Dijets at RHIC: What can we learn from A_j?

B. Mueller speaking for **C.Coleman-Smith**

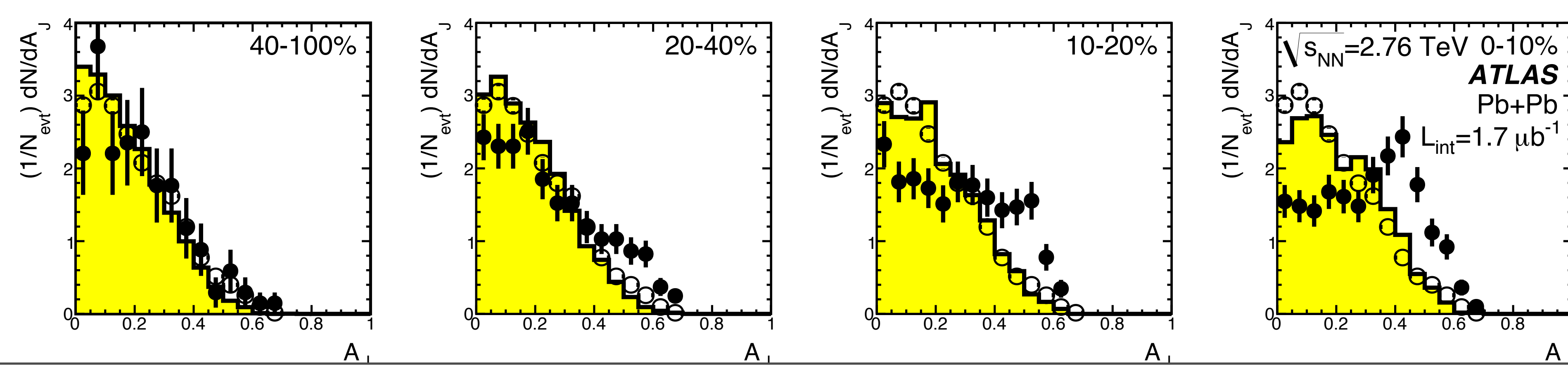
HardProbes - 2012

See arXiv:1205.6781 (May 30, 2012)

Dijet Observables at RHIC

$$A_j = \frac{E_{T1} - E_{T2}}{E_{T1} + E_{T2}}$$

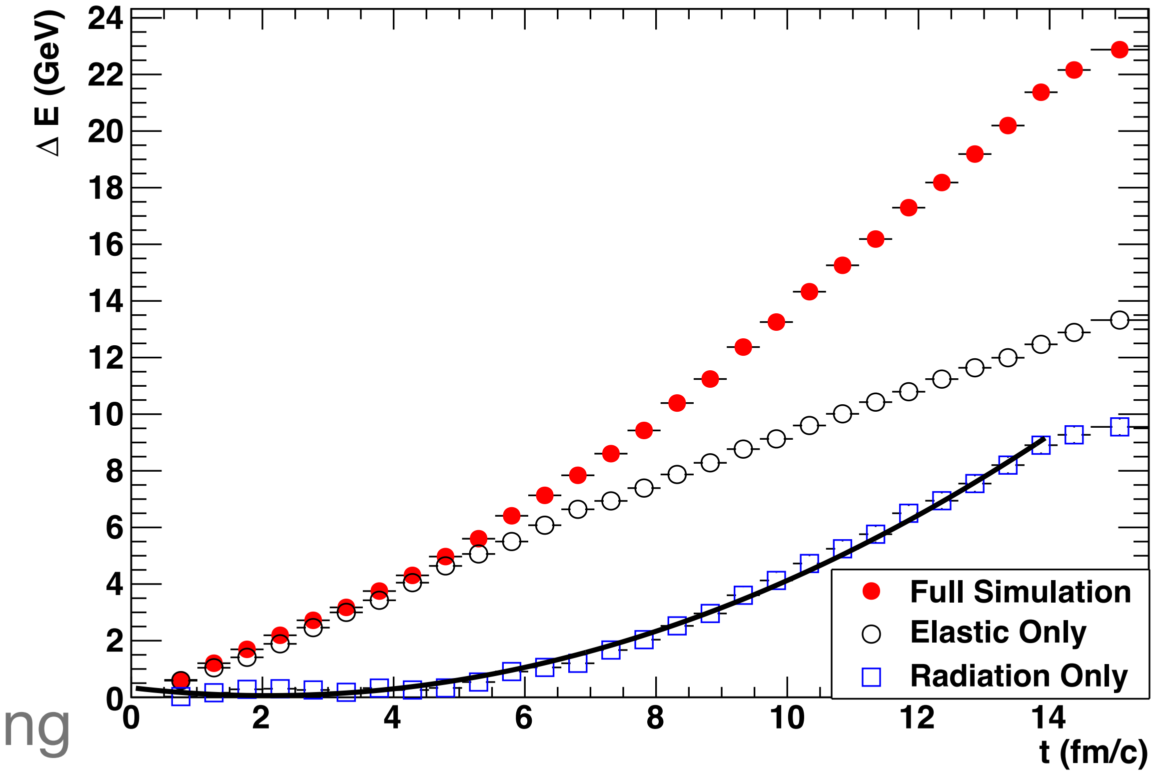
- LHC Dijet Asymmetry A_j shows strong modification of reconstructed jets.
- Identified jets measurements are possible at RHIC, which observables are the most informative? Is the dijet asymmetry the best? Are there other suitable intra-jet observables?
- Need to understand dependence of observables upon underlying processes to make useful deductions about the nature of the QGP.
- Carry out a systematic analysis of the sensitivity of dijet observables at RHIC scales. Use VNI/BMS Parton Cascade Model.



VNI/BMS, a simple-enough transport model

- VNI/BMS models partonic transport via the Boltzmann equation. Treats medium and jet on an equal footing.

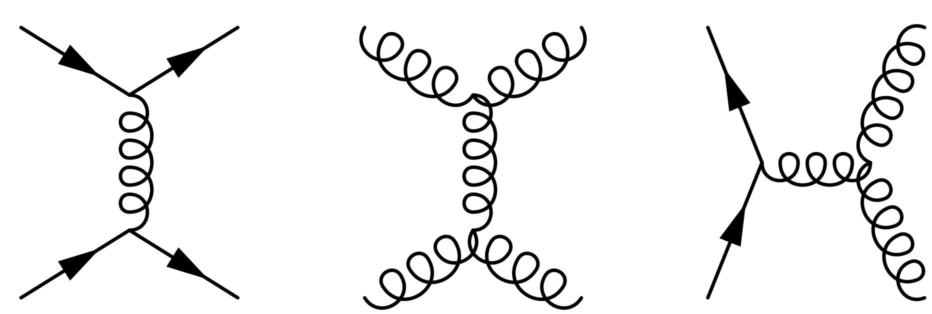
$$p^{\mu}\frac{\partial}{\partial x^{\mu}}F_k(x,\mathbf{p}) = \sum_{processes} \mathcal{C}_i F.$$



- Interactions are tree level 2->2 scatterings and final-state radiation. Radiation includes leading order (BDMPS-Z) LPM effect.

$$-\Delta E_{\mathrm{BDMPS}} = \frac{\alpha_s C_R}{8}\frac{\mu^2}{\lambda_g}L^2 \log\frac{L}{\lambda_g}.$$

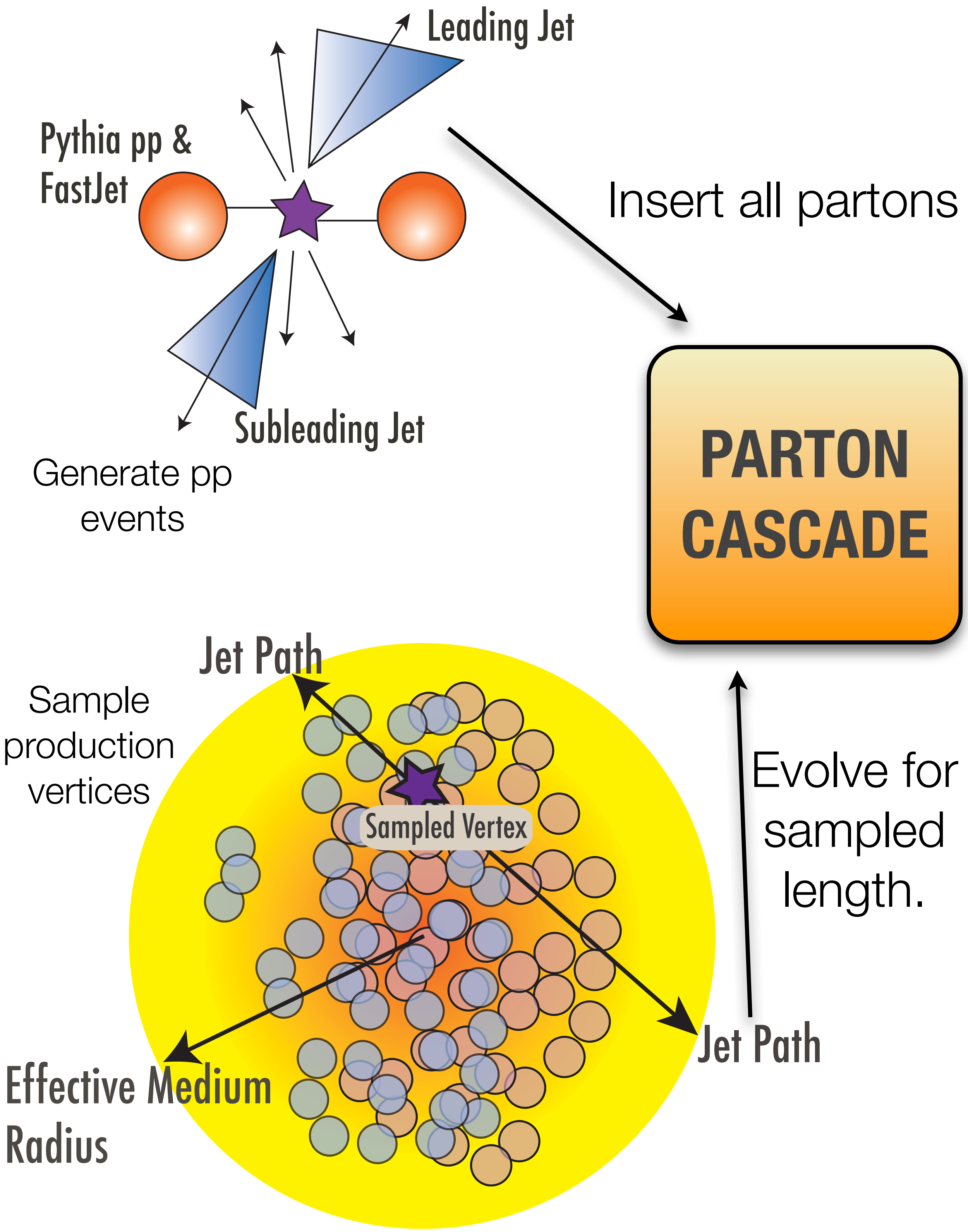
- Medium is a box of thermal partonic QGP at a fixed temperature. No expansion!



- A generated jet is injected, cascade of interacting partons are tracked. Evolution of entire jet is recorded.

- A Jet-finder is applied in post-processing stage, jet development can be extracted for varying jet-definitions.

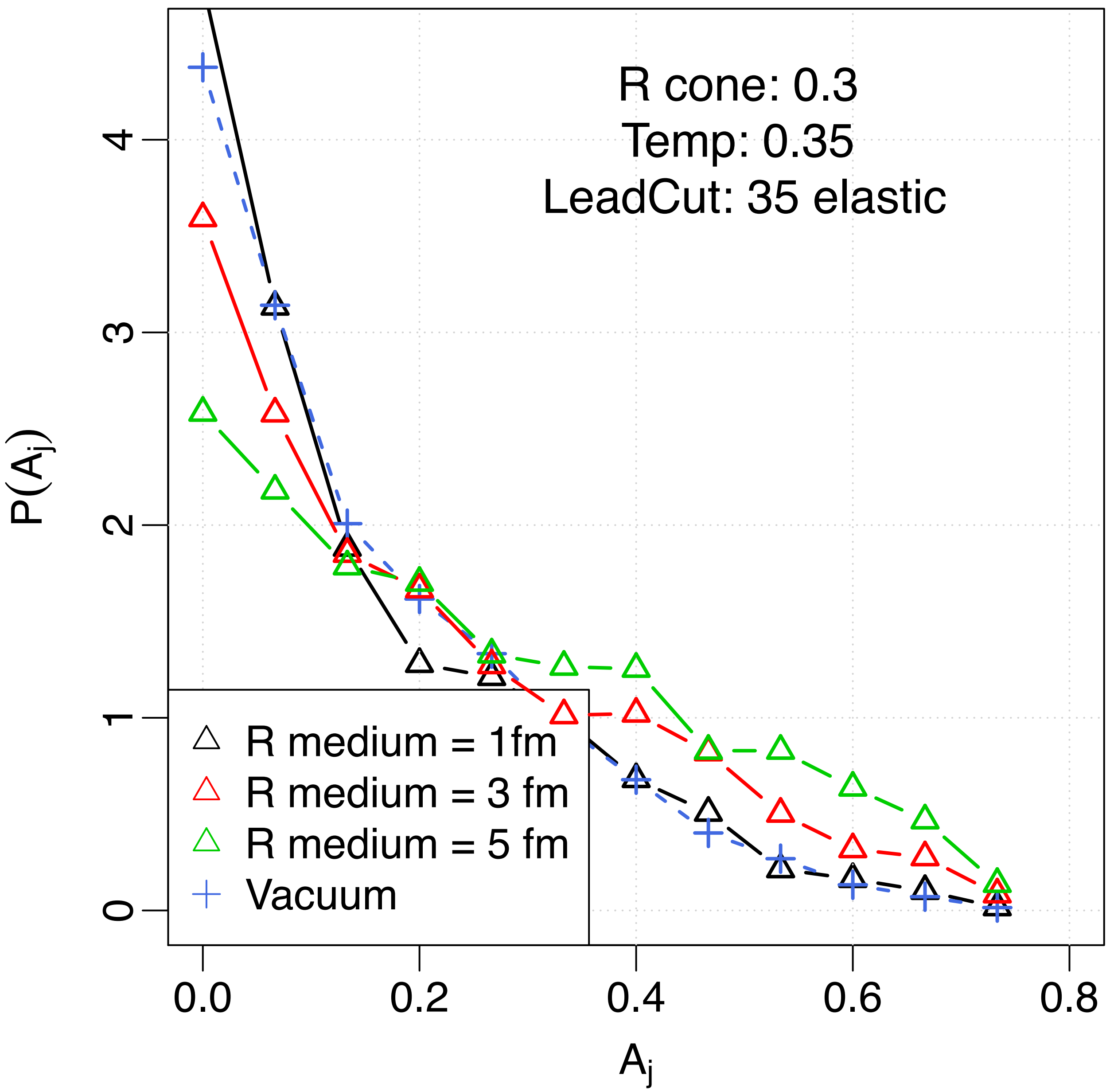
Dijet Asymmetry at RHIC

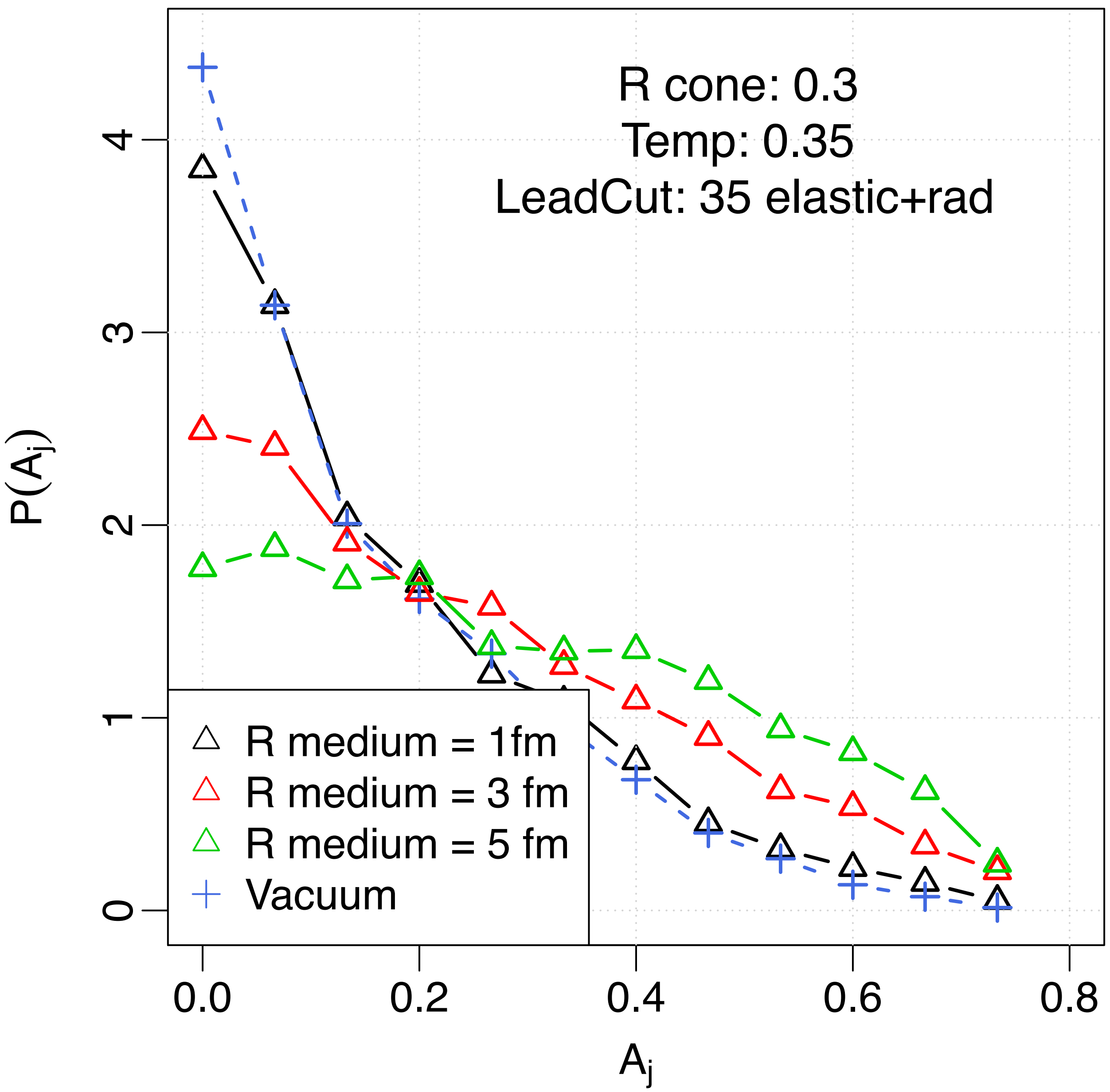


- Use VNI/BMS to understand dependence of A_j and other observables on:
  - qhat, determined by the medium temperature: T = 250, 350, 450 MeV
  - Cuts on leading jet energy and cone-radius:
    Elead > 20, 35, 50 GeV, R = {0.2, 0.3, 0.4}
  - Interaction mechanism, elastic or elastic +radiative
- Generate pp events at 200 GeV using Pythia 8, of acceptable dijet pairs using FastJet.
- Sample production vertices uniformly within a circular medium of some radius R.
- Insert partonic contents of each jet into parton cascade box and evolve for sampled path length.

Dijet Asymmetry - Varying Circular Medium Radius

Longer medium radius increases asymmetry

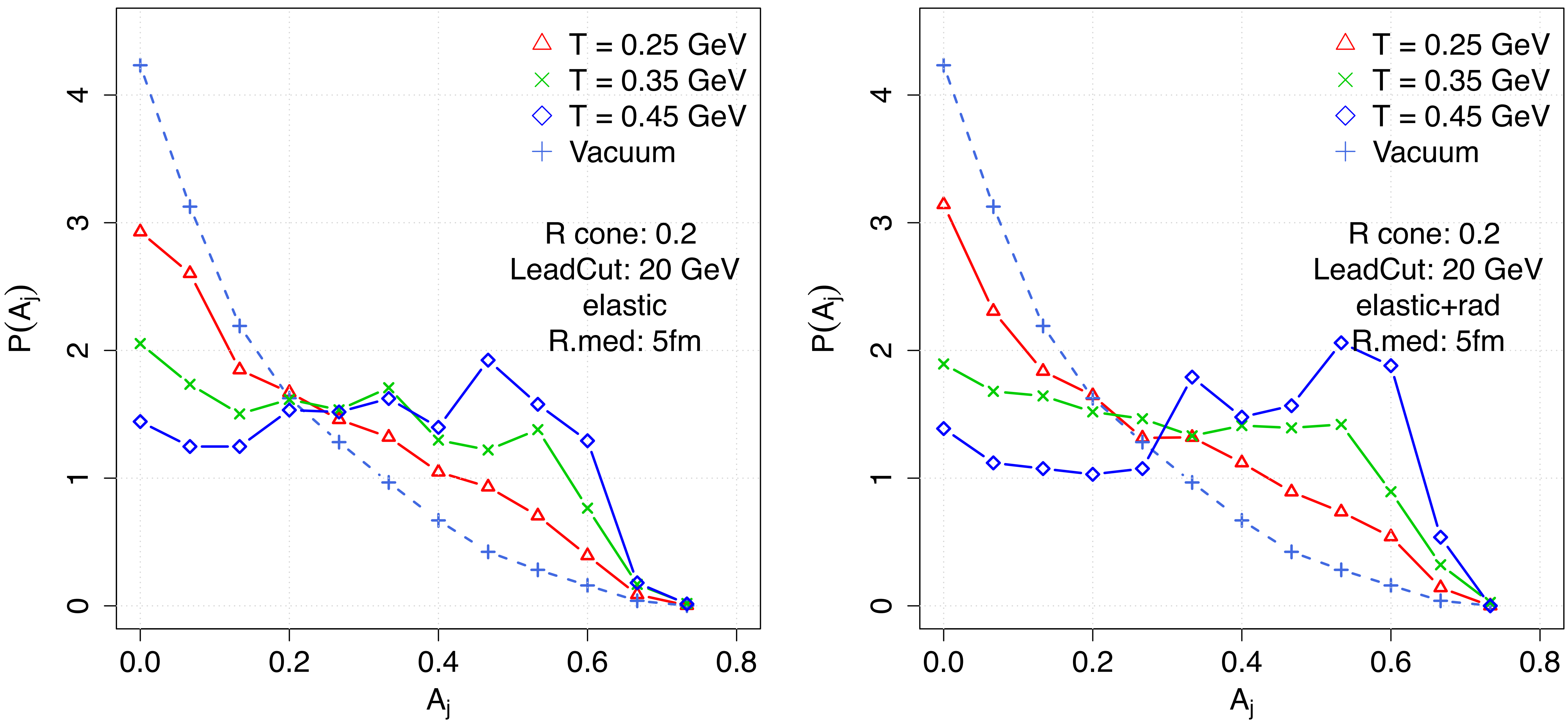




Medium does not expand, temperature is constant

Dijet Asymmetry - Varying Medium Temperature

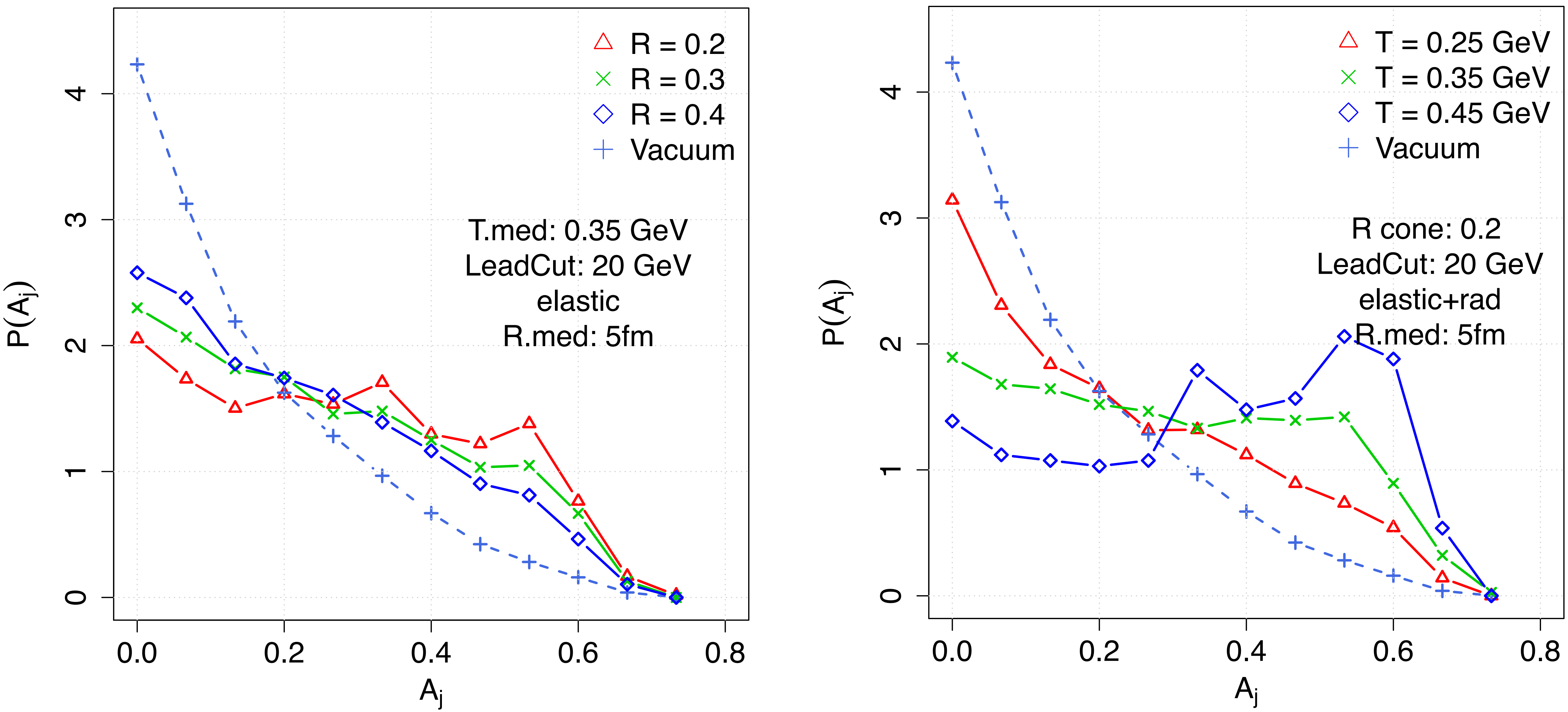
medium radius fixed at 5fm



Nevents T<0.45 ~ 4000
Nevents T=0.45 ~ 2000

Increasing medium temperature increases asymmetry.

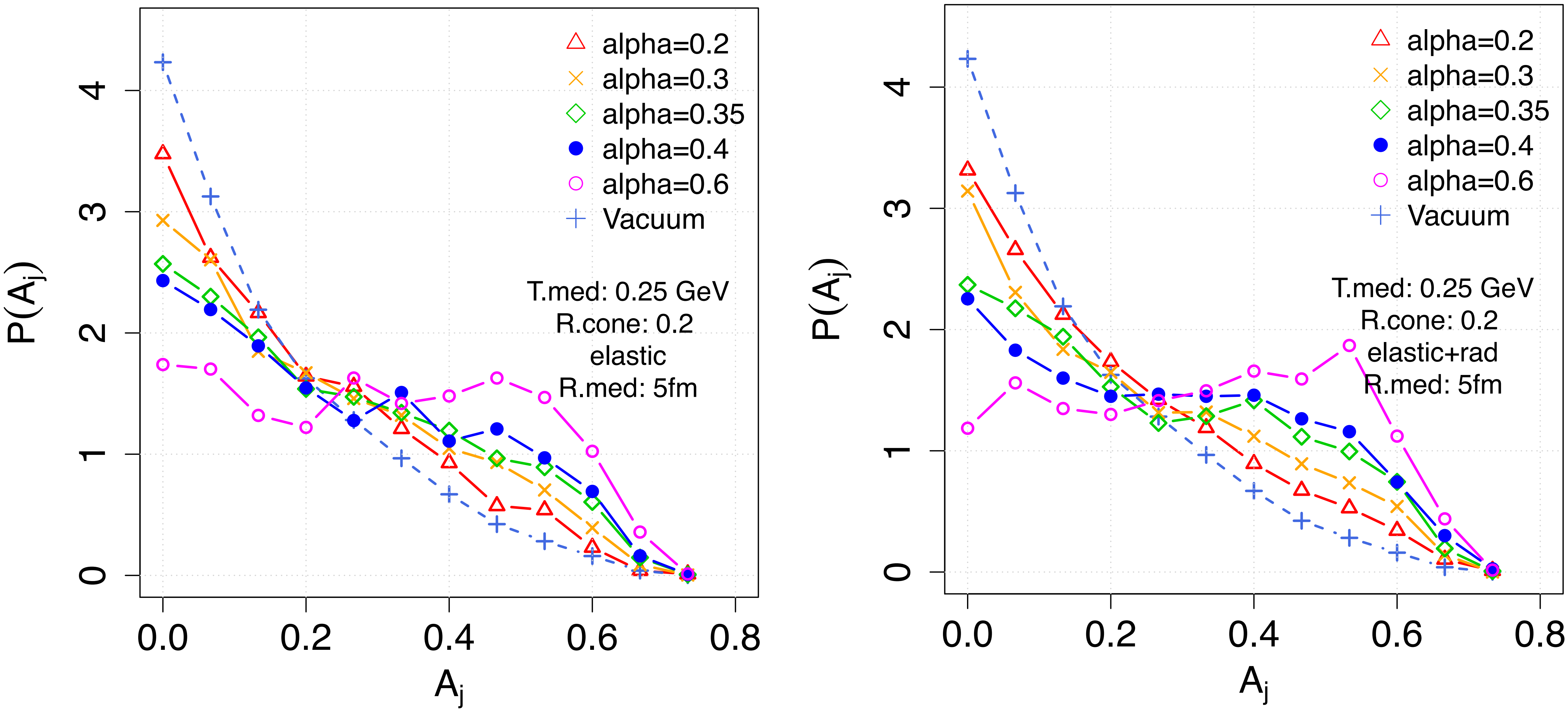
Dijet Asymmetry - Varying Jet Cone Radius



Increased Cone Radius reduces asymmetry, captures more of the modified jet

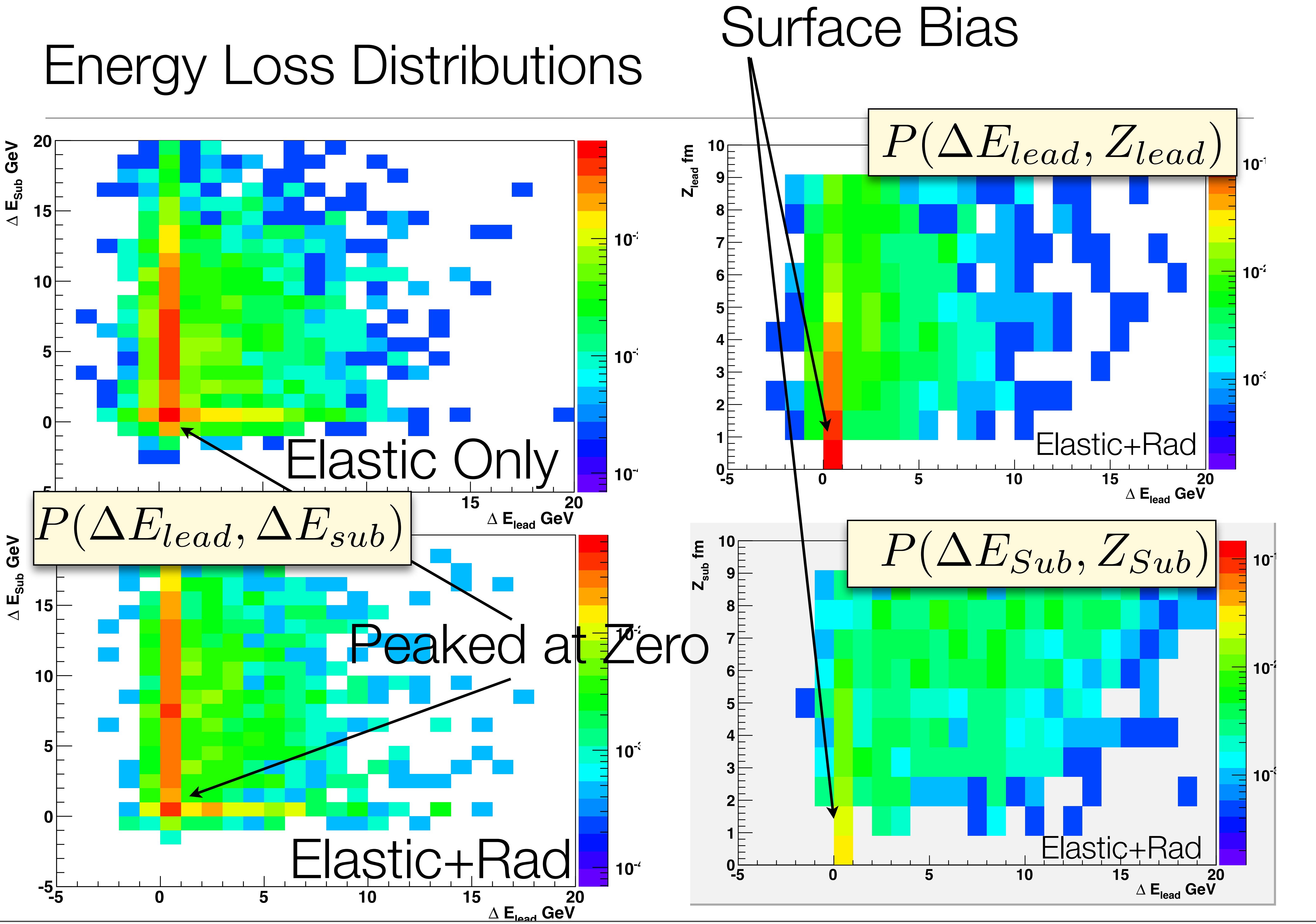
Dijet Asymmetry - Varying Strong Coupling

medium radius fixed at 5fm



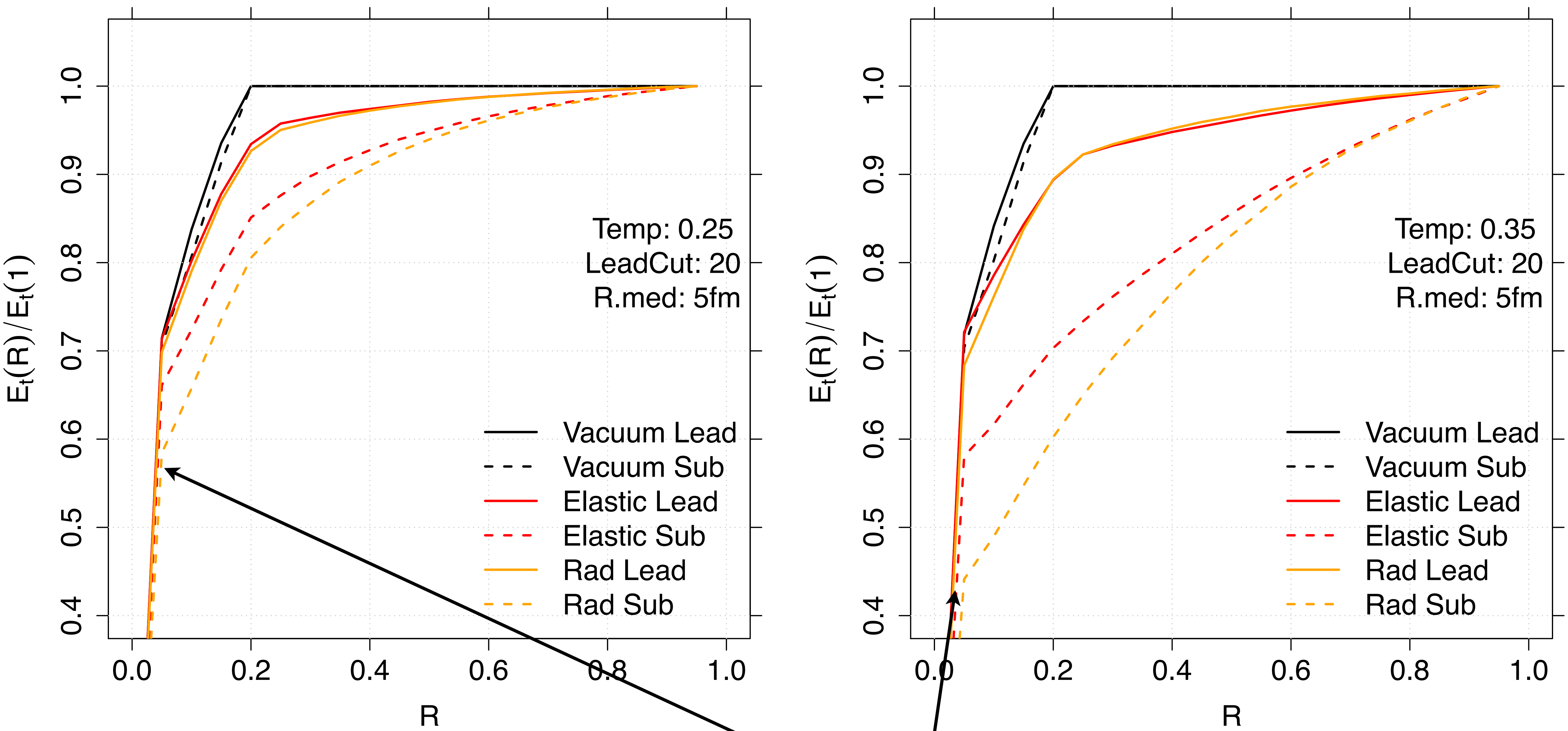
medium temperature T = 250 MeV

Energy Loss Distributions



Jet Shape

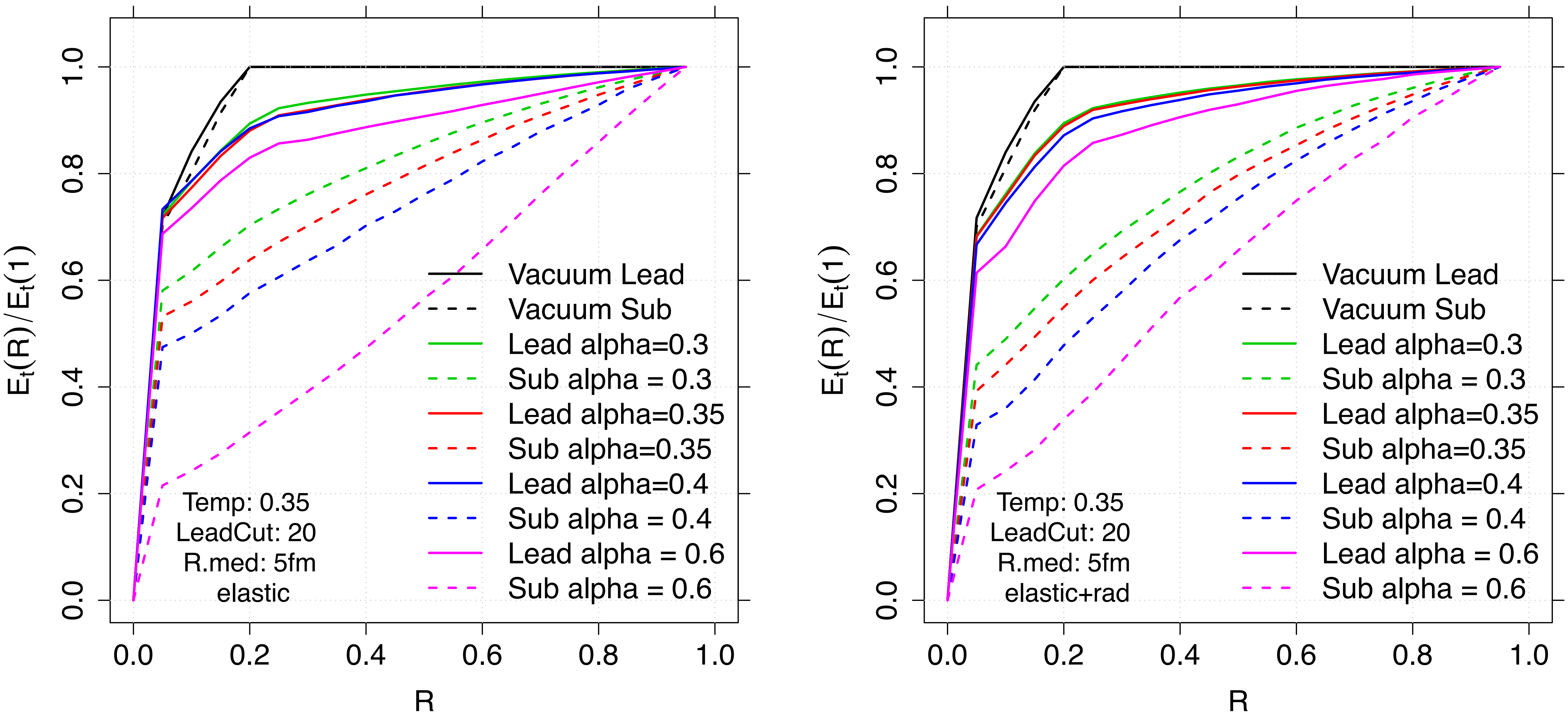
Reconstruct jets with Anti-Kt at successively larger cone radii



Clear separation between elastic (red) and radiative (orange) modes and leading and subleading jets

Difference between medium temperatures is very strong, note values as R->0

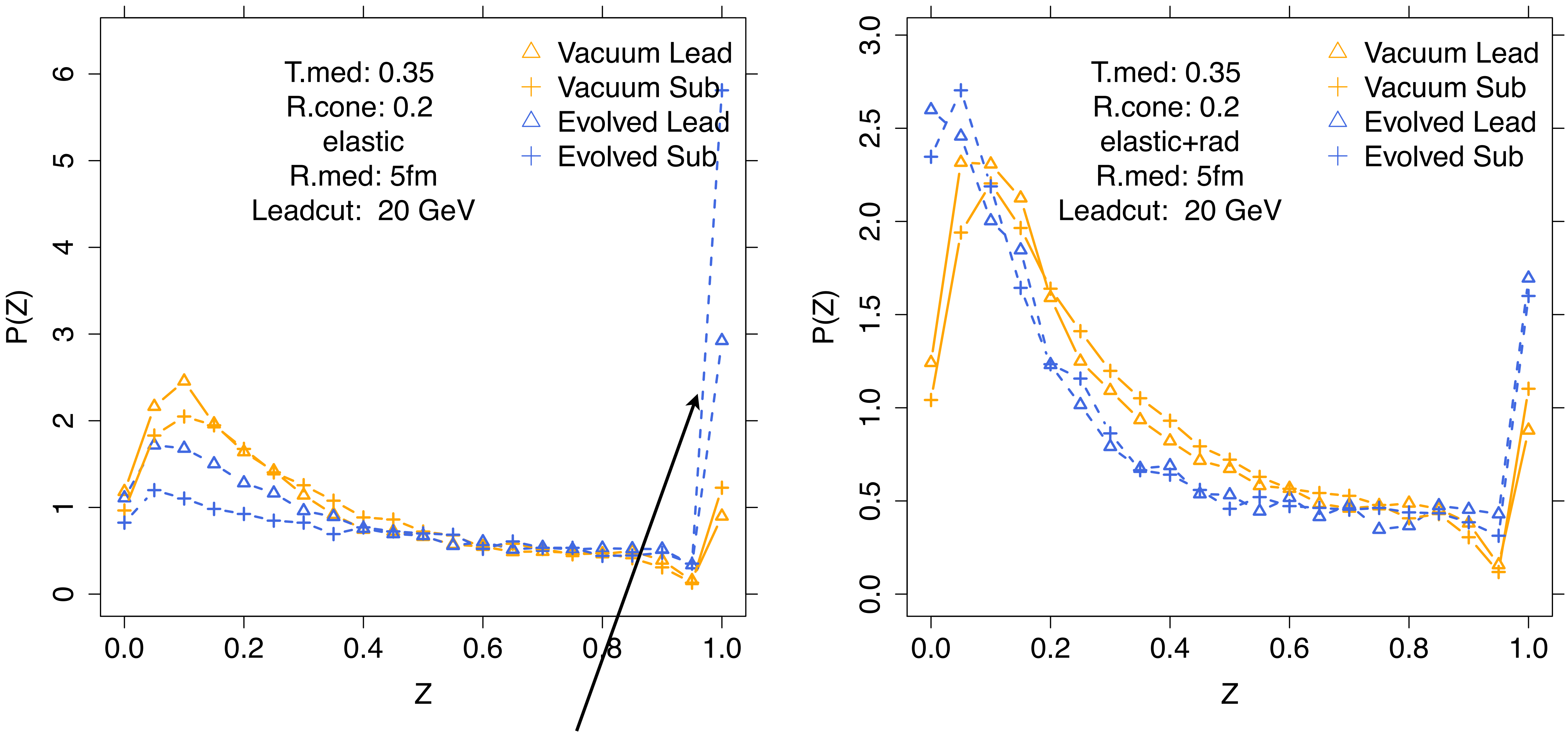
Jet Shape - 2, varying strong coupling



elastic interactions only

elastic+radiative

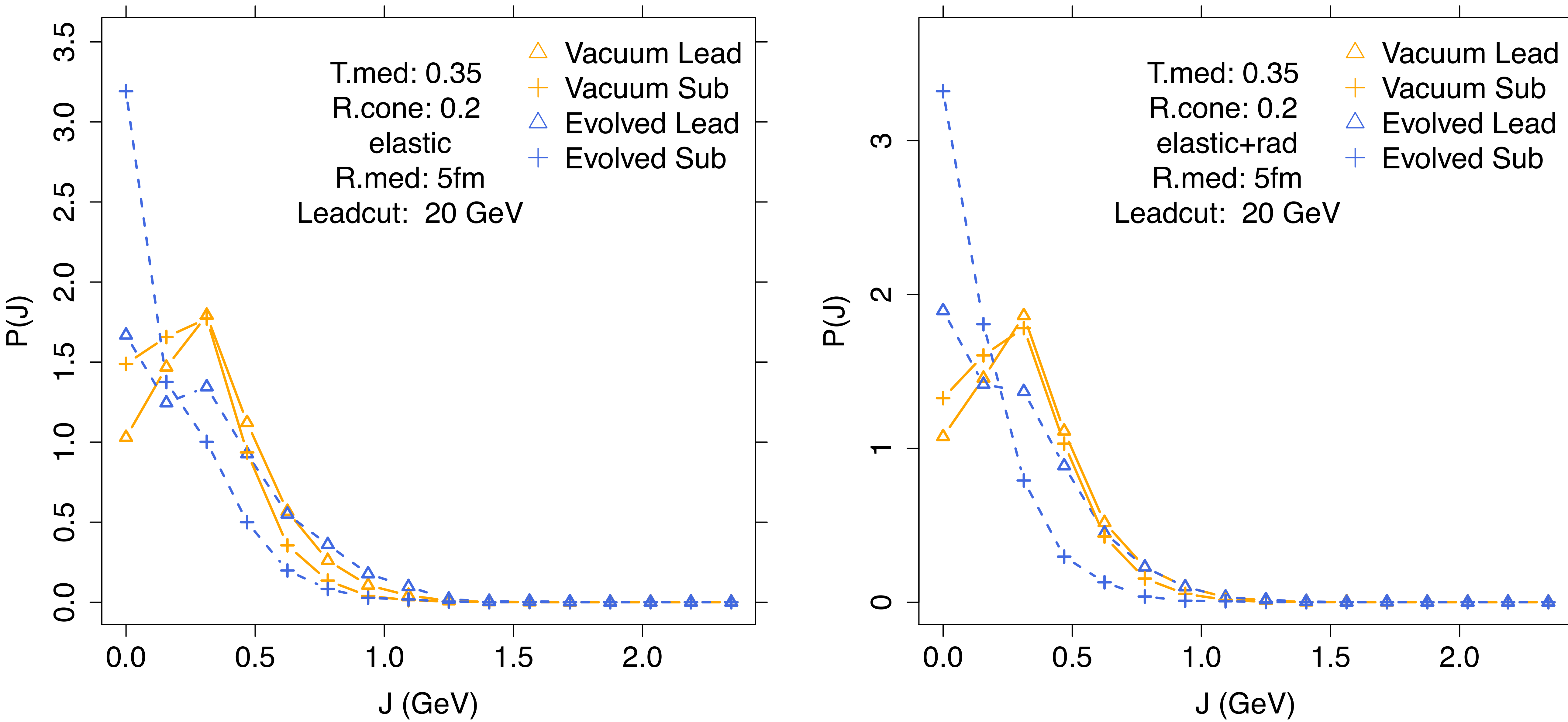
VNI/BMS Partonic Fragmentation - z



Single parton jet peak **enhanced** by evolution
soft partons scattered out of the jet

Radiation fills in soft region, z=1 peak is still enhanced

VNI/BMS Partonic Fragmentation j_T



Evolution tends to soften the distribution transverse to the jet axis (fixed R)

Conclusions

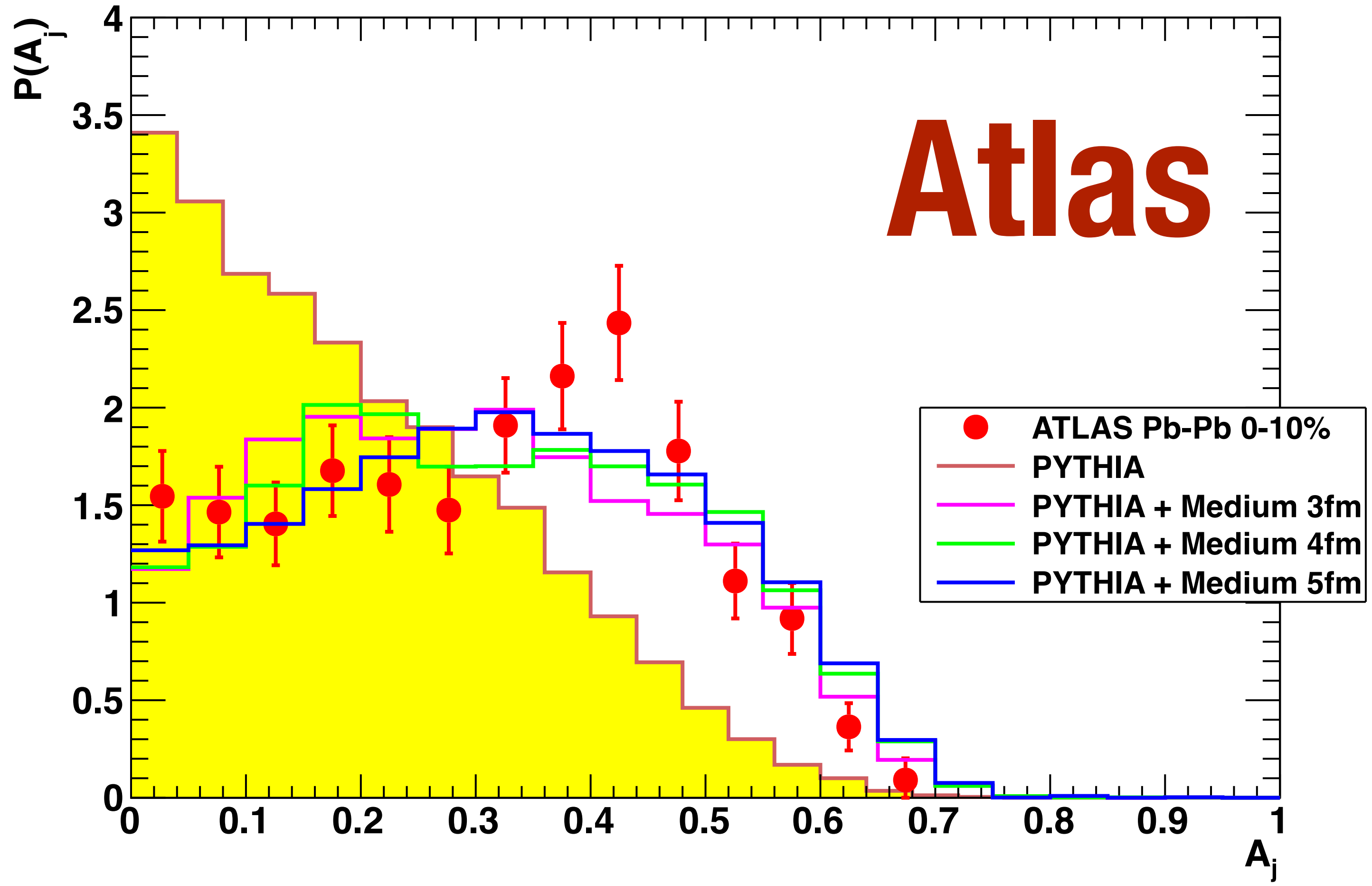
- RHIC Dijet Asymmetry is sensitive to: strong coupling, medium radius, medium temperature and cone radius. Sometimes this is subtle.
- Many jets are not modified, leading jets are strongly surface biased (this is a consequence of pQCD value for qhat!)
- Those that are modified have a softened radial profile (jet shape), partons are scattered transverse to the jet axis, transverse fragmentation profile softened.
- Partonic fragmentation distributions are peaked at z = 1 for RHIC jets, fragmentation changes <N> and redistributes p_t.
- Interplay of vacuum and medium evolution is clearly important for these observables. Working to implement a simple-enough fragmentation scheme to complement this analysis.

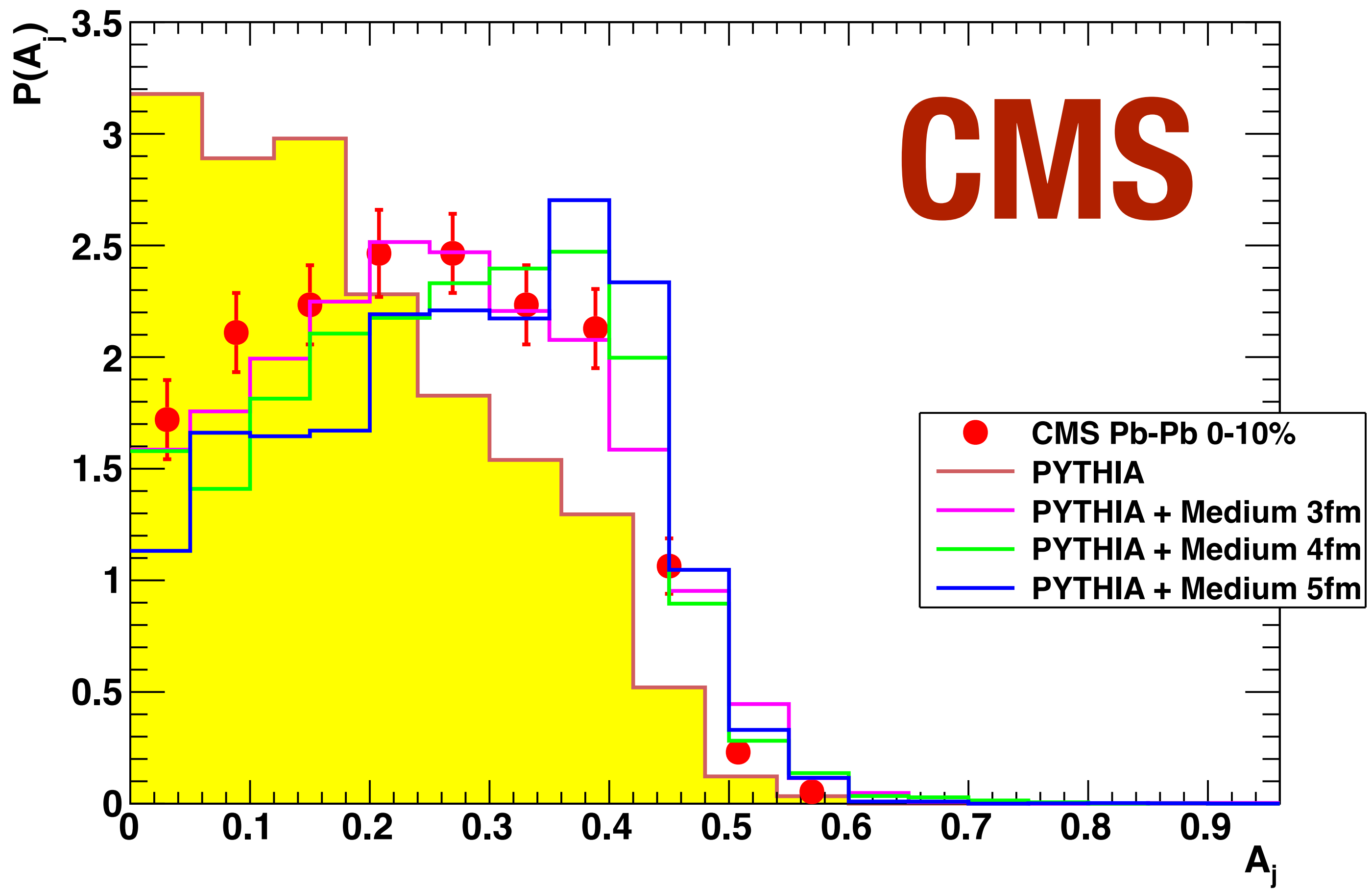
Extra Results

LHC Results

Circle Mode + Glauber Vertices can reproduce LHC data reasonably well.

Central collisions (0-10%)



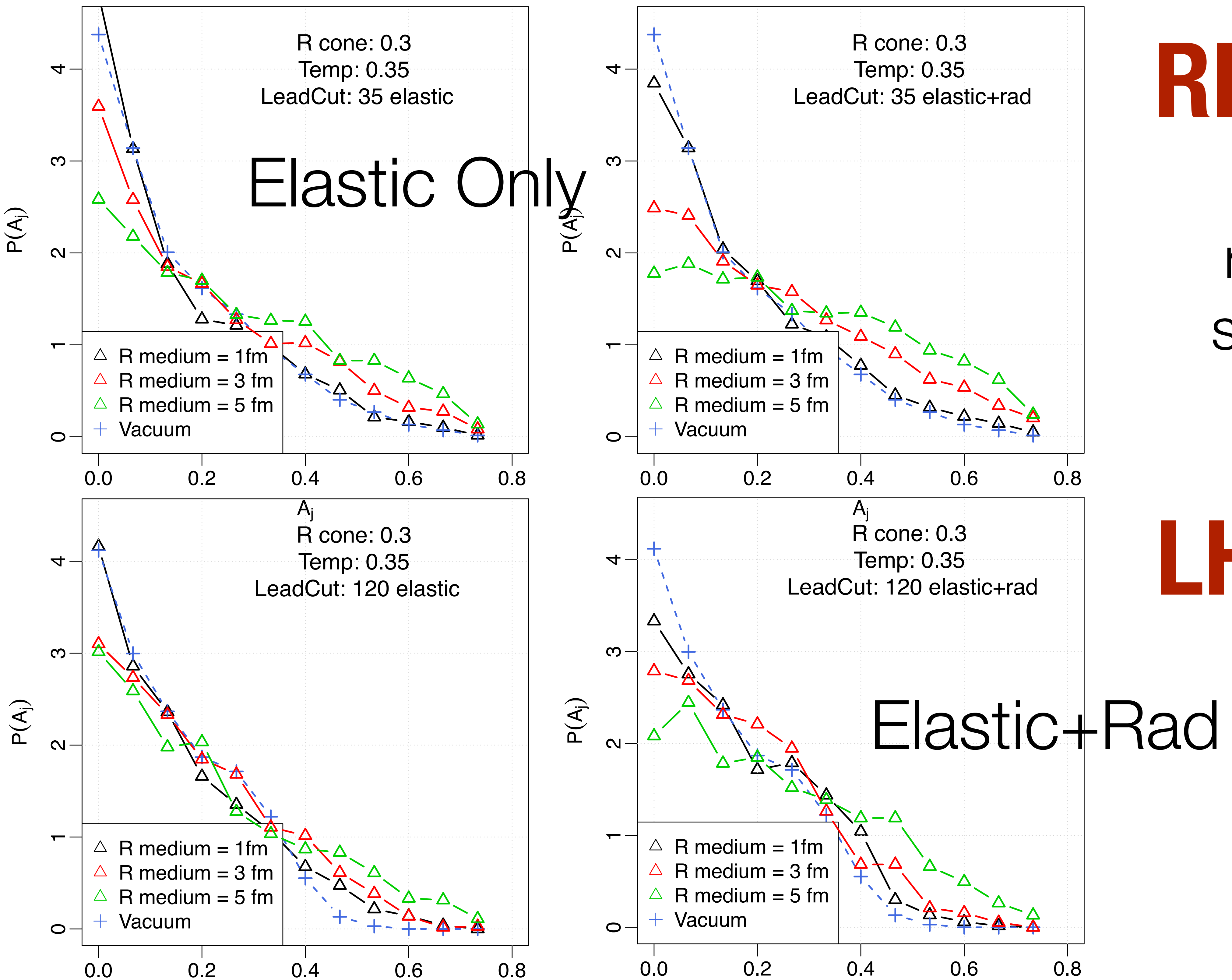


Both results include detector smearing effect

$$E_t^\star \sim N(E_t, \alpha\sqrt{E_t}), \quad \alpha \simeq 1.2$$

Presented at QM 2011

LHC/RHIC Comparison. - Medium Radius

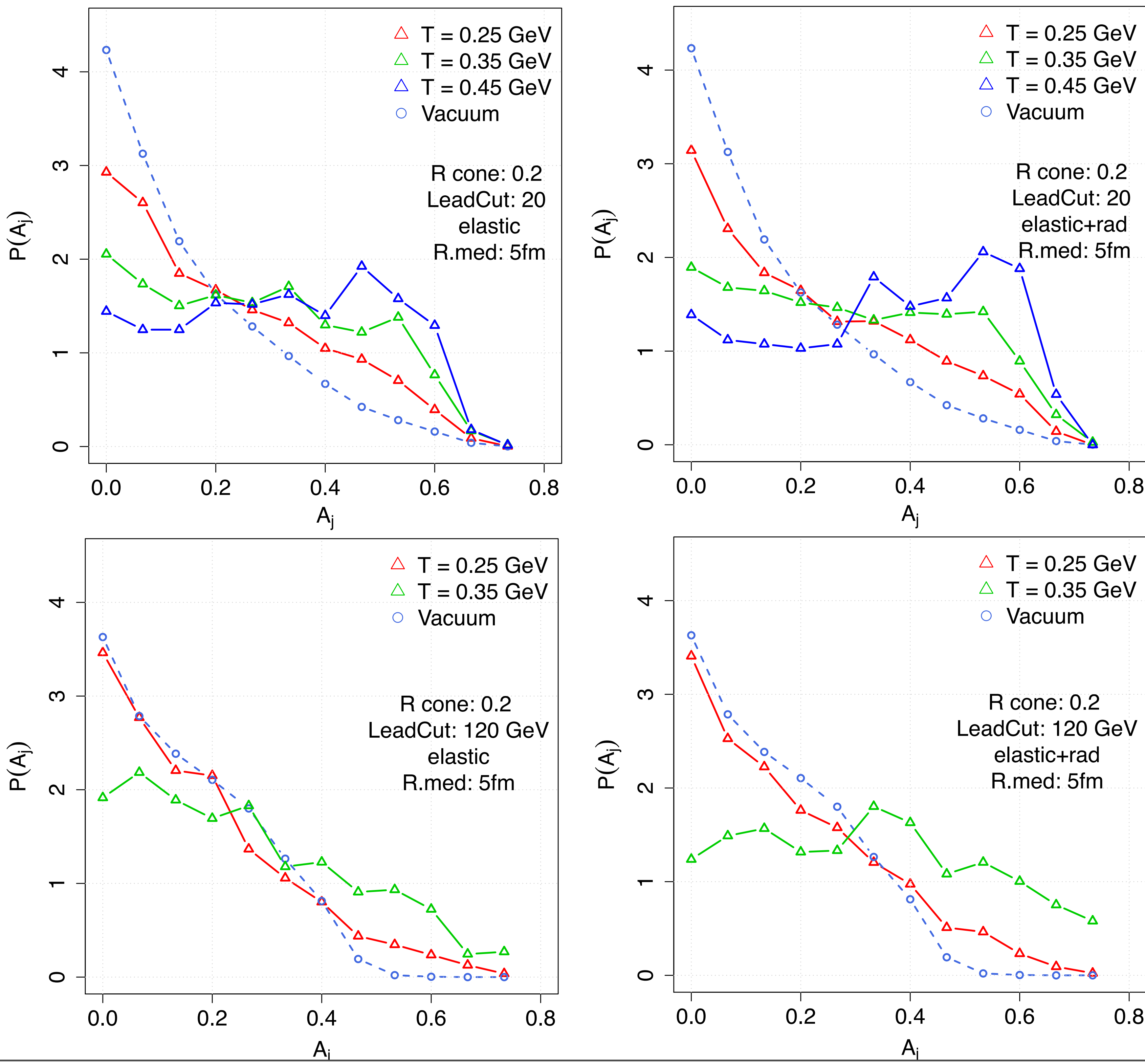


RHIC

RHIC scale results are more strongly modified by medium length

LHC

LHC/RHIC - Varying Medium Temperature

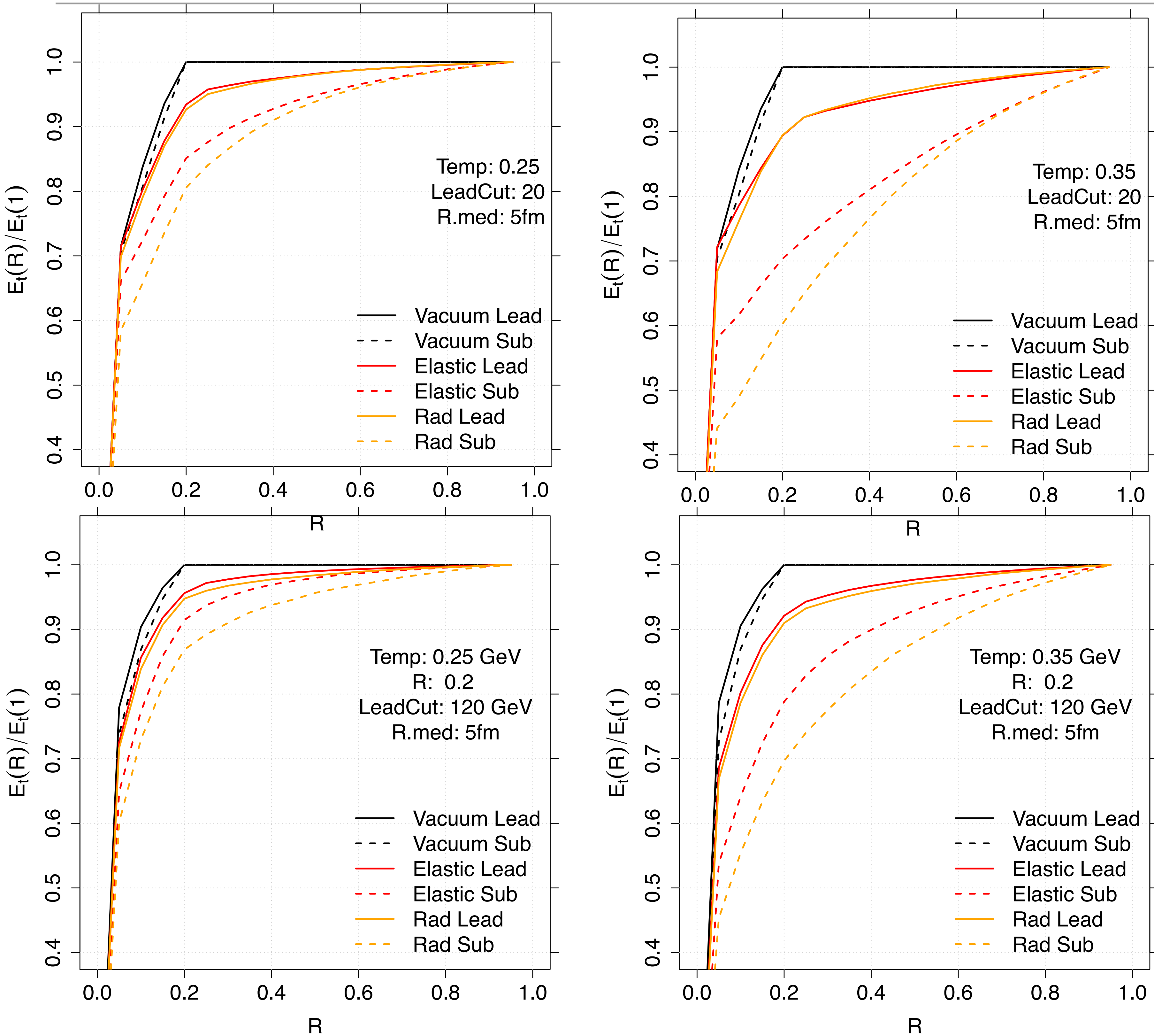


RHIC

Modification is similar between scales

LHC

LHC/RHIC - Jet Shape



RHIC

RHIC profiles are broader than LHC

LHC

LHC fragmentation - Z

Scattering partons out of jet **hardens** Z distribution

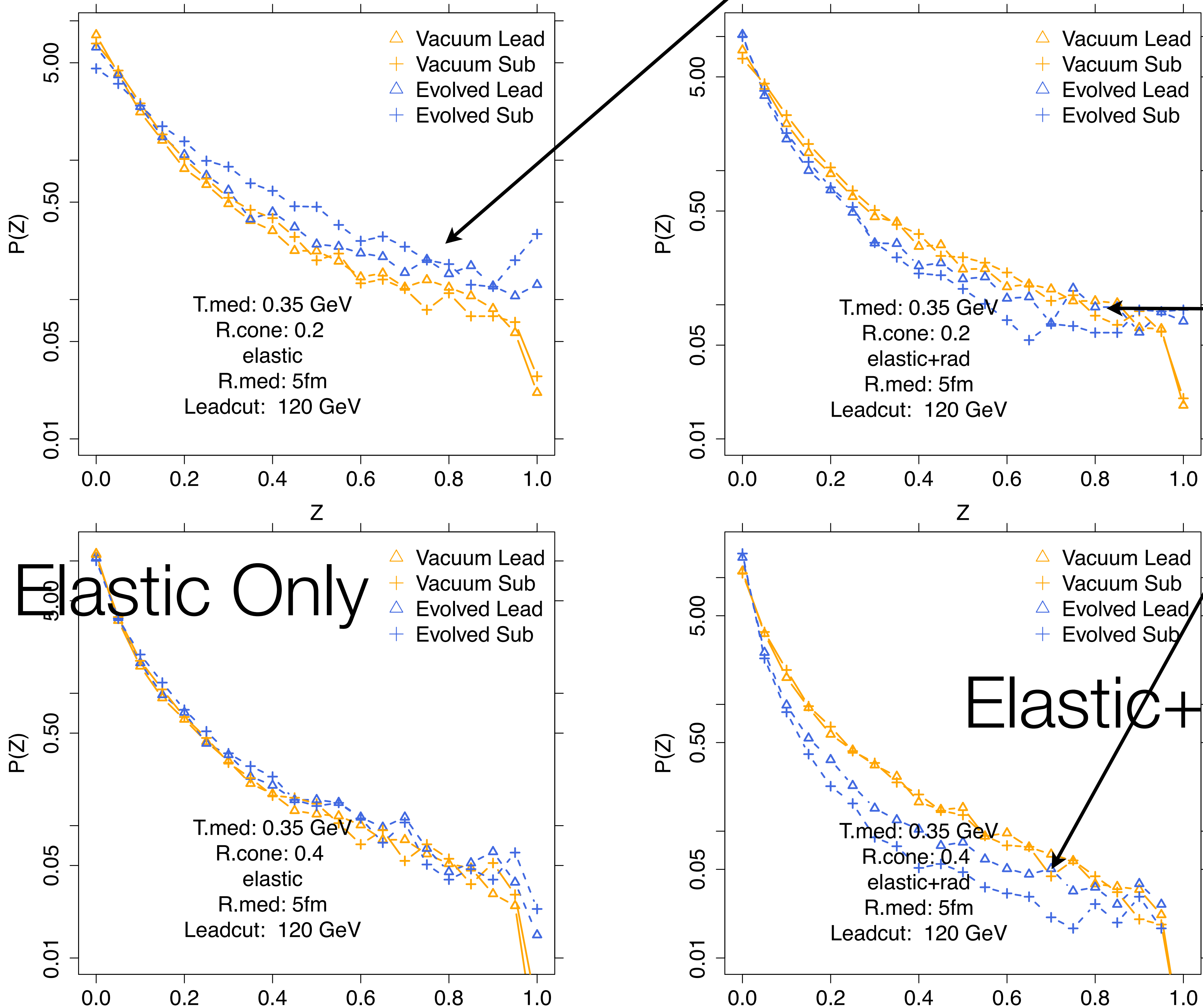
R = 0.2

Radiation **softens** Z distribution

R = 0.4

Elastic Only

Elastic+Rad



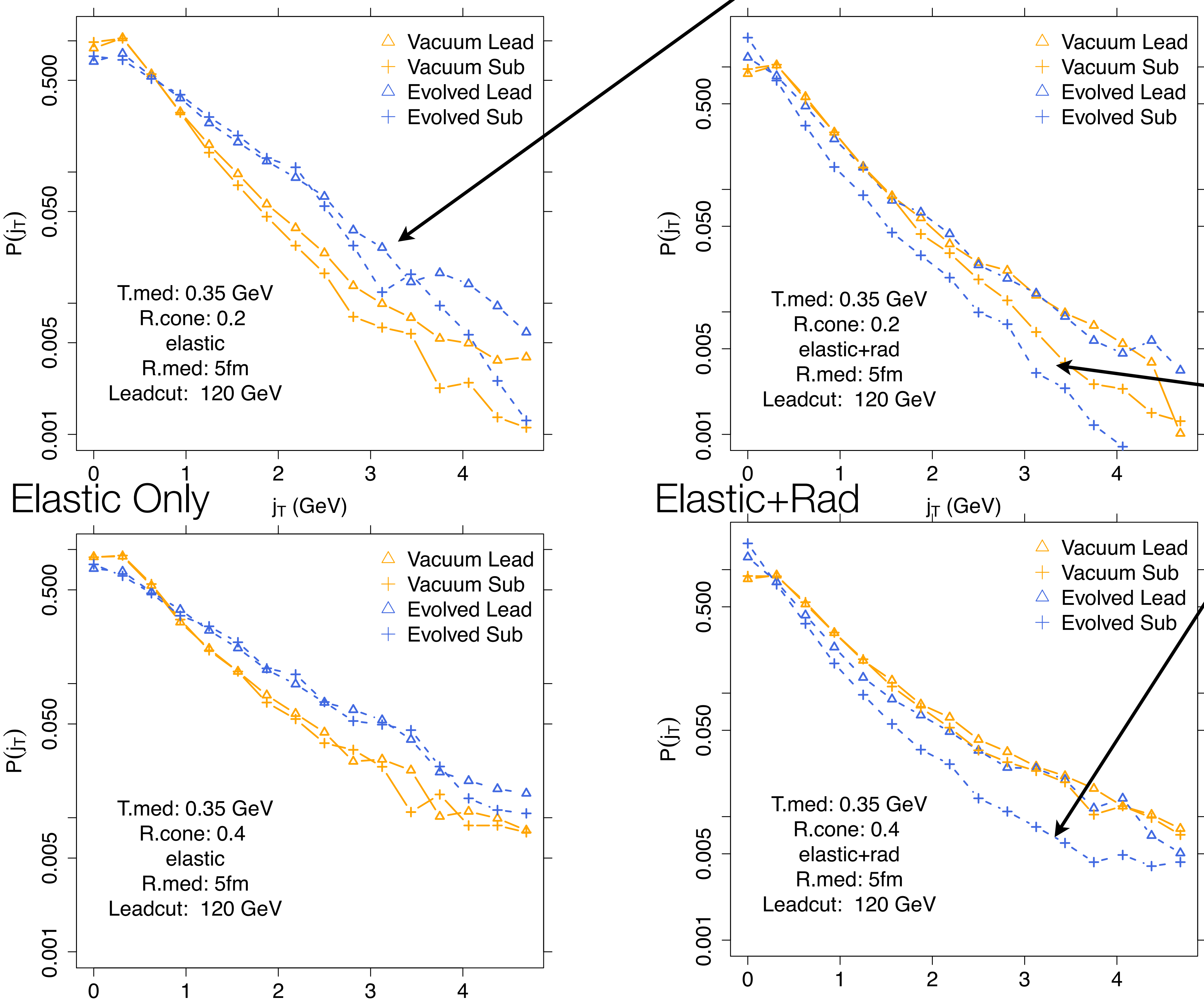
LHC Fragmentation - J

Elastic scattering moves partons to higher jt

R = 0.2

Radiation **softens** Jt distribution

R = 0.4



Backup Information

Coherence Effects in QCD Radiation

- Coherence scales with formation time

$$\tau_f = \frac{2\omega}{q_\perp^2}$$

- Gluon scattering dominates
- Incoherent emission, Bethe-Heitler

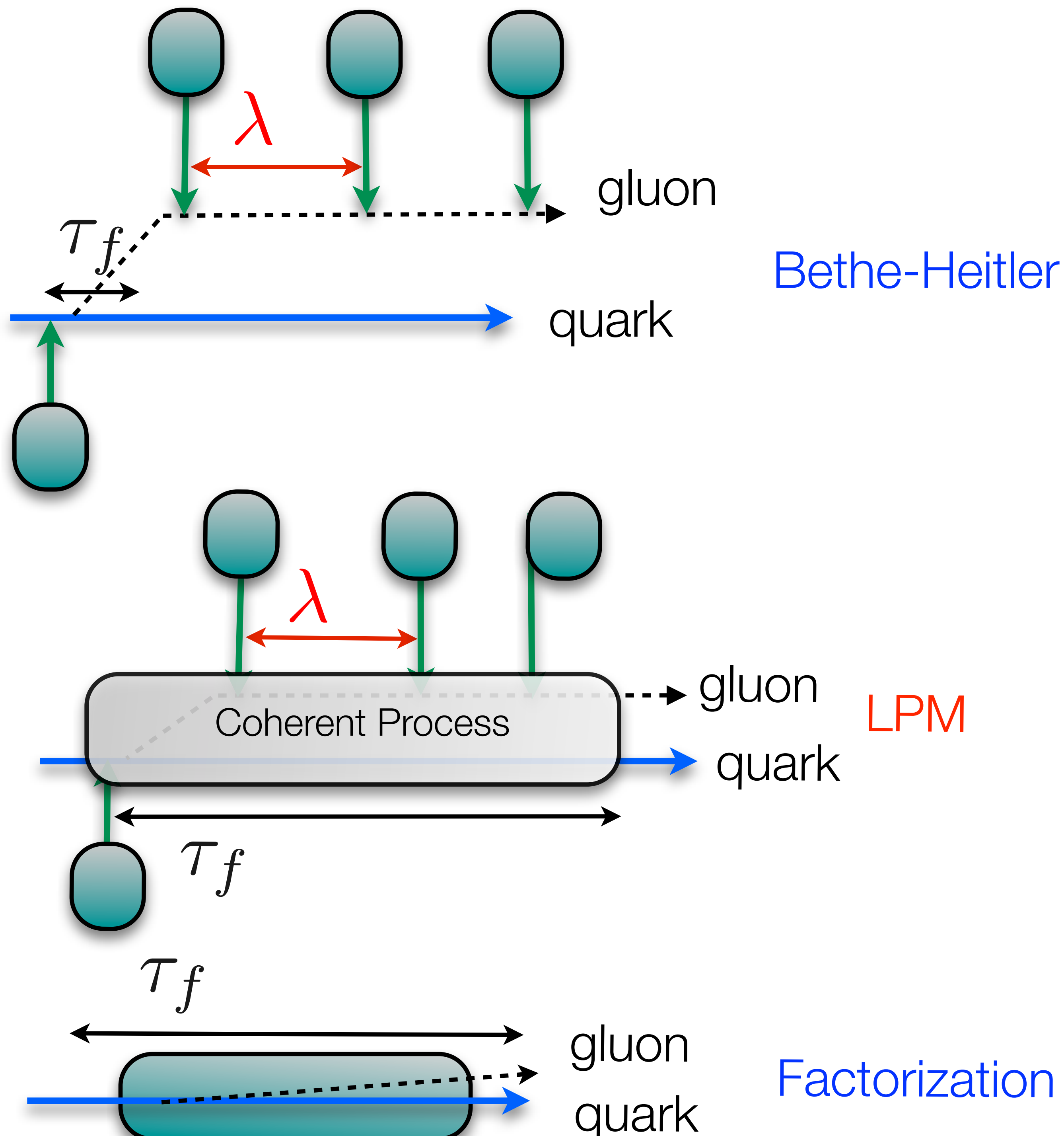
$$\Delta E \propto L$$

- Individual scattering centers not resolved. Coherent radiation. LPM effect

$$\Delta E \propto L^2$$

- Coherence length exceeds medium, Factorization limit.

$$\Delta E \propto \sqrt{E} L$$



[9] Landau.L.D, Pomeranchuk.I *Dokl.Akad.Nauk.Ser.Fiz 92 (1953)*, Migdal.A.B *Phys.Rev.103:1881 (1956)*

Zapp and Wiedemann, LPM Algorithm

- Probabilistic local implementation of coherence, gives rise to an L^2 energy loss.

- Post Inelastic scattering, compute formation time of emitted gluon

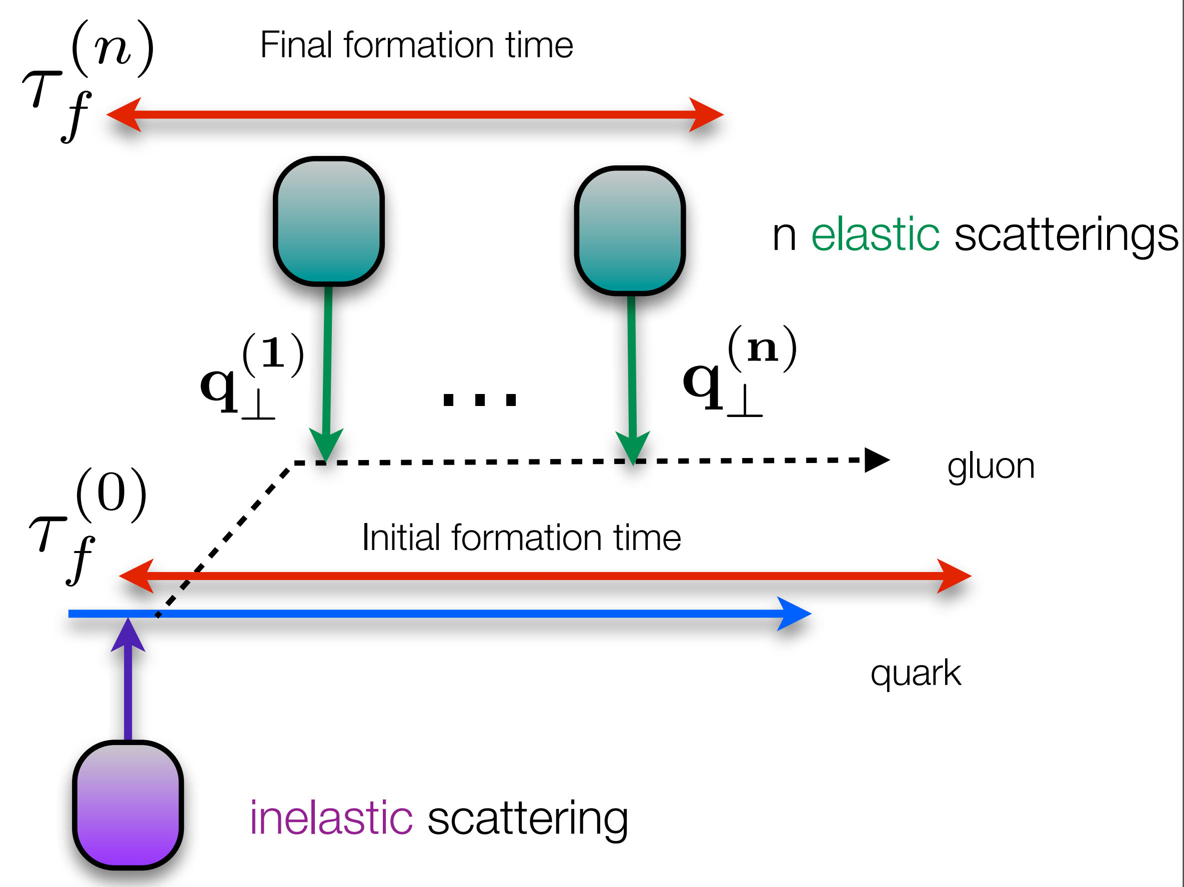
  - Emitting parton does not interact during this time

  - Radiated gluon rescatters elastically off the medium, recompute modified formation time

  - Repeat until formation time expires

  - Quark and gluon propagate freely

- Simulates coherent emission from multiple centers



$$\tau_f^{(n)} = \frac{2\omega}{\left(\mathbf{k}_\perp + \sum_{i=0}^{n} \mathbf{q}_\perp{}^{(i)}\right)^2}$$

Zapp K, Wiedemann U. *Phys Rev Lett,* 103 (2009) JEWEL
CCS, S.A.Bass, D.K.Srivastava, *hep-ph/1101.4895*