Jet-Triggered Back-Scattering Photons for QGP Tomography

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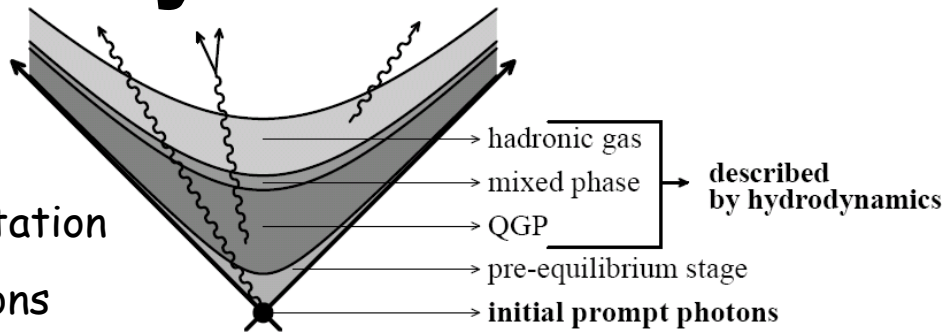
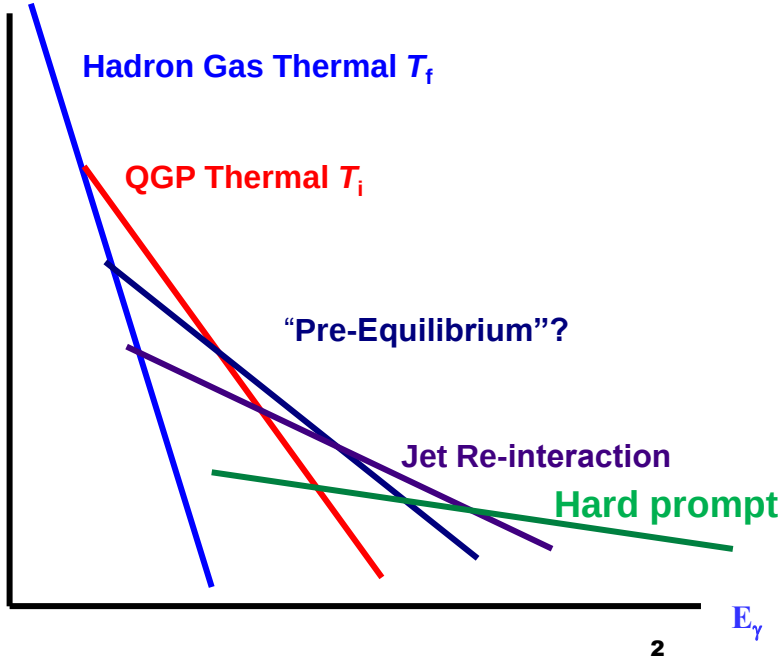
Quark Matter 2012
Washington DC, August 15, 2012

Direct Photons in Heavy Ion Collisions



- Sources:
  - Initial hard photons + jet fragmentation
  - Pre-equilibrium + jet-medium photons
  - Thermal radiation from QGP, HRG and hadronization (→ poster by Guangyao Chen)
- Goals:
  - Separate sources experimentally.
  - Put constraints on QGP/QCD properties
- Single inclusive spectra
  - Hierarchy in momentum ~ hierarchy in average momentum transfer/temperature)



Initial Hard Photons + Fragmentation

- Background for our jet-medium photon search.
- Prompt photons from initial hard scattering of partons in the nuclei: calculable in collinear factorized pQCD.

$$d\sigma^{N+N\to\gamma+\ldots} = \sum_{a,b} f_{a/N} \otimes d\sigma^{a+b\to\gamma+\ldots} \otimes f_{b/N}$$

PDF — Parton cross section — PDF

- Photons fragmenting off jets created in initial collisions

$$d\sigma^{N+N\to\gamma+\ldots} = \sum_{a,b,c} f_{a/N} \otimes d\sigma^{a+b\to c+\ldots} \otimes f_{b/N} \otimes D_{c/\gamma}$$

PDF — Parton cross section — PDF — FF

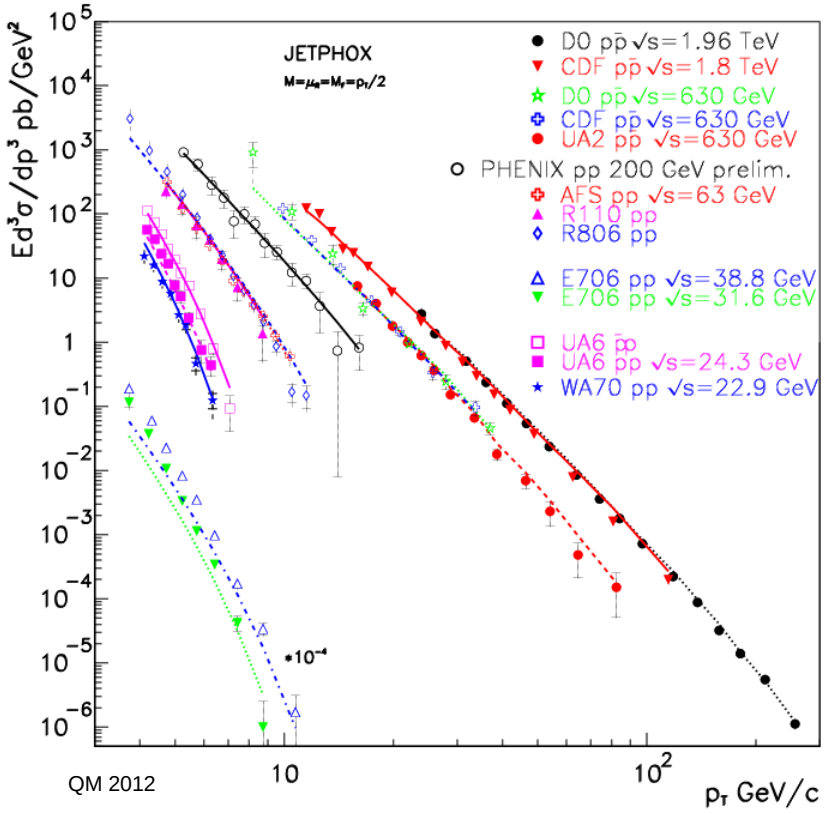
- Can be calculated in LO and NLO e.g. by JETPHOX.

Initial Hard Photons + Fragmentation

- Data in p+p well described by JETPHOX NLO calculations.
- A safe baseline!

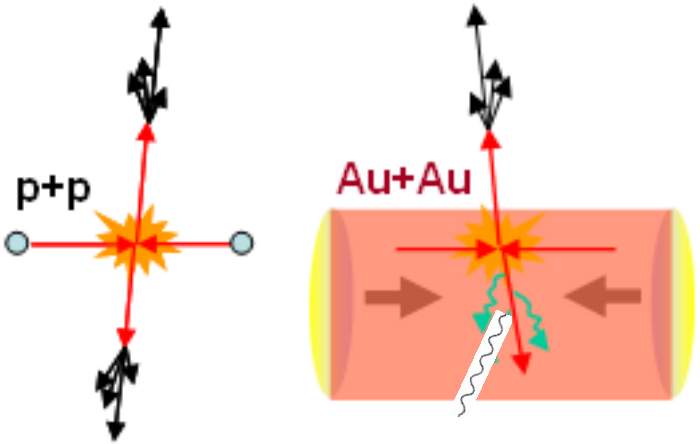
Photon world data @ hadron colliders

[Aurenche et al., PRD 73 (2006)]



Jet-Medium Photons

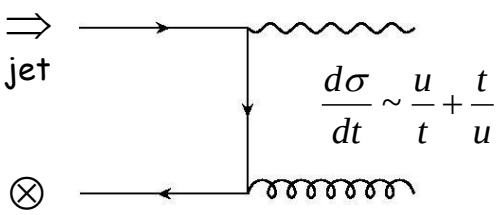
- Photon radiation induced by hard partons interacting with QGP



[RJF, Müller & Srivastava, PRL 90 (2003)]

[Zakharov, JETP Lett. (2004)]

- Particularly interesting kinematics: back-scattering peak in annihilation and Compton scattering of high momentum quarks



$$\vec{p}_\gamma \approx \vec{p}_{jet}$$
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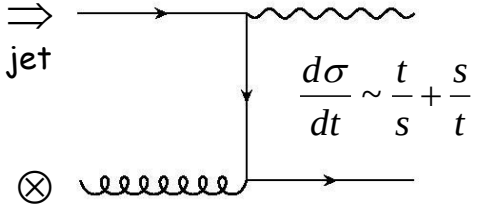
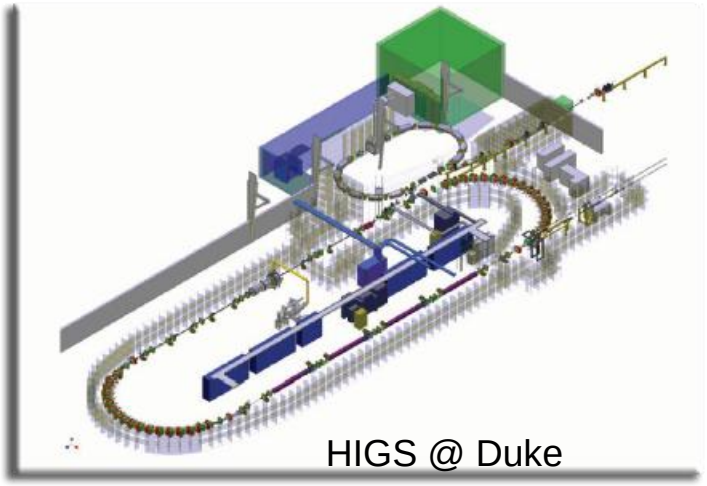


Back-Scattering Photons

- Same diagrams in QED: routinely used to convert high energy electron beams into gamma-ray beams
  - E.g. HIGS and ALICE facilities
  - (~1 eV) γ + (~1 GeV) e $\rightarrow$ (~1 GeV) γ + e



- Here:
  - (~200 MeV) g+ (~10 GeV) q $\rightarrow$ (~ 10GeV) γ + q

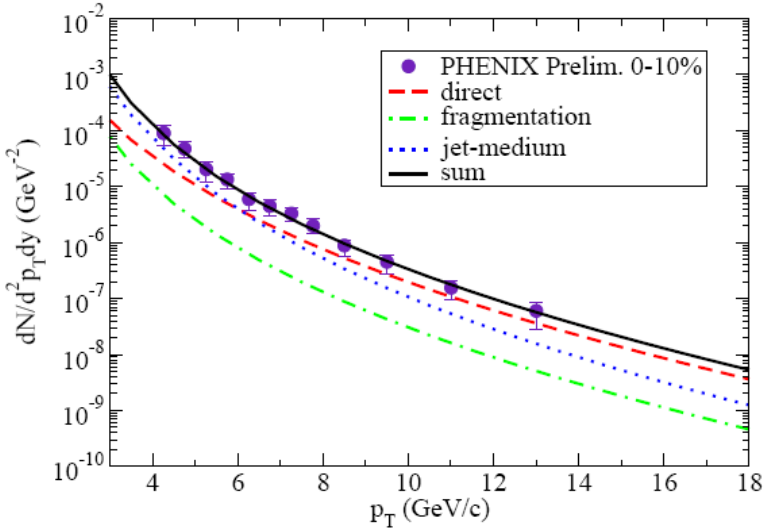
- Yield for jet phase space distribution f and QGP with temp. T:

$$E_\gamma \frac{dN_\gamma}{d^3 p_\gamma} = \frac{\alpha \alpha_s}{8\pi^2} \int d^4x \frac{2}{3} \left[f_q(p_\gamma) + f_q(p_\gamma) \right] T^2 \left(\ln \frac{4E_\gamma T}{m^2} + C \right)$$

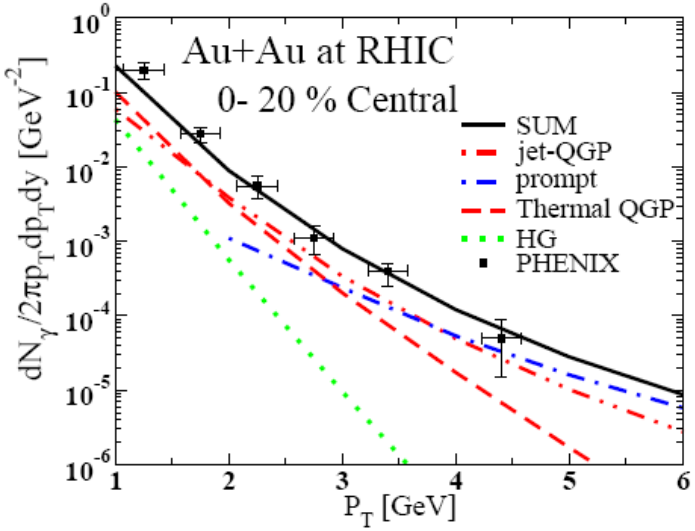
[RJF, Müller & Srivastava, PRL 90 (2003)]

How to Measure Those Photons?

- Inclusive yield and R_{AA}: hopeless



[Qin, Ruppert, Gale, Jeon & Moore, PRC 80 (2009)]



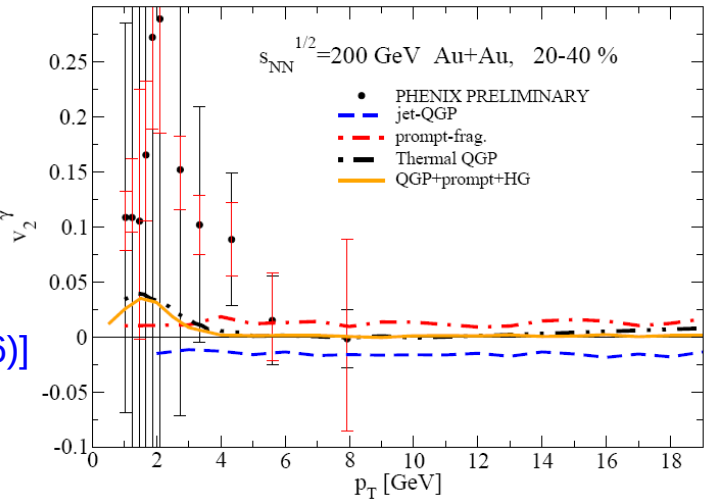
[Turbide, Gale, Frodermann & Heinz, PRC 77 (2007)]

- Negative v_2 for jet-medium photons!

  [Turbide, Gale & RJF, PRL 96 (2006)]

- Expected signal too small for current experimental resolution.

  [Chatterjee, Frodermann, Heinz, Srivastava, PRL 96 (2006)]

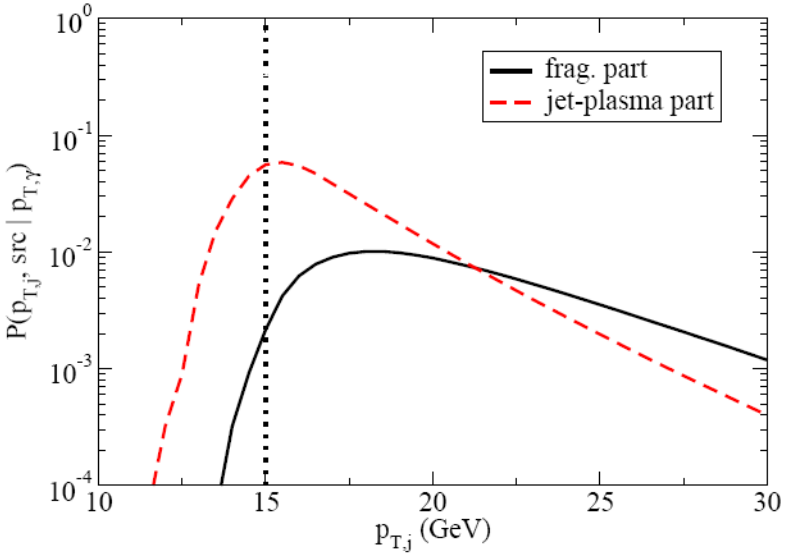


Photon-Jet Correlations

- Back-Scattering Photons:
  - Strong correlation of photon momentum and original jet momentum.
  - Strong correlation with away-side jet momentum.
- Related to photon triggered jet/hadron measurements
  - Note: jet-medium photon dilute the correlation you need for measuring energy loss/modified fragmentation.

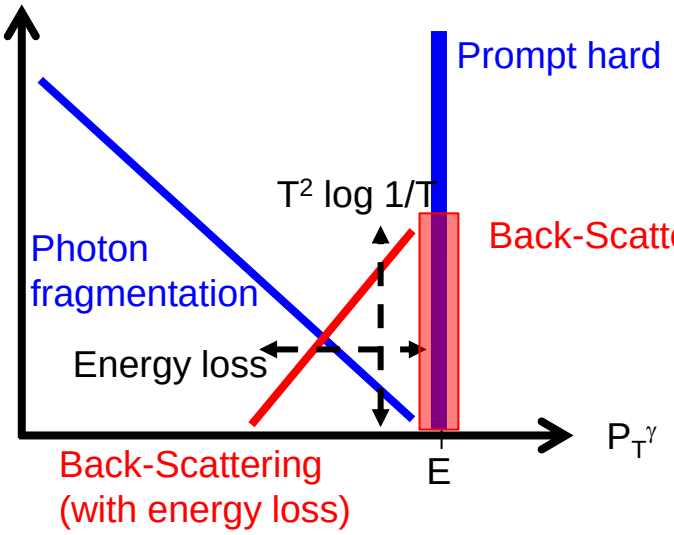
[Qin, Ruppert, Gale, Jeon, Moore, EPJ C61 (2009); PRC 80 (2009)]

- Strategy:
  - Use away-side jet as trigger
  - Compare to p+p to get rid of prompt hard photons
  - No contamination by thermal + pre-equilibrium photons!



Jet-Triggered Photons

- Idealized picture: photons opposite a jet of fixed energy E in leading order (LO) kinematics.



Blue: background
Red: back-scattering

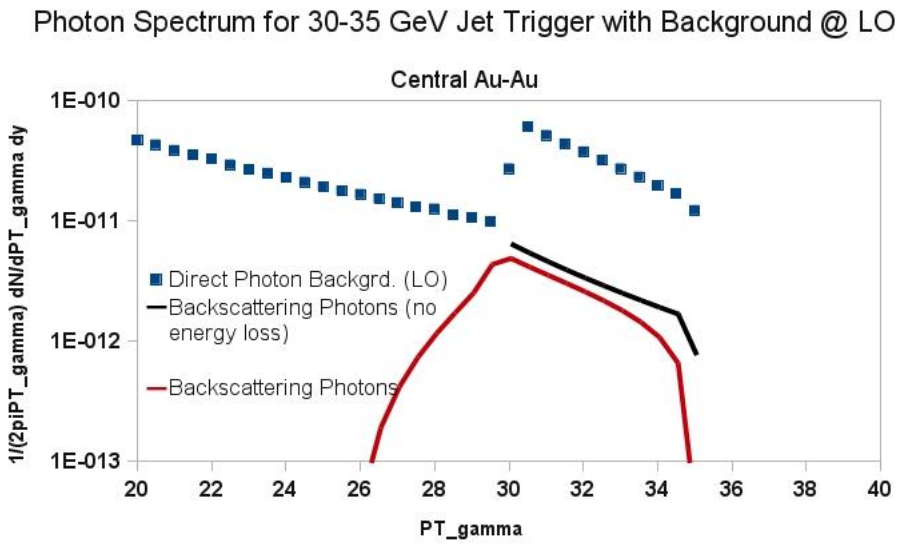
- Important information stored in those photons: Perturbative mechanism? Medium Temperature? Parton energy loss?
- Is nature kind? Have to account for finite trigger windows, kinematics beyond LO, etc.

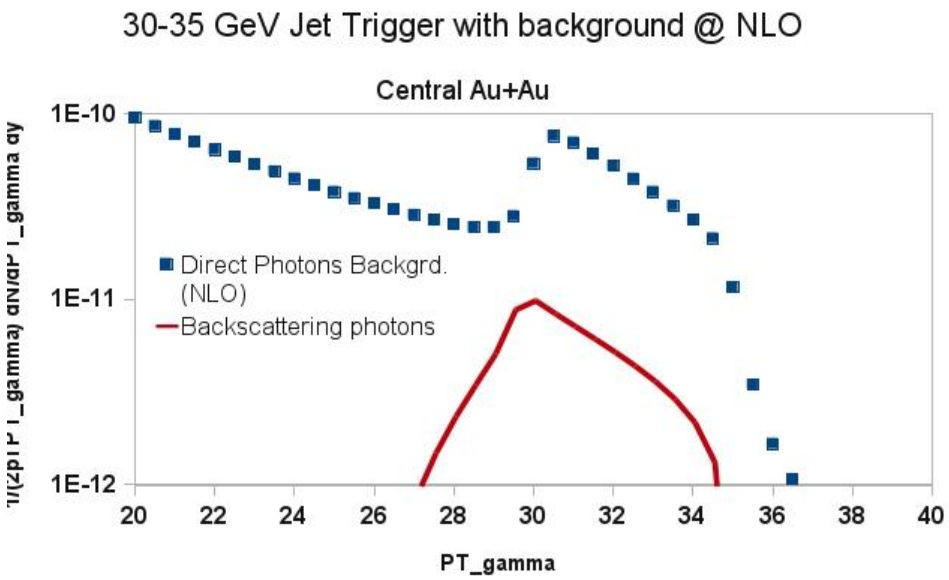
Jet-Triggered Photons: RHIC

- Test feasibility with 30-35 GeV trigger jet in central Au+Au @ 200 GeV.
- Look for photons on away side $\pm 15^\circ$ from trigger jet direction.
- 3 scenarios:
  - LO kinematics; no parton energy loss
  - LO kinematics; parton energy loss on (for quarks/gluon before conversion ; fitted to single inclusive R_{AA}).
  - Background calculated at NLO; parton energy loss on

Jet-Triggered Photons: RHIC

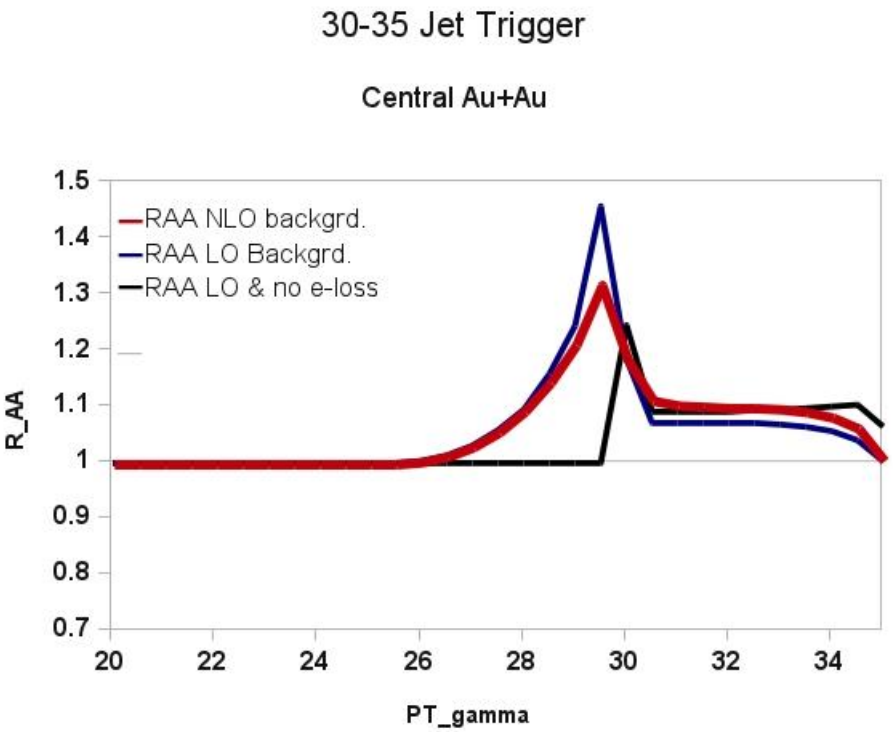
- Backscattering photons underneath "trigger peak"
- Energy loss: leakage of signal to smaller momenta
- NLO: smoothened out "trigger peak".





Jet-Triggered Photons: RHIC

- R_{AA}: clear backscattering peak despite finite trigger interval.

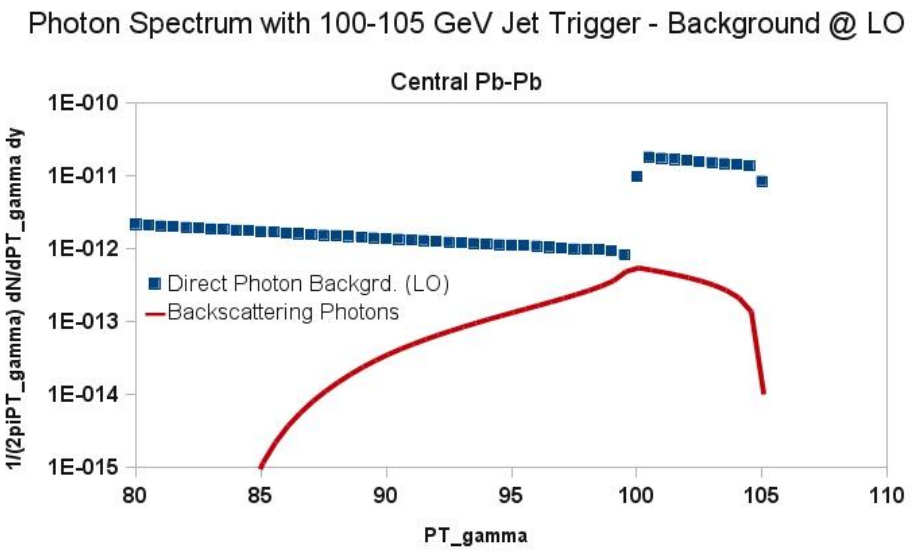


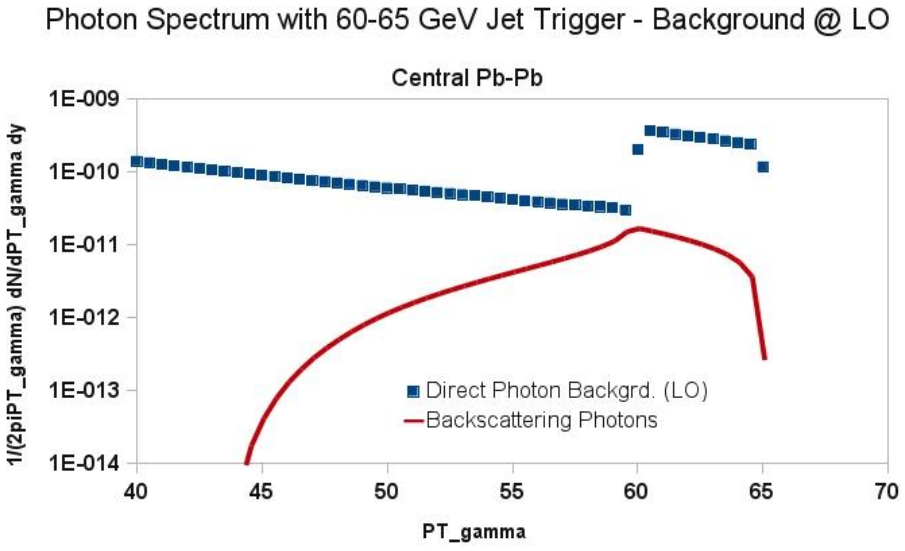
- Signal washed out in NLO but surviving.

Jet-Triggered Photons: LHC

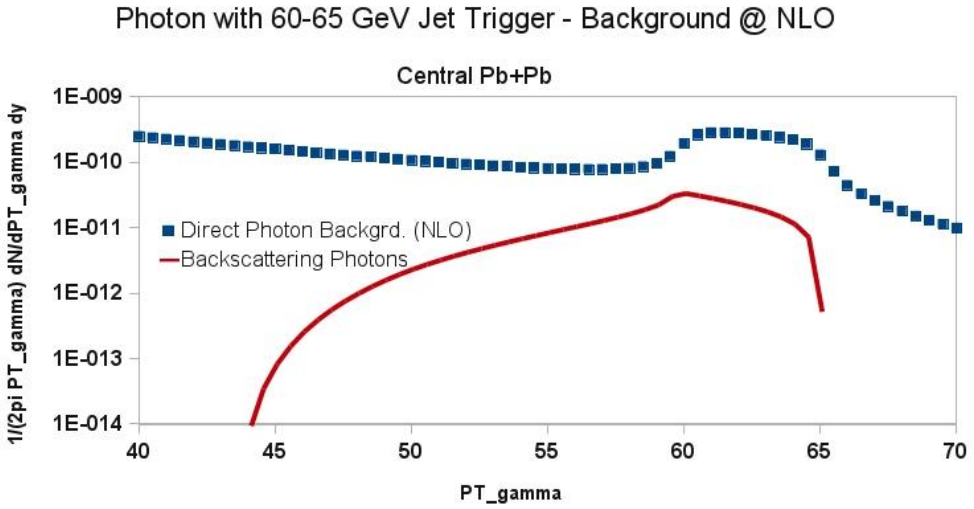
- Test feasibility with 60-65 and 100-105 GeV trigger jets in central Pb+Pb @ 2.76 TeV.
- Look for photons on away side $\pm 15^\circ$ from trigger jet direction.
- 2 scenarios:
  - LO kinematics; parton energy loss on
  - Background calculated at NLO; parton energy loss on

Jet-Triggered Photons: LHC



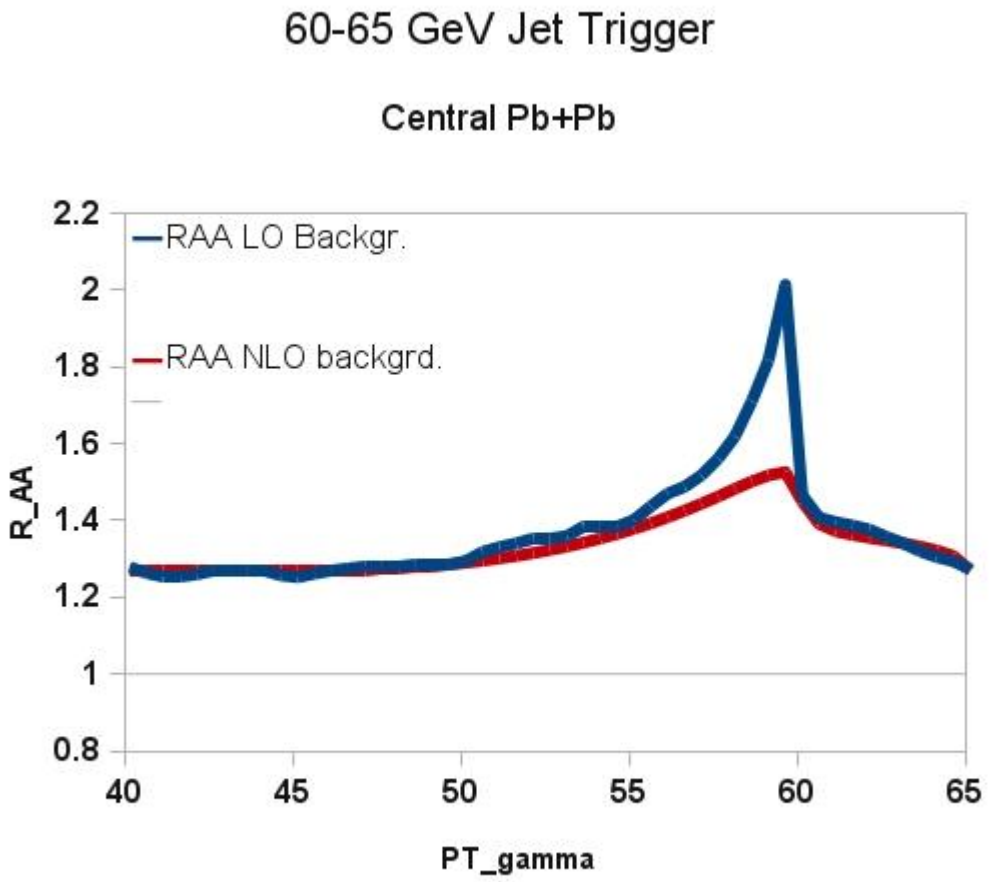


- No big difference between trigger energies.



Jet-Triggered Photons: LHC

- R_{AA}: clear backscattering peak despite finite trigger interval.



How To Search

- Strategies to maximize the signal
  - Similar to finding high-z photon fragmentation function.
  - Choose trigger energies as low as possible: enhance signal over background
  - Smaller trigger window: sharper peak structure
  - Isolation cut for photon: probably not very effective
  - Veto for a second large energy jet and tightening of cuts on azimuthal angle. could improve the signal.
  - Influence of R?

- To improve this estimate:
  - Jet energy loss
  - NLO kinematics for signal
  - Proper accounting for finite jet resolution

Conclusions

- Jet-medium back-scattering photons contain interesting physics
- Tight correlations of back-scattering photons with trigger jet $E_T \rightarrow$ back-scattering peak in jet-photon correlations
- Look for rapid changes in jet-triggered photon R_{AA} below the trigger window.

Backup

Inclusive Photon

- Same energy loss and fireball model as for triggered spectra.