

Prospect of seeing photon induced tau final states with early data

Robindra Prabhu
Bonn University
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- (1) Motivation
- (2) Event Signatures, cross sections & kinematics
- (3) Backgrounds, offline selection strategies & triggering
- (4) Summary / Outlook

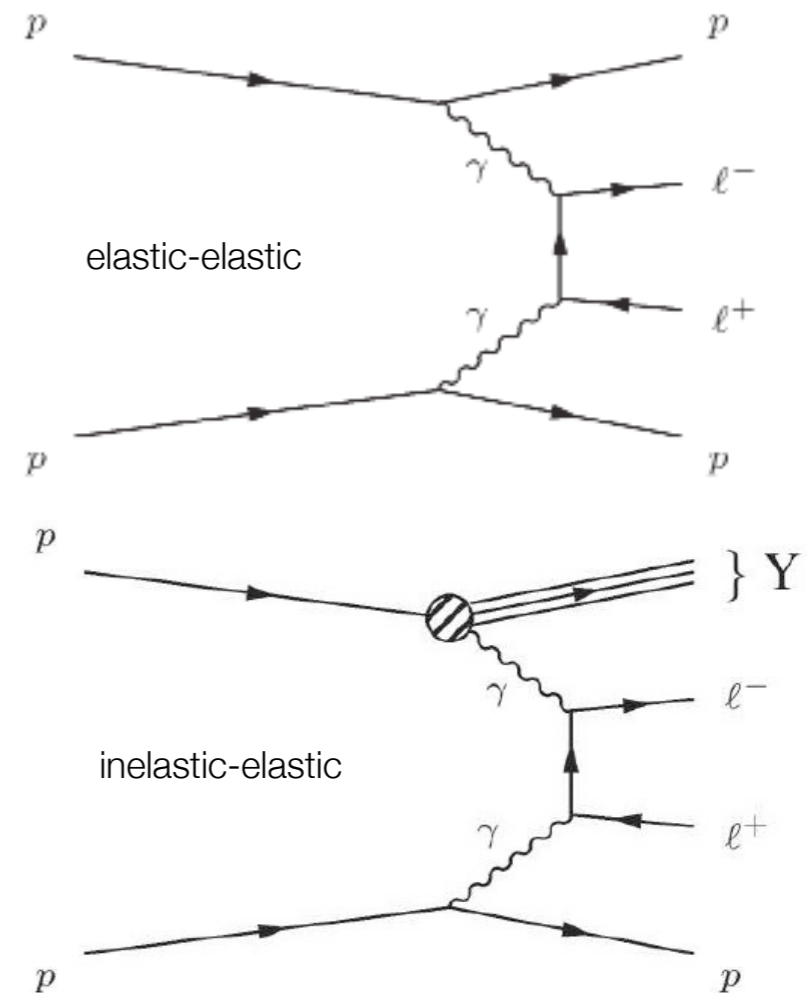
Two-photon exchange

- **Elastic-Elastic**

- two (central) leptons (taus)
 - back-to-back (balanced in pT), opp. charge
 - protons scattered at small angles wrt beamline
 - pure QED: cross section known to $< 1\%$

- **Inelastic-Elastic / Inelastic-Inelastic**

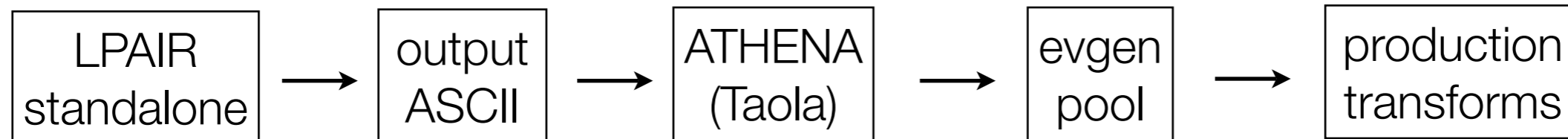
- signal similar to above
 - one or both protons dissociate, but appear exclusive when remnants escape detector
 - cross sections similar to elastic signal, but large theoretical uncertainties
 - still a potentially nice source of taus



Monte Carlo event generation

- Generator LPAIR for elastic and inelastic two-photon processes

- not part of ATLAS MC Generator suite

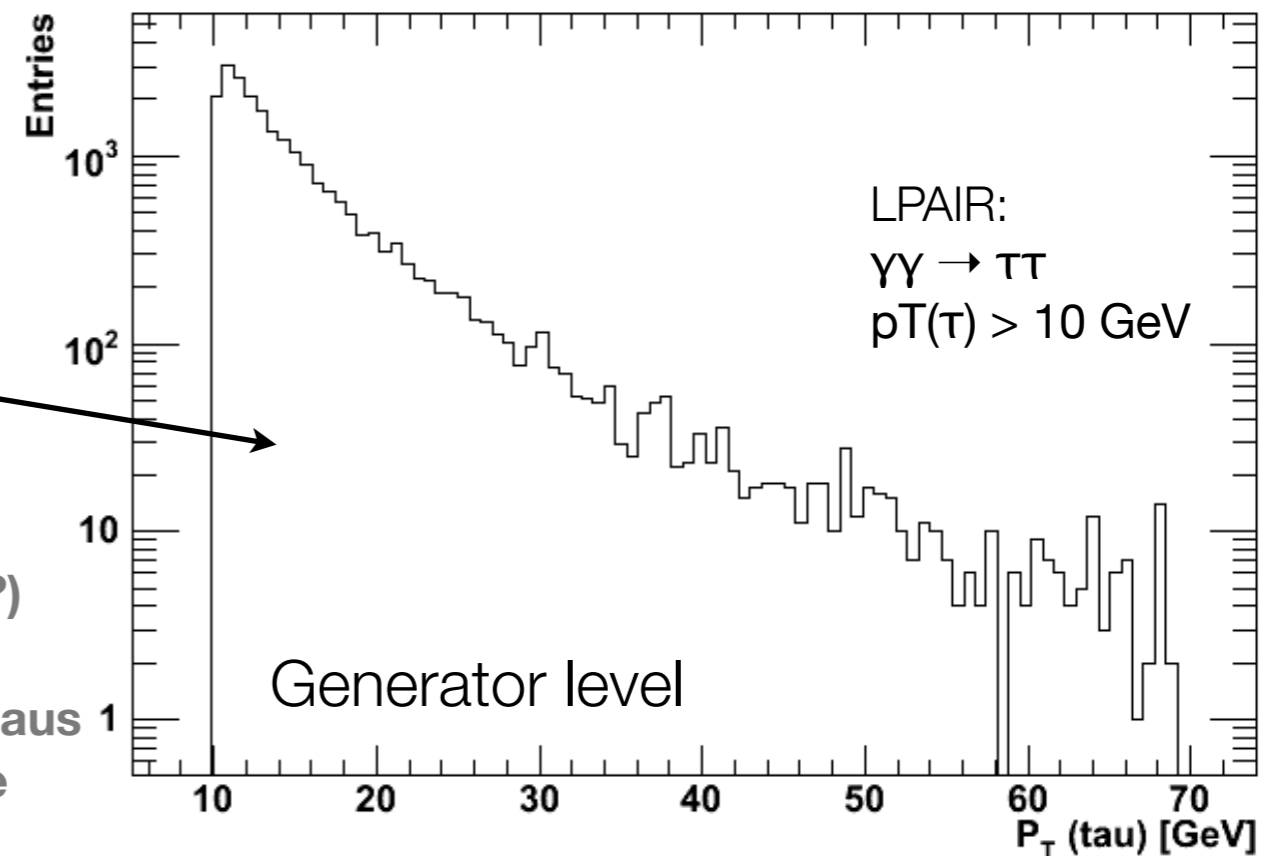


Signal strongly peaked at low p_T :

- challenging to ID and reconstruct
- low trigger thresholds required!

1. First confirmation of tau-channel at hadron collider (?)

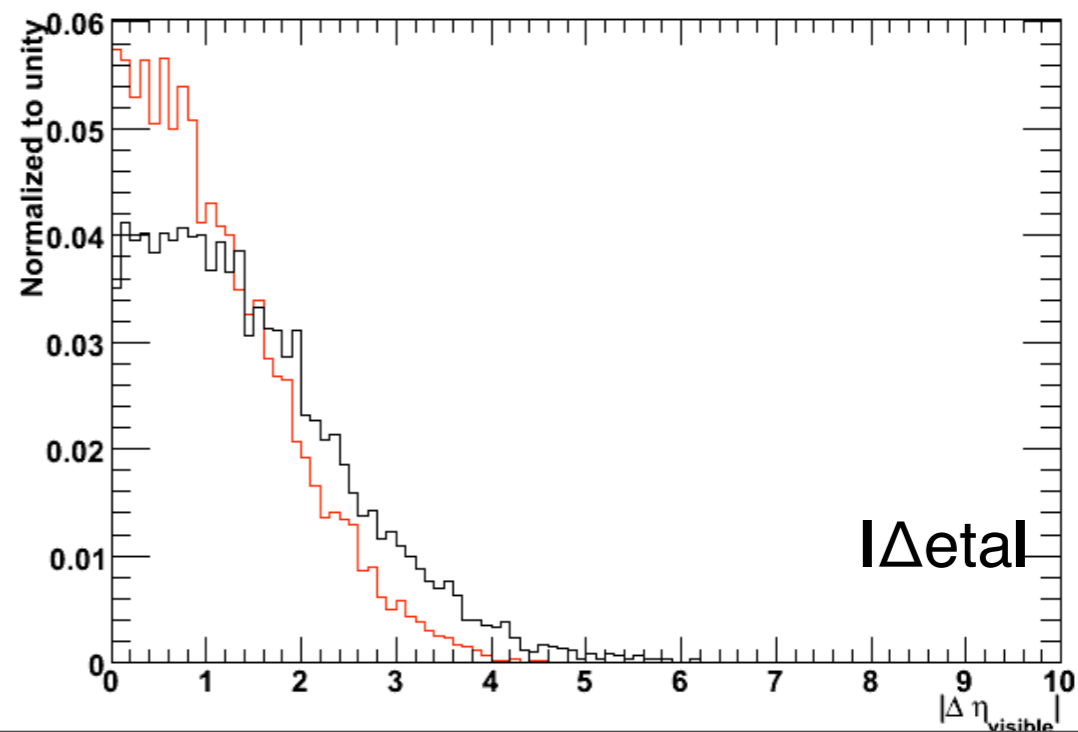
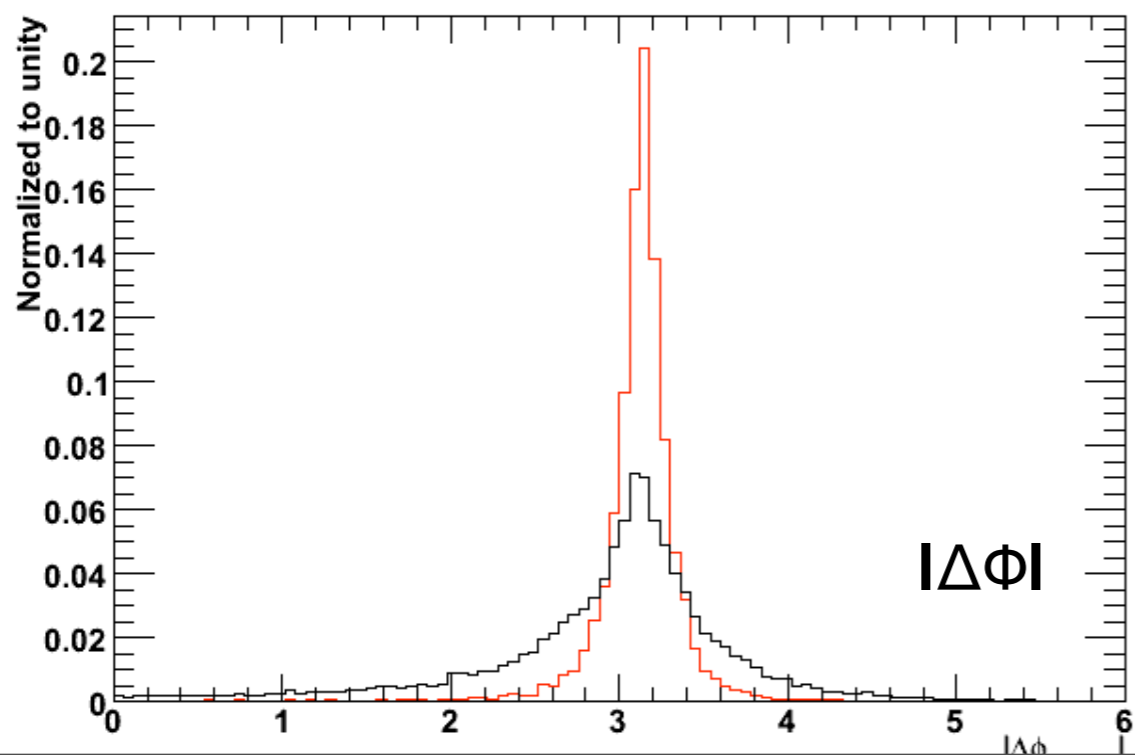
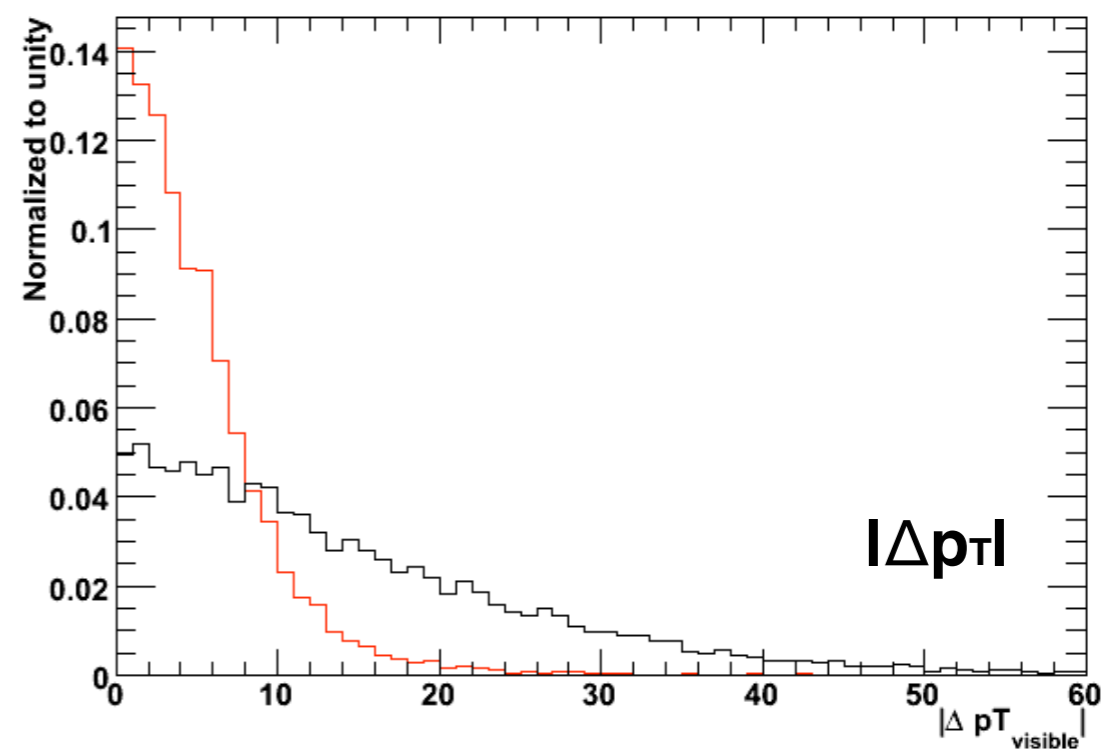
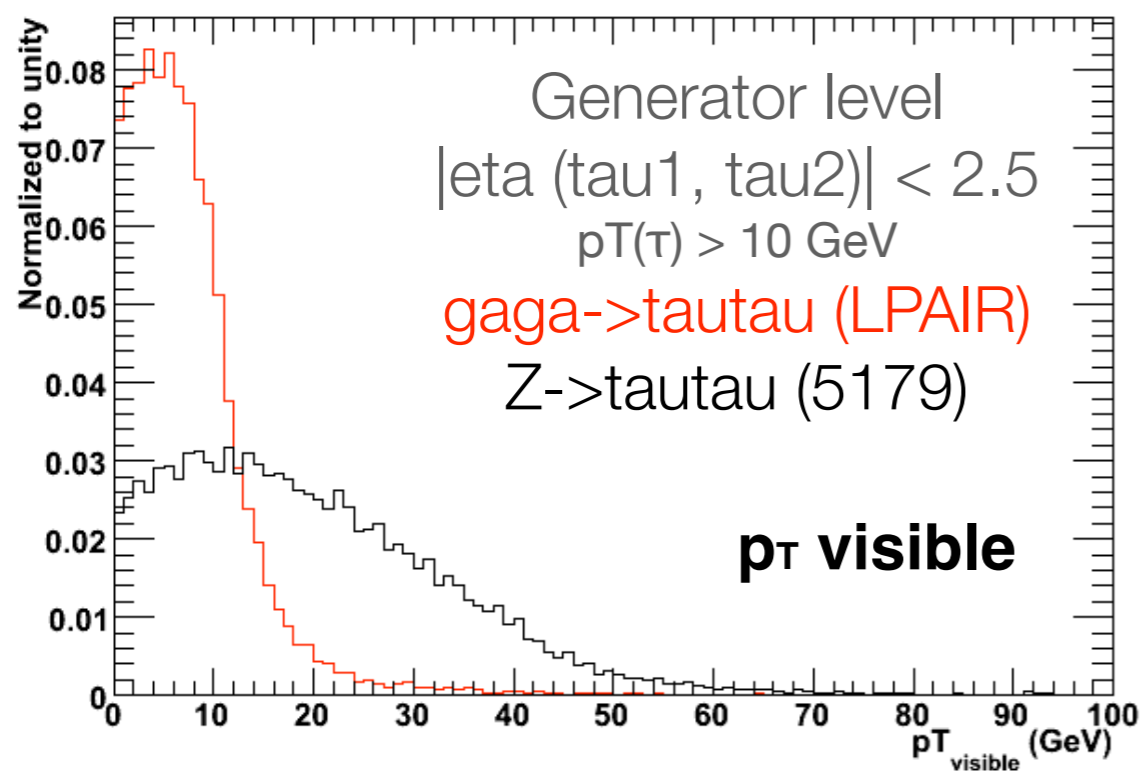
2. Potentially a unique and clean source of very low p_T taus
-> understand performance in extreme low- p_T regime



LPAIR cross section estimates

	Elastic-Elastic		Inelastic-Elastic		Inelastic-Inelastic		Elastic-Elastic		Elastic-Inelastic		Inelastic-Inelastic	
	14 TeV	10 TeV	14 TeV	10 TeV	14 TeV	10 TeV	14 TeV	10 TeV	14 TeV	10 TeV	14 TeV	10 TeV
pT >	σ (pb)	σ (pb)		σ (pb)		σ (pb)	σ (pb) $ \eta < 2.5$	σ (pb) $ \eta < 2.5$	σ (pb) $ \eta < 2.5$	σ (pb) $ \eta < 2.5$	σ (pb) $ \eta < 2.5$	σ (pb) $ \eta < 2.5$
0	219.75	186.25		125.20		88.99	68.030	60.65	48.07	43.05	36.54	32.63
5	11.996	9.764										
10	2.136	1.683					1.160	0.982	1.229	1.047	1.502	1.265
15	0.725	0.563							0.502	0.417	0.662	0.545
20	0.330	0.255					0.208	0.169	0.260	0.210	0.360	0.294

Event topology and kinematics



Backgrounds

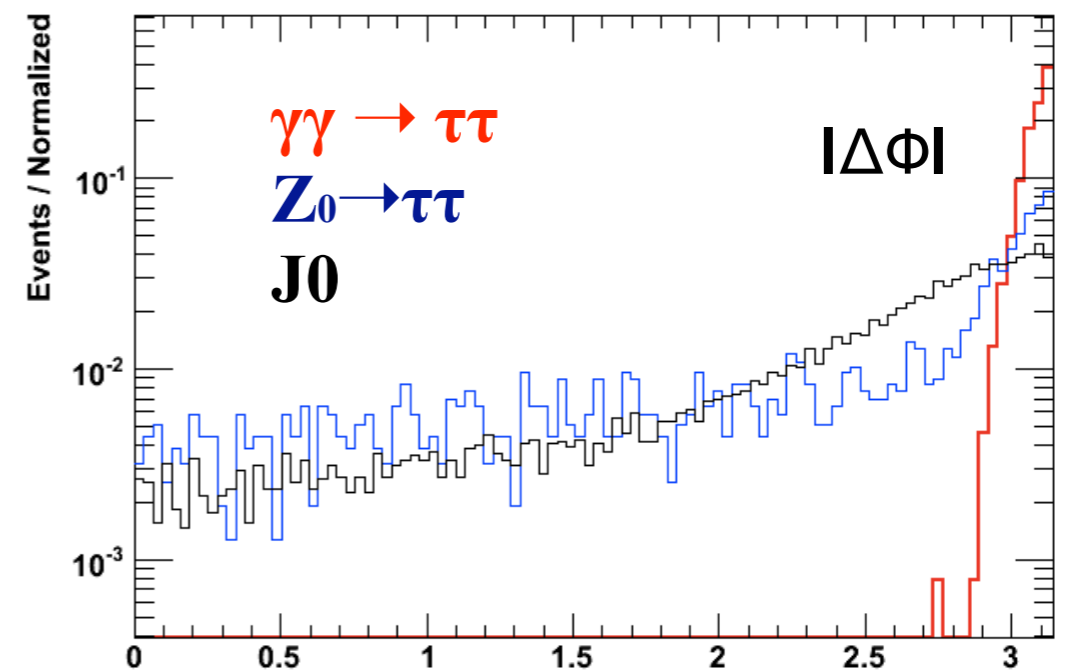
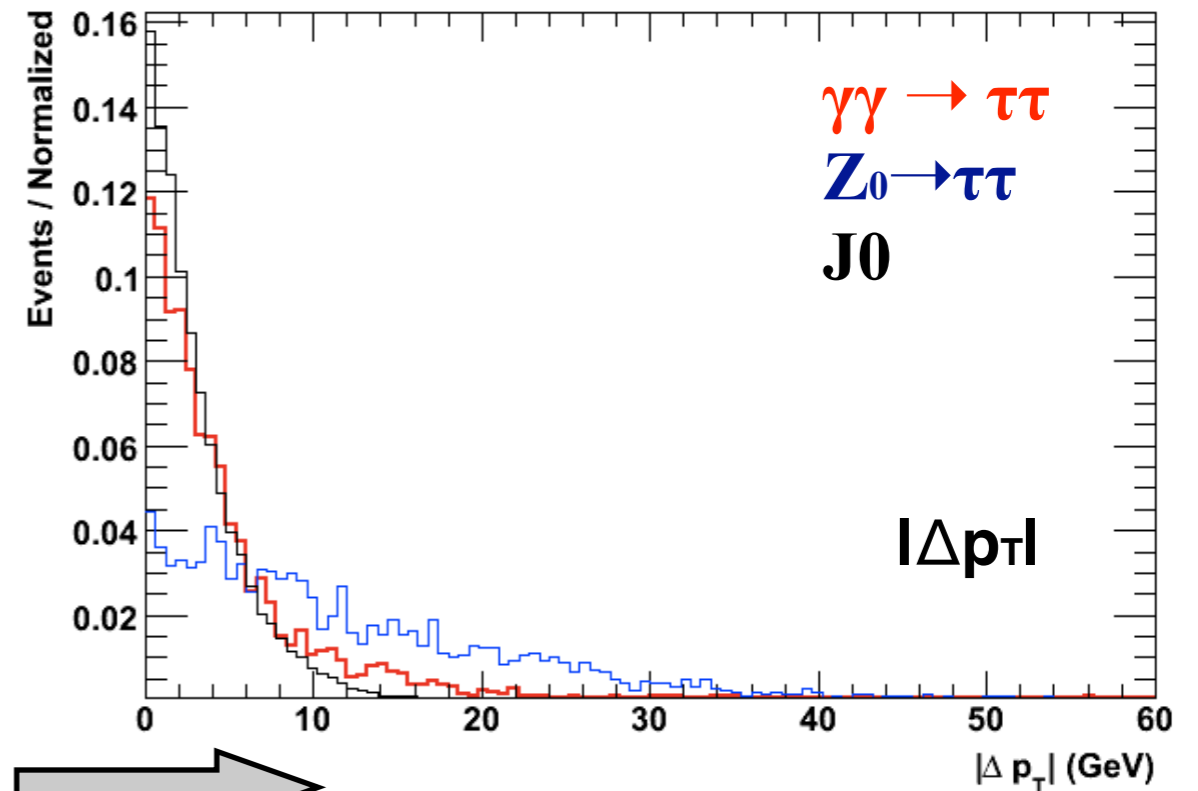
- Non-exclusive backgrounds:

- $Z_0/\gamma \rightarrow l+l-$
- $(J/\Psi \rightarrow l+l-)$
- $W+W \rightarrow l+l-$
- b/c jets $\rightarrow l+l-$
- QCD / min bias

- Exclusive backgrounds:

- $\gamma\gamma \rightarrow qq$
- (Upsilon $\rightarrow l+l-$)
- $(\gamma\gamma \rightarrow \mu+\mu-)$

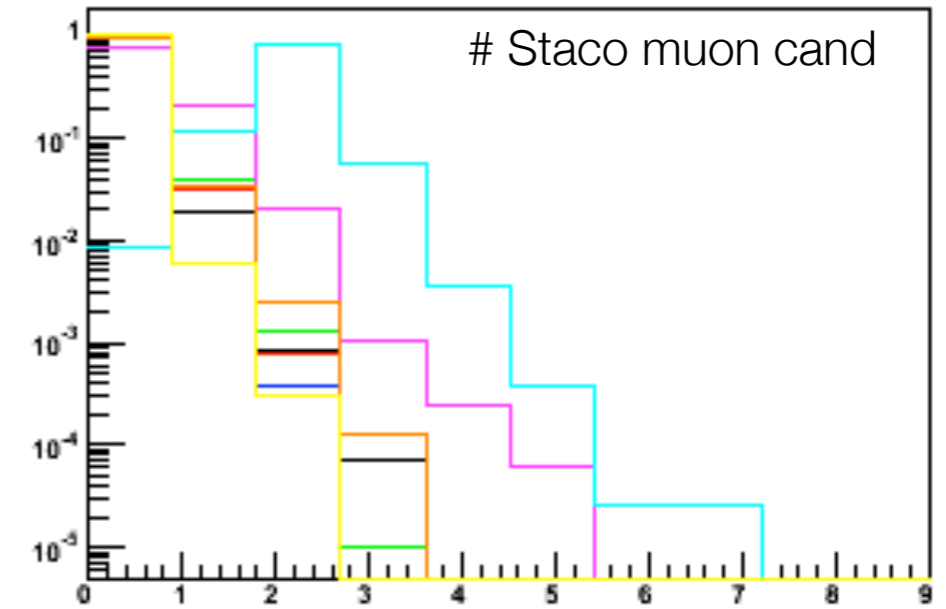
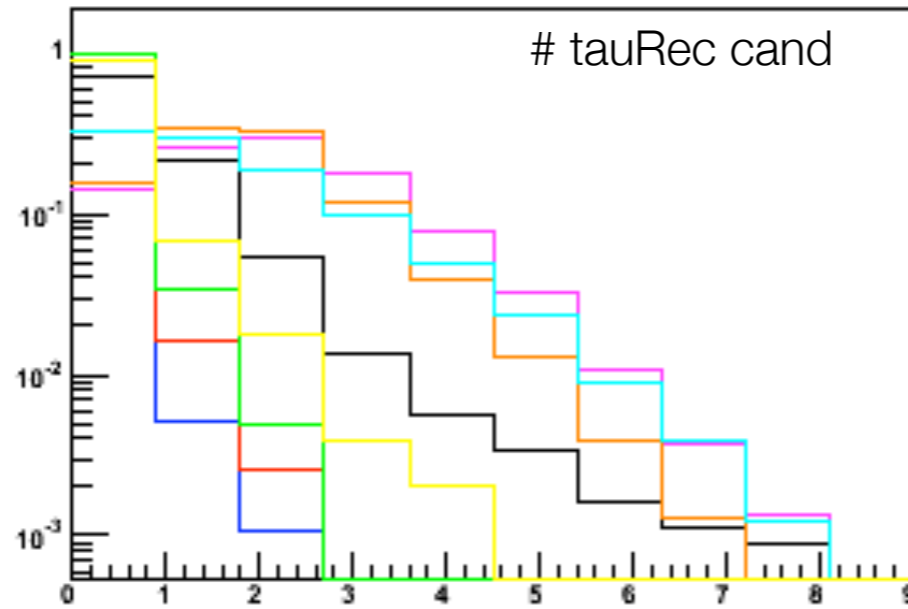
Require **exactly** two tau candidates



Number of objects before selection

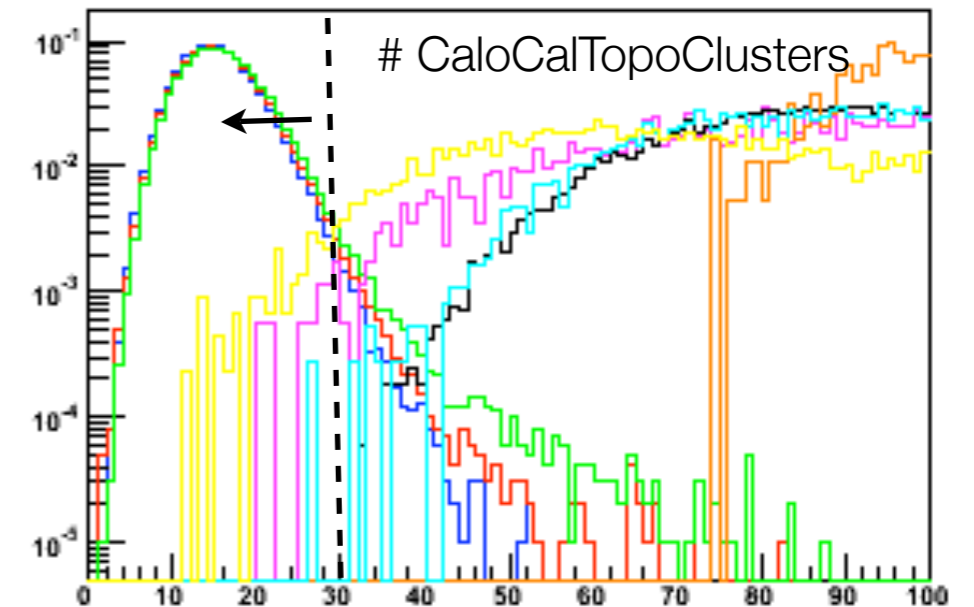
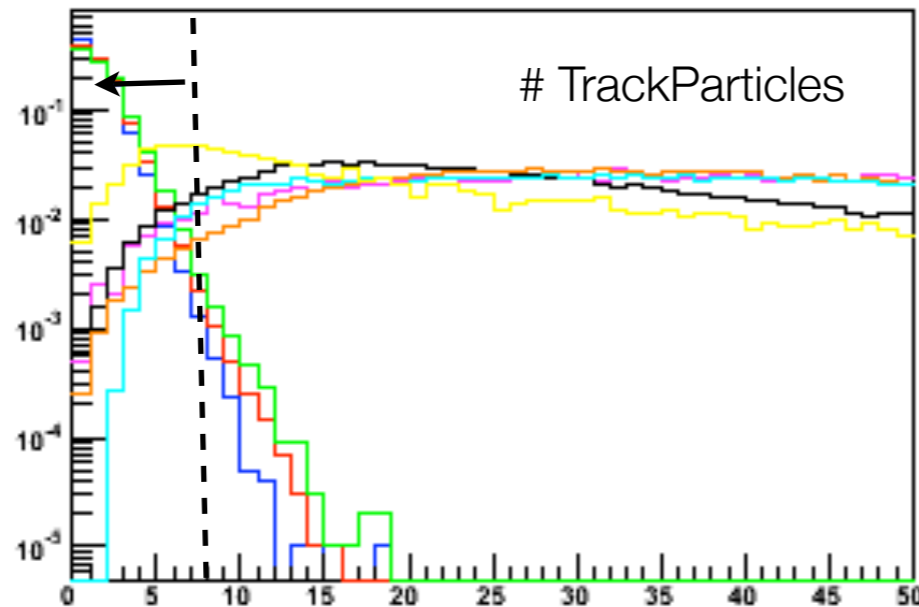
LPAIR: EI-EI
 LPAIR: Inel-EI
 LPAIR: Inel-Inel

 Z->tautau (5179) *
 J0 (5009) *
 J1 (5010) *
 JPsi->mumu (017504)
 MinBias (105001)

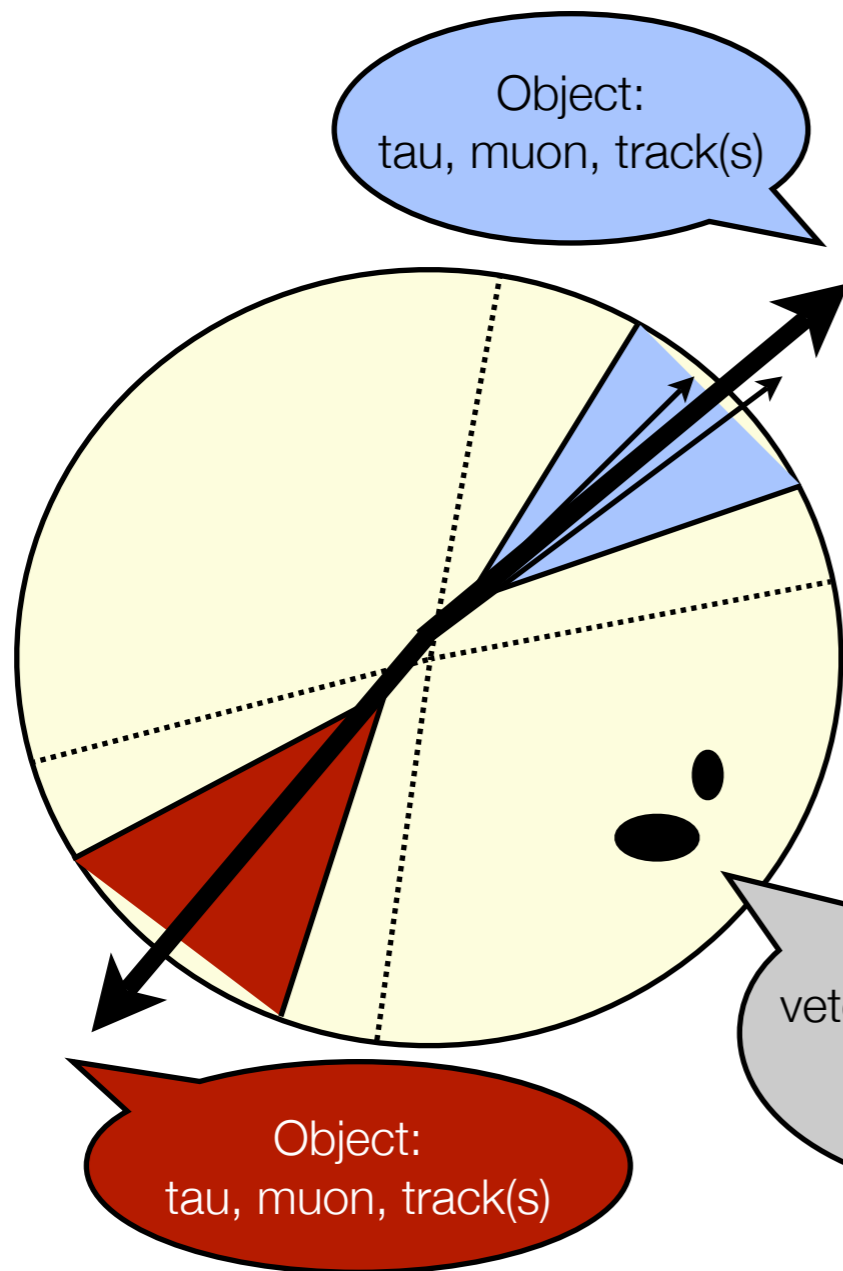


(*) 14 TeV samples

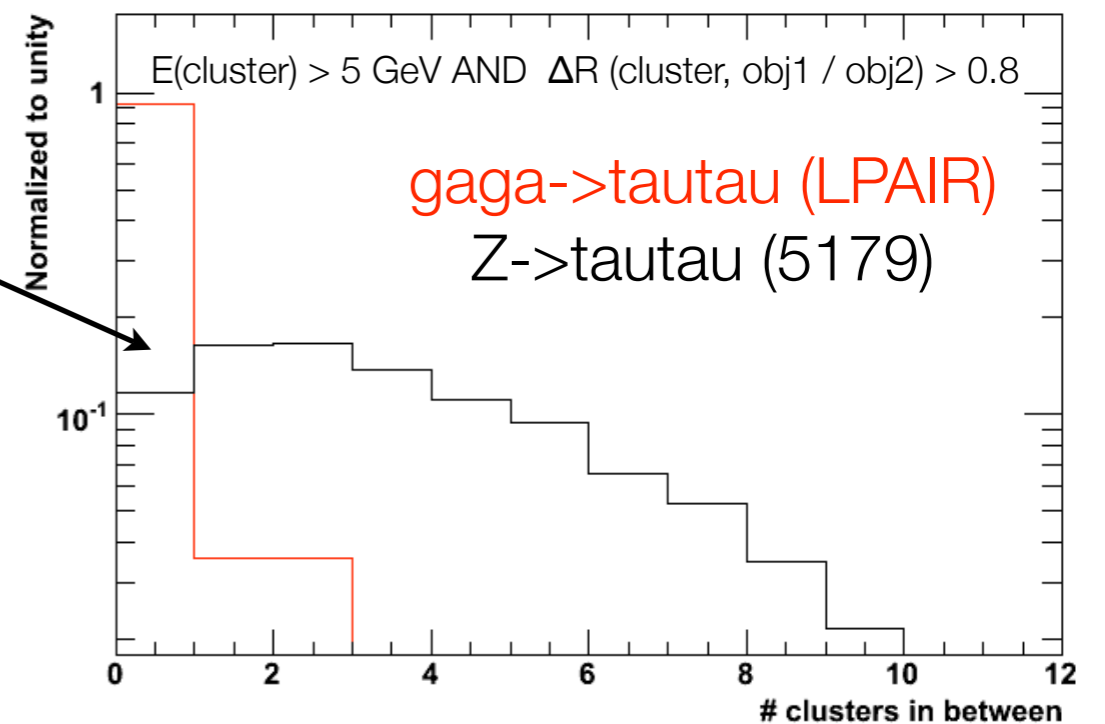
Missing:
 Z->mu,mu
 WW
 Upsilon
 ga+ga -> mu + mu
 ga+ga -> q+q



Generic offline selection strategy



- Try to exploit key event features:
 - Acoplanarity: 2 isolated back-to-back objects
 - Exclusivity: "nothing in between"
- Assumptions
 - low luminosity -> no/little pileup
 - dissociated protons escape down the beamline



Try this selector in 5 different flavours...

Tau-Tau

- (1) exactly 2 tauRec candidates
- (2) (# TopoClusters < 30) AND (# TrackParticles < 8)
- (3) $|\Delta\phi(\text{cand 1, cand 2})| > 2.7$
- (4) $\Delta p_T(\text{cand 1, cand 2}) < 10 \text{ GeV}$
- (5) (# clusters btw < 1) AND (# tracks btw < 1)

Tau-Mu

- (1) (exactly 1 tauRec candidate) AND (# muon candidates > 0)
- (2) (# TopoClusters < 30) AND (# TrackParticles < 8)
- (3) $|\Delta\phi(\text{tauRec cand, leading muon cand})| > 2.7$
- (4) $\Delta p_T(\text{tauRec cand, leading muon cand}) < 10 \text{ GeV}$
- (5) (# clusters btw < 1) AND (# tracks btw < 1)

Tau-Track

- (1) (exactly 1 tauRec candidate) AND (# tracksFound=1 or 3)
- (2) (# TopoClusters < 30) AND (# TrackParticles < 8)
- (3) (# clusters btw < 1) AND (# tracks btw < 1)

Muon-Track

- (1) (exactly 1 muon candidate) AND (# tracks > 0)
- (2) (# TopoClusters < 30) AND (# TrackParticles < 8)
- (3) (muon $p_T > 3 \text{ GeV}$) AND ($0 < \text{tracksFound} \leq 3$)
- (4) (# clusters btw < 1) AND (# tracks btw < 1)

1p-3p

- (1) (# tracks ≥ 2)
- (2) (# TopoClusters < 30) AND (# TrackParticles < 8)
- (3) maximum $\Delta\phi$ btw tracks > 2.7
- (4) # tracks in cone 0.4 about either track is 0 and 1/2 respectively
- (5) (# clusters btw < 1) AND (# tracks btw < 1)

tracksFound $\equiv |\text{deltaPhi}(\text{Tau/Muon, track})| > 2.7 \text{ AND } p_T(\text{lead track}) > 1 \text{ GeV}$

cluster btw $\equiv E(\text{cluster}) > 5 \text{ GeV} \text{ AND } \Delta R(\text{cluster, obj1 / obj2}) > 0.8$

track btw $\equiv p_T(\text{track}) > 3 \text{ GeV} \text{ AND } \Delta R(\text{track, obj1 / obj2}) > 0.8$

Track selection: "Std cuts Det. Paper"

pTMin = 500

IPd0Max = 2

IPz0Max = 10

nHitSi = 7

Cut flows 100 pb⁻¹

Tau-Tau, Tau-Muon

Tau - Tau	El-El	Inel-El	Inel-Inel	Z->tautau	J0	J1	JPsi	min bias
Total # events	18625	12520	8999	112890	1.20E+12	8.60E+10	1.58E+10	5.26E+12
(1) (exactly 2 tauRec cand)	28	28	40	33008	6.40E+12	2.80E+10	3.90E+09	4.60E+09
(2) (# TopoClusters < 30) && (# TrackParticles < 8)	22	22	31	14	0	0	0	0
(3) deltaPhi(tau1, tau2) > 2.9	22	18	24	14	0	0	0	0
(4) deltaPt(tau1, tau2) < 10 GeV	18	15	19	14	0	0	0	0
(5) (# clusters btw < 1) && (# tracks btw) < 1	17	13	19	0	0	0	0	0

Tau - Muon	El-El	Inel-El	Inel-Inel	Z->tautau	J0	J1	JPsi	min bias
Total # events	18625	12520	8999	112890	1.20E+12	8.60E+10	1.58E+10	5.26E+12
(1) (exactly 1 tauRec cand) && (# muon cand > 0)	21	28	31	6404	5.80E+09	1.10E+08	4.60E+09	2.30E+08
(2) (# Clusters < 30) && (# Tracks < 8)	20	26	30	14	0	0	0	0
(3) deltaPhi(tauRec cand, leading muon) > 2.9	10	13	6	14	0	0	0	0
(4) deltaPt(tauRec cand, leading muon) < 10 GeV	8	12	6	0	0	0	0	0
(5) (# clusters btw < 1) && (# tracks btw) < 1	8	11	6	0	0	0	0	0

Cut flows 100 pb⁻¹

Tau-Track, Muon-Track

Tau - Track	El-El	Inel-El	Inel-Inel	Z->tautau	J0	J1	JPsi	min bias
Total # events	18625	12520	8999	112890	1.20E+12	8.60E+10	1.58E+10	5.26E+12
(1) (exactly 1 tauRec cand) && (# trackFound=1 or 3)	19	15	16	10075	8.67E+10	1.20E+09	1.68E+09	5.00E+09
(2) (# TopoClusters < 30) && (# TrackParticles < 8)	17	14	12	14	0	0	0	0
(5) (# clusters btw < 1) && (# tracks btw) < 1	16	12	12	0	0	0	0	0

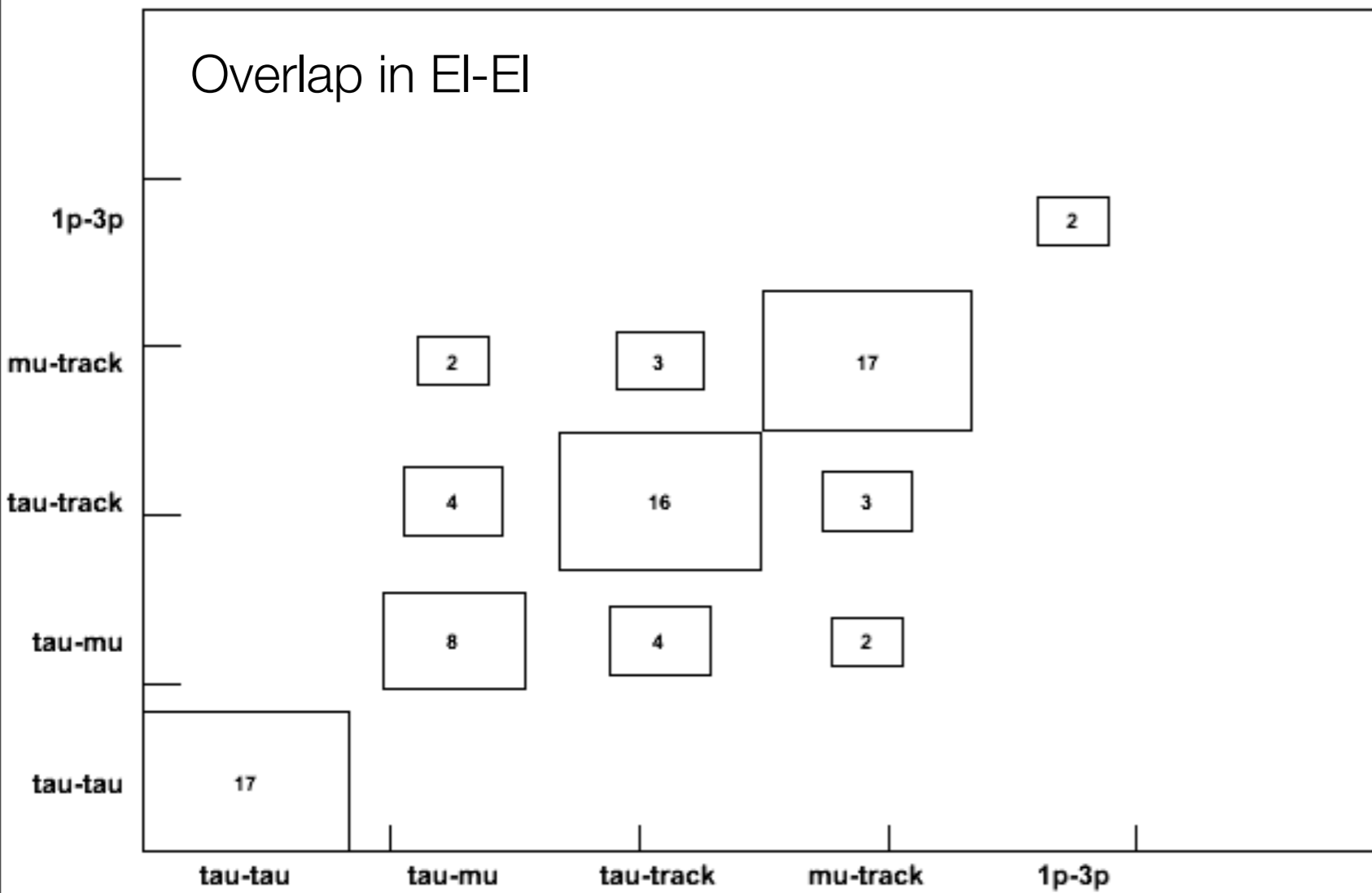
Muon - Track	El-El	Inel-El	Inel-Inel	Z->tautau	J0	J1	JPsi	min bias
Total # events	18625	12520	8999	112890	1.20E+12	8.60E+10	1.58E+10	5.26E+12
(1) (exactly 1 muon cand) && (# tracks > 0)	335	347	333	22819	2.20E+10	3.60E+08	1.90E+09	1.60E+09
(2) (# TopoClusters < 30) && (# TrackParticles < 8)	334	344	325	36	0	0	0	0
(3) (muon pT > 3 GeV) && (0 < trackFound <=3)	19	11	9	21	0	0	0	0
(5) (# clusters btw < 1) && (# tracks btw) < 1	17	11	9	0	0	0	0	0

Cut flows 100 pb⁻¹

1 prong - 3 prong

1p - 3p	EI-EI	Inel-EI	Inel-Inel	Z->tautau	J0	J1	JPsi	min bias
Total # events	18625	12520	8999	112890	1.20E+12	8.60E+10	1.58E+10	5.26E+12
(1) (# tracks >= 2)	674	572	479	22819	2.20E+10	3.60E+08	1.90E+09	1.60E+09
(2) (# TopoClusters < 30) && (# TracksParticles < 8)	659	555	454	36	0	0	0	0
(3) maximum delta phi btw tracks > 2.9	145	89	62	21	0	0	0	0
(4) # tracks in cone 0.4 about either track is 0 and 1/2	3	5	5	0	0	0	0	0
(5) (# clusters btw < 1) && (# tracks btw < 1)	2	4	1	0	0	0	0	0

Signal selector overlap



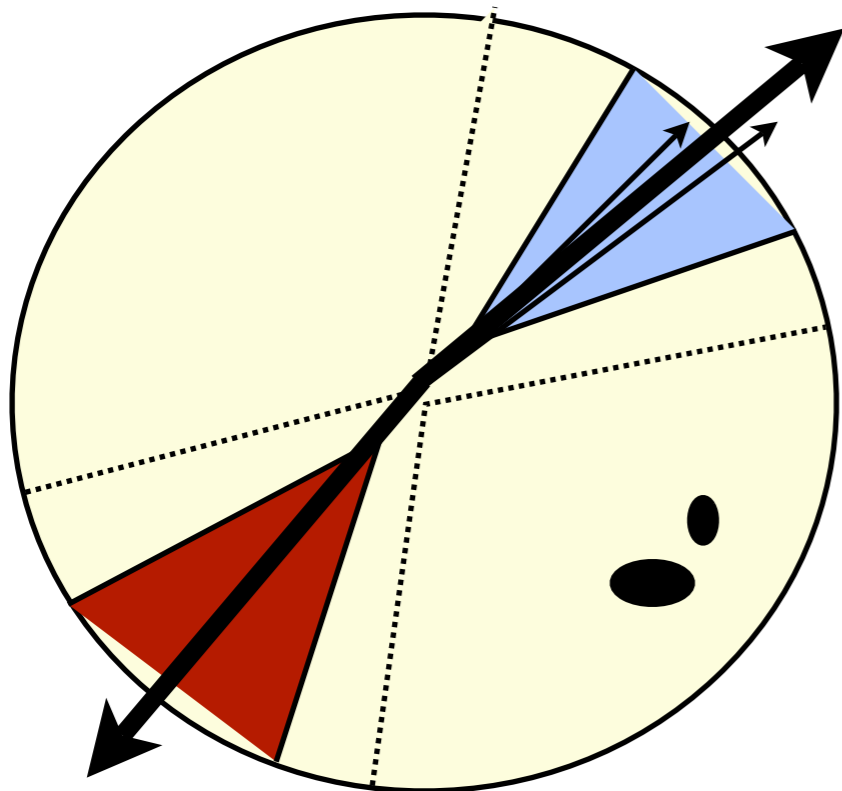
- Selection overlap is small, combine for greater yield

- Number of events uniquely selected by one selector @ 100 pb⁻¹:

Elastic-Elastic	48
Inelastic-Elastic	40
Inelastic-Inelastic	38
Total:	126

Dedicated trigger?

- Selected events do not fire available triggers
- Opt for a dedicated trigger exploiting key event features, e.g.:
 - L1 exclusive di-”object” trigger: 2 object candidates, no other calo deposit
 - HLT dedicated trigger: exactly 2 objects, p_T imbalance < 10 GeV, acoplanarity $< \pi - 0.6$



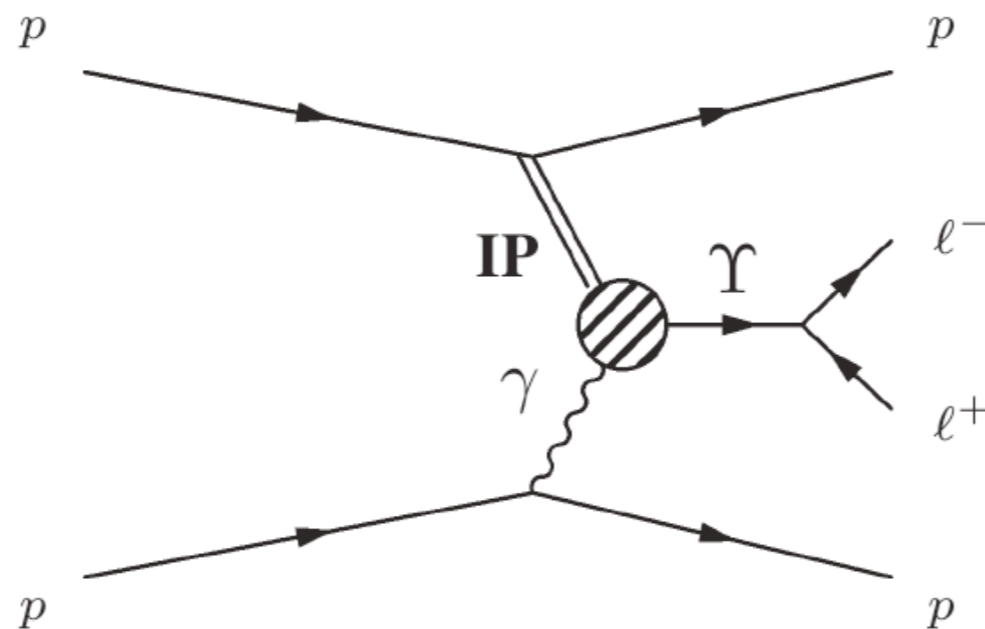
Summary / Outlook

- With the first 100pb^{-1} a significant signal for exclusive dilepton production is expected. Can the tau-channel be seen?
- If so, first confirmation at hadron collider. Unique source of very low p_T taus.
- First pass selection looks encouraging. Need to understand all backgrounds to obtain robust numbers.
- If we decide to hunt for these events, a dedicated trigger will most likely be required

Backups ++

Event Features

- Another possible tau source:
 - **Upsilon** photoproduction
 - quasi-real photon fluctuates into qq pair which interacts diffractively
 - not considered in this study, but worth keeping in mind



Data samples

- valid1.105001.pythia_minbias.recon.AOD.e380_a80_tid039473 (10K)
[5.156 e10 pb]
- mc08.017504.Pythia_directJpsimu4mu4.recon.AOD.e323_s400_d99_r474
(38.6K) [1.584e8 pb]
- misal1_mc12.005179.ZtautauNoEF.v12000605 (15.9K) [1128.37 pb]
- misal1_csc11.005009.J0_pythia_jetjet.v12003107_tid004665 (70K)
[1.170e10 pb]
- ideal2_mc12.005010.J1_pythia_jetjet.digit.v13003004

Trigger Output

- Output from TriggerDecisionTool in 14.2.0.1

AnalysisSkeleton SUCCESS All events : 982
AnalysisSkeleton SUCCESS All ditau events : 108
AnalysisSkeleton SUCCESS All muon events : 108
AnalysisSkeleton SUCCESS All events passing tau trigger EF_mu10: 38 (total: 3.86965%, ditau selection: 35.1852%)
AnalysisSkeleton SUCCESS All events passing tau trigger EF_mu4: 86 (total: 8.75764%, ditau selection: 79.6296%)
AnalysisSkeleton SUCCESS All events passing tau trigger EF_mu4_j10: 36 (total: 3.66599%, ditau selection: 33.3333%)
AnalysisSkeleton SUCCESS All events passing tau trigger EF_mu6: 85 (total: 8.6558%, ditau selection: 78.7037%)
AnalysisSkeleton SUCCESS All events passing tau trigger EF_tau12: 25 (total: 2.54582%, ditau selection: 23.1481%)
AnalysisSkeleton SUCCESS All events passing tau trigger EF_tau12i_e10: 0 (total: 0%, ditau selection: 0%)
AnalysisSkeleton SUCCESS All events passing tau trigger EF_tau16i_mu10: 7 (total: 0.712831%, ditau selection: 6.48148%)
AnalysisSkeleton SUCCESS All events passing tau trigger EF_tau16i_mu6: 10 (total: 1.01833%, ditau selection: 9.25926%)
AnalysisSkeleton SUCCESS All events passing tau trigger EF_tauNoCut: 57 (total: 5.80448%, ditau selection: 52.7778%)
AnalysisSkeleton SUCCESS All events passing tau trigger L1_MU10: 79 (total: 8.04481%, ditau selection: 73.1481%)
AnalysisSkeleton SUCCESS All events passing tau trigger L1_MU4: 98 (total: 9.97963%, ditau selection: 90.7407%)
AnalysisSkeleton SUCCESS All events passing tau trigger L1_MU4_J10: 56 (total: 5.70265%, ditau selection: 51.8519%)
AnalysisSkeleton SUCCESS All events passing tau trigger L1_MU6: 96 (total: 9.77597%, ditau selection: 88.8889%)
AnalysisSkeleton SUCCESS All events passing tau trigger L1_TAU5: 60 (total: 6.10998%, ditau selection: 55.5556%)
AnalysisSkeleton SUCCESS All events passing tau trigger L1_TAU6: 53 (total: 5.39715%, ditau selection: 49.0741%)
AnalysisSkeleton SUCCESS All events passing tau trigger L1_TAU9I_MU10: 22 (total: 2.24033%, ditau selection: 20.3704%)
AnalysisSkeleton SUCCESS All events passing tau trigger L1_TAU9I_MU6: 26 (total: 2.64766%, ditau selection: 24.0741%)
AnalysisSkeleton SUCCESS All events passing tau trigger L2_mu10: 42 (total: 4.27699%, ditau selection: 38.8889%)
AnalysisSkeleton SUCCESS All events passing tau trigger L2_mu4: 90 (total: 9.16497%, ditau selection: 83.3333%)
AnalysisSkeleton SUCCESS All events passing tau trigger L2_mu4_j10: 40 (total: 4.07332%, ditau selection: 37.037%)
AnalysisSkeleton SUCCESS All events passing tau trigger L2_mu6: 89 (total: 9.06314%, ditau selection: 82.4074%)
AnalysisSkeleton SUCCESS All events passing tau trigger L2_tau12: 36 (total: 3.66599%, ditau selection: 33.3333%)
AnalysisSkeleton SUCCESS All events passing tau trigger L2_tau12i_e10: 0 (total: 0%, ditau selection: 0%)
AnalysisSkeleton SUCCESS All events passing tau trigger L2_tau16i_mu10: 12 (total: 1.222%, ditau selection: 11.1111%)
AnalysisSkeleton SUCCESS All events passing tau trigger L2_tau16i_mu6: 16 (total: 1.62933%, ditau selection: 14.8148%)
AnalysisSkeleton SUCCESS All events passing tau trigger L2_tauNoCut: 60 (total: 6.10998%, ditau selection: 55.5556%)

Selection: Require at least 1 tauRec cand and 1 muon

CDF & CMS programmes

- feasibility of electron and muon channels confirmed at Tevatron:
 - Andrew Hamilton, PhD thesis: http://www-cdf.fnal.gov/thesis/cdf8322_exclusive_ee_&_gg.pdf
- CMS appears to have a rich “diffractive & forward physics programme”, including two photon processes and Upsilon photoproduction:
 - <https://twiki.cern.ch/twiki/bin/view/CMS/DiffractionAndFwdPhysicsTalksLibrary>
 - Xavier Rouby, PhD thesis: <http://edoc.bib.ucl.ac.be:81/ETD-db/collection/available/BelnUcetd-09112008-213742/unrestricted/main.pdf>
- CMS has dedicated triggers for electron and muon channels
- heard of plans to pursue muon channel for luminosity studies in ATLAS, not aware of any full-fledged studies
 - Bryan Caron, PhD thesis: “Luminosity measurement at the LHC”