribution) still **retains** this information...as **simply** and **precisely** (if mother is unpolarized)

....**no matter** what is the **boost distribution** of mother!

boost distribution depends on **production mechanism, mother mass, PDF's...**



Application

- Top mass:
 - Location of peak in measured b-jet energy distribution
 - Assuming M_W (but no need to detect it at all!), get M_t
- CMS on July 9, 2013:

“...I guess you will be pleased to hear that we have now someone within CMS who is planning to try an m_t extraction with the 8 TeV data following *your* Ansatz....

However, since that group is only starting now, we can't expect to see results *too soon*...”
- Can *ATLAS* be far behind?!

HEAVY (≥ 1 TEV) DI-Z
RESONANCE SEARCH

Trying spins...

- Spin-1 not allowed, neglecting Z mass (Landau-Yang theorem)
- Spin-0 possible...but SM Higgs light: LHC or (already) from EW fit
- Spin-2 possible: e.g., KK graviton in warped extra dimension
original model (entire SM on TeV brane) 
democratic decays to all SM di-lepton or di-photon is way to go (no need for di-Z)

Theorists wake up ZZ...

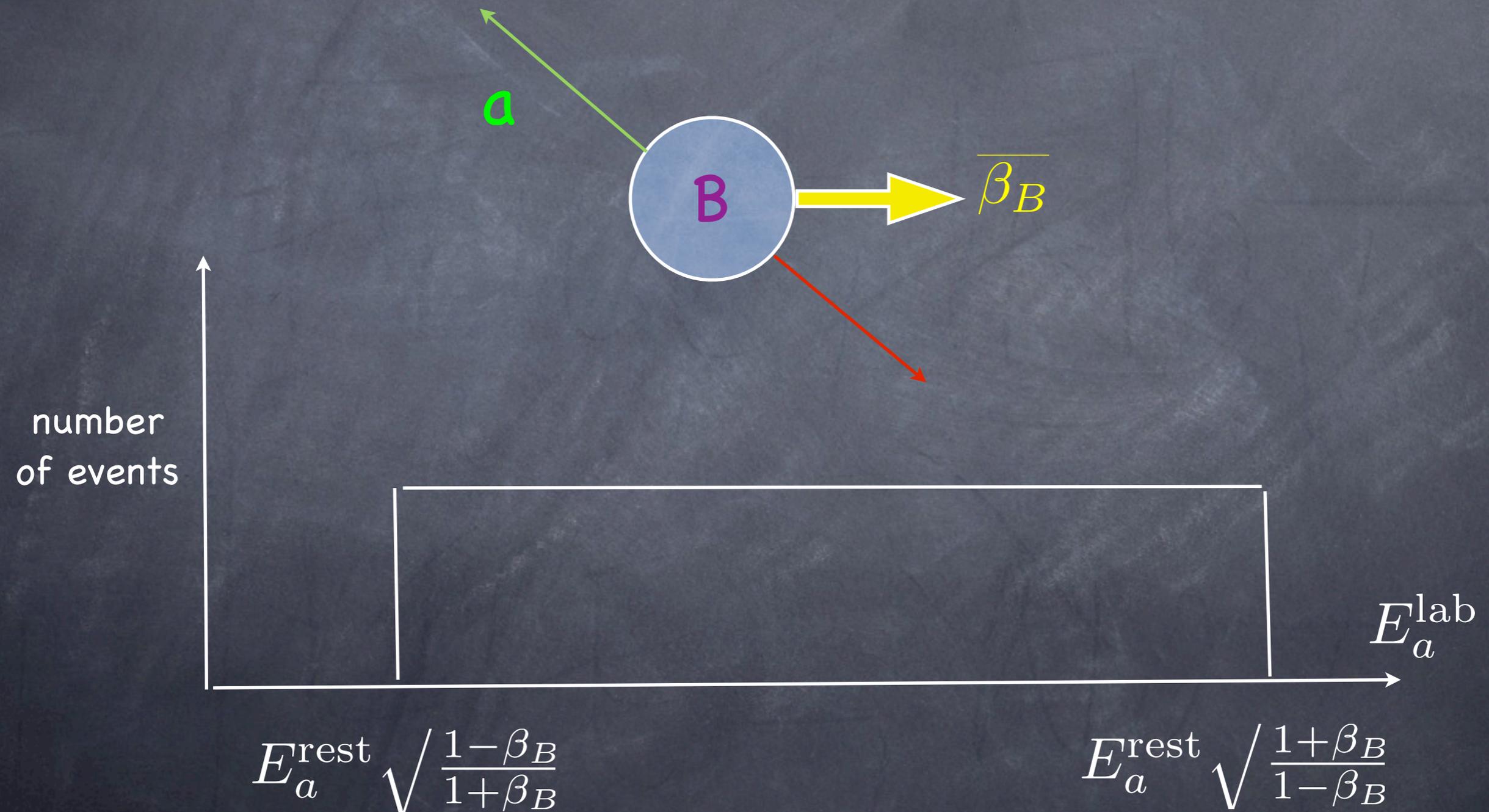
- **Better motivated** model (SM in bulk, address flavor):
di-photon and di-lepton **suppressed**
- di-Z still significant...becomes discovery mode...
(KA, Davoudiasl, Perez, Soni: **hep-ph/0701186**)
- Motivates searches: ATLAS-CONF-2012-150, CMS-EXO-12-014

BACK-UP

“INVARIANCE” OF TWO-
BODY DECAY KINEMATICS

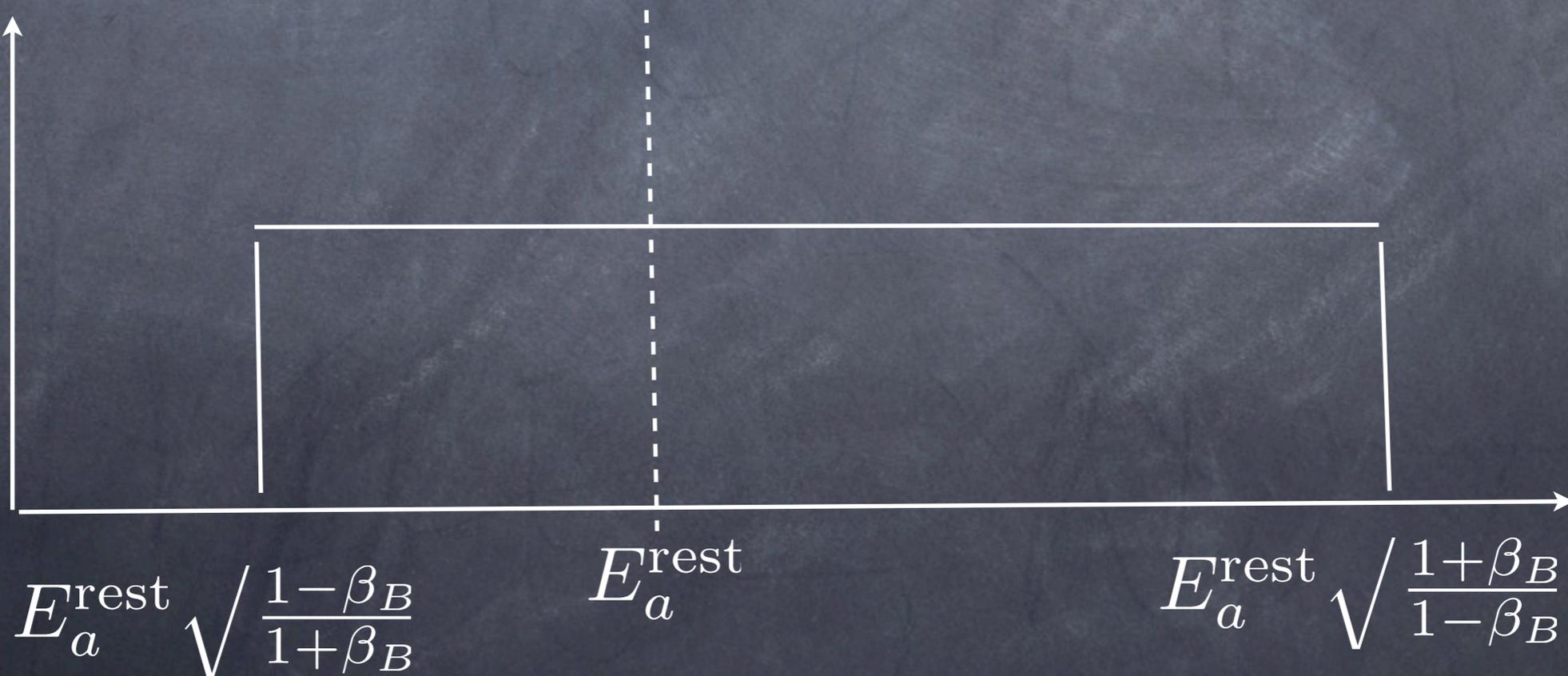
Rectangle for **fixed**, but **arbitrary** boost

- In general: $E_a^{\text{lab}} = E_a^{\text{rest}} \gamma_B (1 + \beta_B \cos \theta_{aB})$
- Assume unpolarized mother: $\cos \theta_{aB}$ is flat



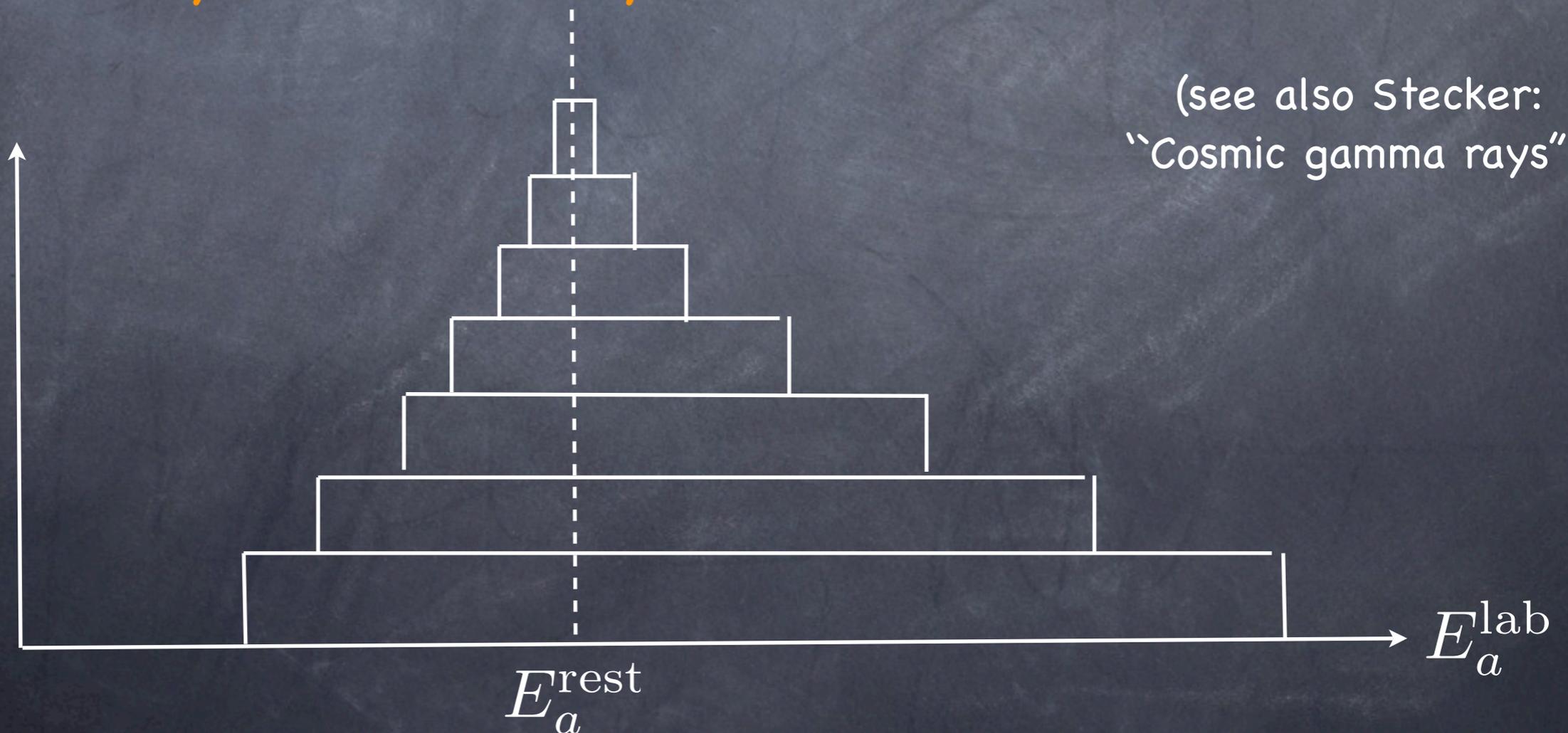
Rectangle vs. rest energy

- contains E_a^{rest} (for **any** boost)
- no other** E_a^{lab} gets **larger** contribution from given boost than does E_a^{rest}
- no other** E_a^{lab} is contained in **every** rectangle
- asymmetric** on linear (symmetric on **log...**)



(Generic) Boost distribution: "stacking" up rectangles

- distribution of E_a^{lab} has **peak** at E_a^{rest}
- ...**no matter** what is the **boost distribution!**
- boost distribution depends on **production mechanism, mother mass, PDF's...**



How to "avoid" plateau

- Boost distribution does not vanish close to $\gamma_B = 1$

