Diphotons Cross-Section with a Matrix Method

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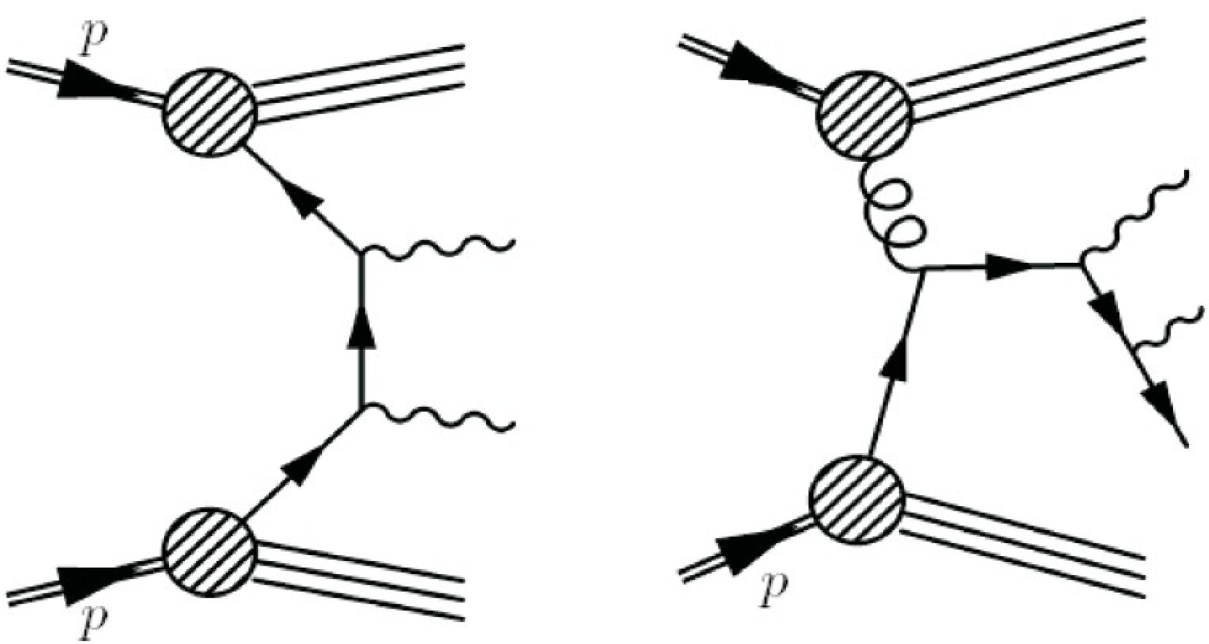
Outline

- Motivation
- The CDF matrix method
- Yields with 1 pb^{-1}
- Proposal of an extended matrix method
- First tests
- Summary and Outlook

- Diphoton events:
  - Irreducible Background for several analyses
    → in particular H → γγ
  - Tests of the jet to leading γ fragmentation and perturbative QCD !

- → (Differential) cross-sections
- → pT of γγ system (for example soft gluon ISR)



The CDF matrix method

- 1993: CDF measured the $\gamma\gamma$ cross-section with 4.3 pb^{-1}
  → similar to the situation of ATLAS in the next monts…
- Only needed ~ 250 $\gamma\gamma$ candidates to estimate the number of prompt $\gamma\gamma$ events:

p_T bin (GeV)	N
10 – 12	$22 \pm 12^{+5}_{-3}$
12 – 15	$44 \pm 20^{+19}_{-14}$
15 – 19	$27 \pm 18^{+11}_{-8}$

- Idea:
  - Introduce a quality cut and count (→ N_{ab}, with a,b = fail[F] or pass[P])
    (CDF: compare transverse shower profile to test beam → use χ^2)
  - Use (known) single photon efficiencies $\varepsilon(\gamma)$ and fake rate $\varepsilon(\text{jet})$
  - Build a linear system of equations and solve it (invert the matrix E):

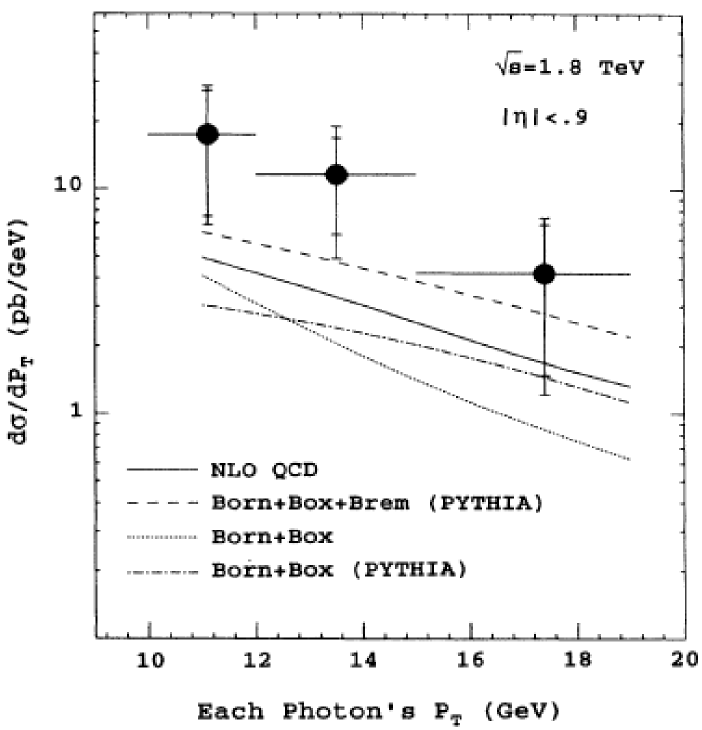
$$\begin{pmatrix} N_{\text{FF}} \\ N_{\text{FP}} \\ N_{\text{PF}} \\ N_{\text{PP}} \end{pmatrix} = E(\epsilon_{\text{jet}}, \epsilon_\gamma) \cdot \begin{pmatrix} W_{\text{jetjet}} \\ W_{\text{jet}\gamma} \\ W_{\gamma\text{jet}} \\ W_{\gamma\gamma} \end{pmatrix}$$

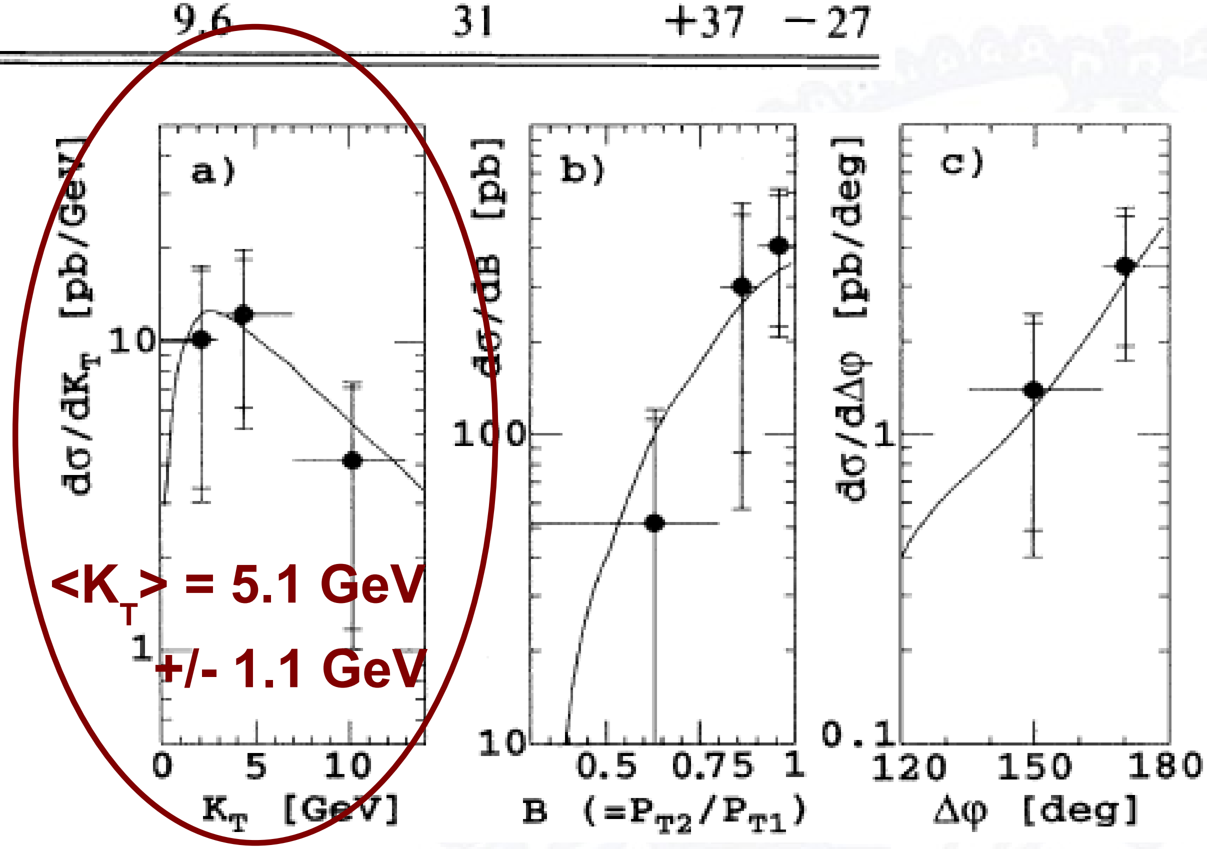
for example: $N_{FP} = (1-\epsilon_{\text{jet}})\epsilon_{\text{jet}} W_{\text{jetjet}} + (1-\epsilon_{\text{jet}})\epsilon_\gamma W_{\text{jet}\gamma} + \ldots$

The CDF matrix method

- After taking into account efficiencies and acceptances & systematics:

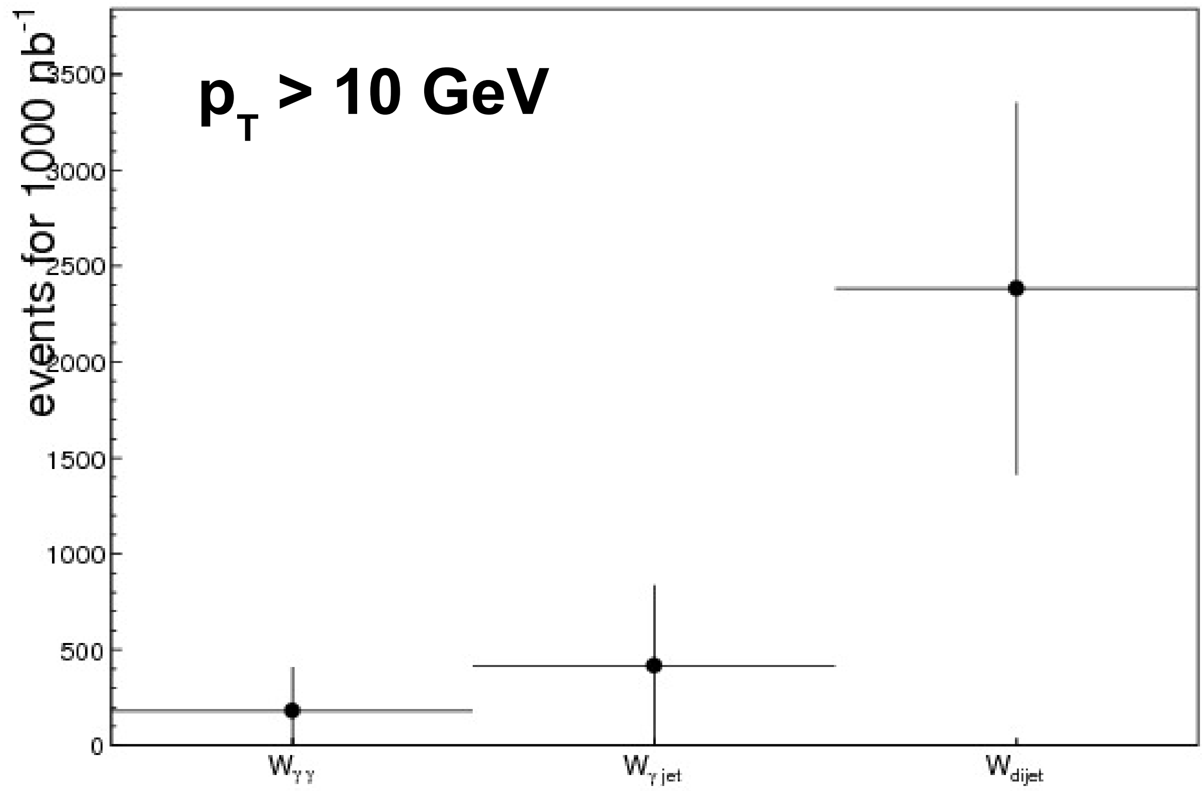
P_T bin (GeV)	Mean P_T (GeV)	$d\sigma/dP_T$ (pb/GeV)	Statistical (%)	Systematic (%)	
10–12	11.1	17.5	57	+31	−21
12–15	13.5	11.6	46	+45	−35
15–19	17.4	4.2	65	+41	−29
10–19	13.3	9.6	31	+37	−27





Yields with 1 pb^{-1}

- Counted number of $\gamma\gamma$ pairs in $\gamma\gamma$, γ+jet, and filtered MB samples, where both γ pass the **tight isEM** cut : **W($\gamma\gamma$), W(γ+jet), W(dijet)**
- Compared with numbers from Giovanni's presentation (28.04.2010)
- → got very similar results, except for filtered MB :
  - PAU samples had only ~ 2/3 of the events mentioned in AMI
  - → yields for MB much higher → more fakes → lower purity …



p_T cut [GeV]	Purity (large errors!)
10	~ 6 %
15	~ 8 %
20	~ 33 %

For simplicity, I just took the diphoton pairs which passed the cut (no parametrisation).
For more than 2 photons, *all pairs* were taken into account.

Proposal of an extended matrix method

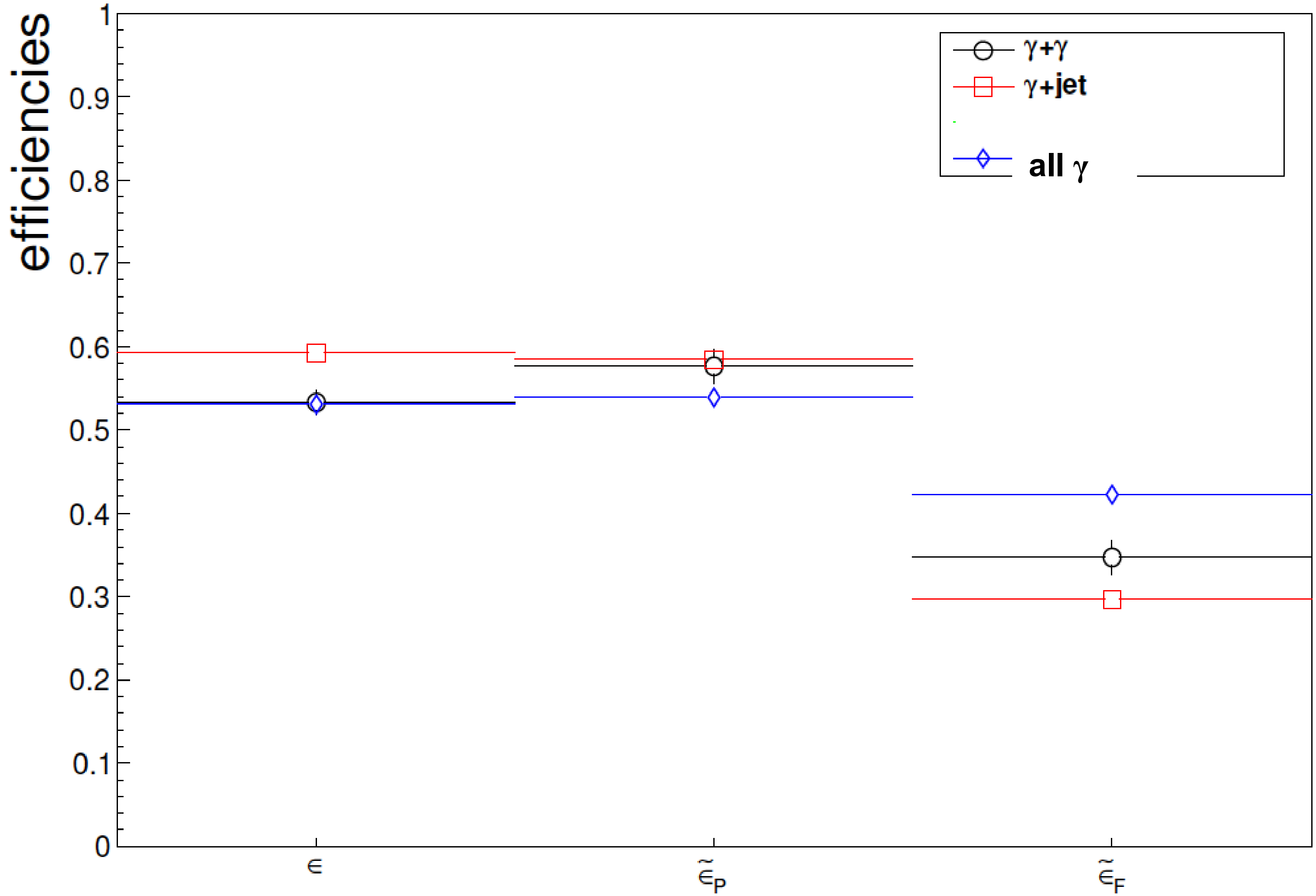
- Could we avoid depending on fake rates?
- Introduce a 2nd cut, for example an isolation cut
  → 10 equation for 3 observables (W(γγ), W(γj), W(jj))
- *N(IN | PP): number of γγ events, where both candidates pass (P) the tight isEM cut, while 1 is is*

$$\mathbf{N} = \begin{pmatrix} N_{\mathrm{II|PP}} \\ N_{\mathrm{IN|PP}} \\ N_{\mathrm{NN|PP}} \\ N_{\mathrm{II|PF}} \\ N_{\mathrm{IN|PF}} \\ N_{\mathrm{NI|PF}} \\ N_{\mathrm{NN|PF}} \\ N_{\mathrm{II|FF}} \\ N_{\mathrm{IN|FF}} \\ N_{\mathrm{NN|FF}} \end{pmatrix} = E \cdot \mathbf{W} = E \cdot \begin{pmatrix} W_{\gamma\gamma} \\ W_{\gamma j} \\ W_{jj} \end{pmatrix}$$

P = pass tight cut
F = fail tight cut
I = isolated
N = non-isolated

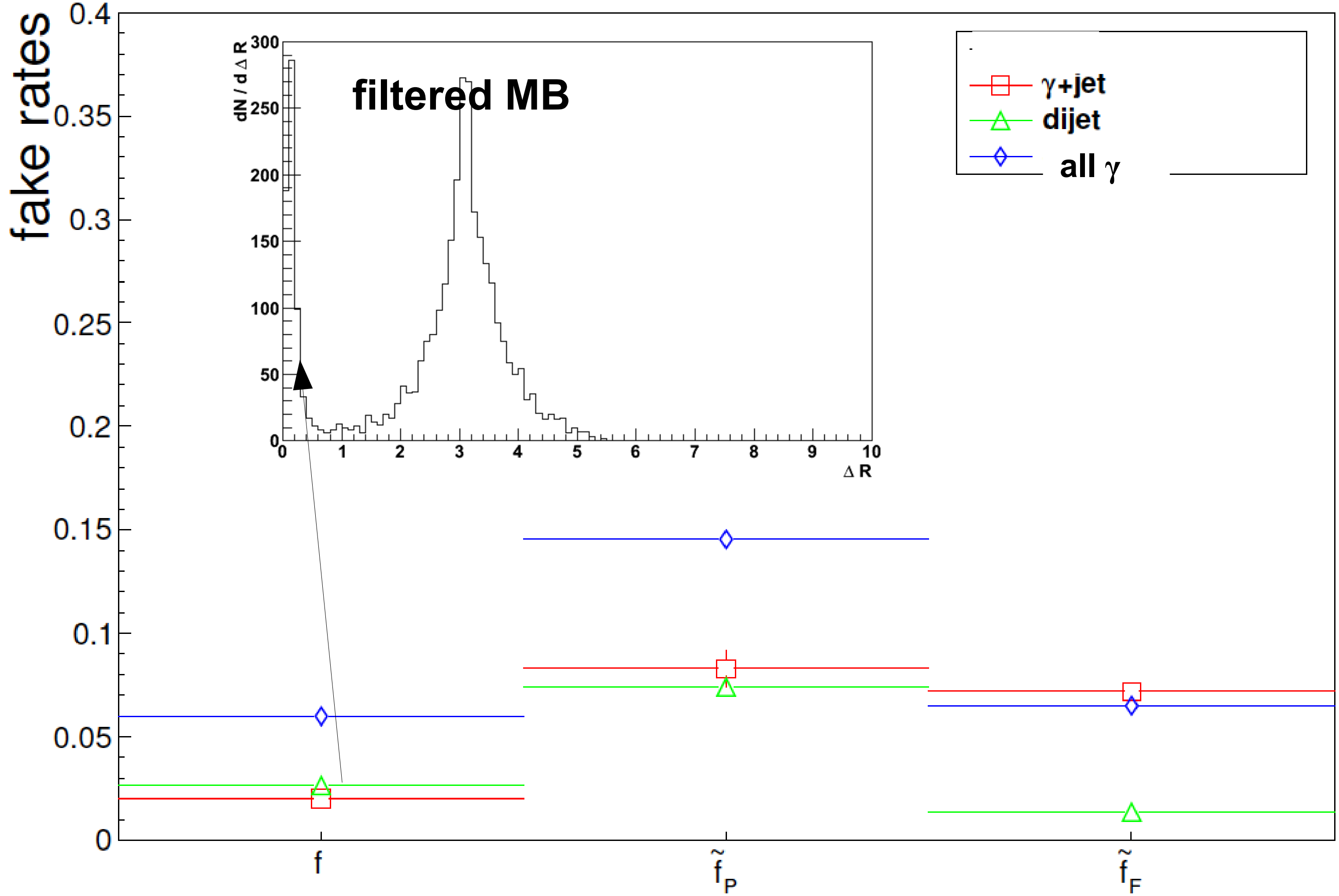
- E depends on 3 efficiencies: $\epsilon = p(P|\gamma),\ \hat{\epsilon}_P = p(I|P|\gamma),\ \hat{\epsilon}_F = p(I|F|\gamma)$
  and 2x3 fake rates (assume they are different for γjet and dijet)
- if efficiencies for γ are known:
  → can afford to retrieve the fake rates from the method
  (if statistics is high enough)

- **Which efficiencies should we take for the method?**



- **For the moment, take the efficiencies from γγ …**
- **Some discrepancies for truth = γγ and truth = γ+jet**
- **Now took the one from γγ**

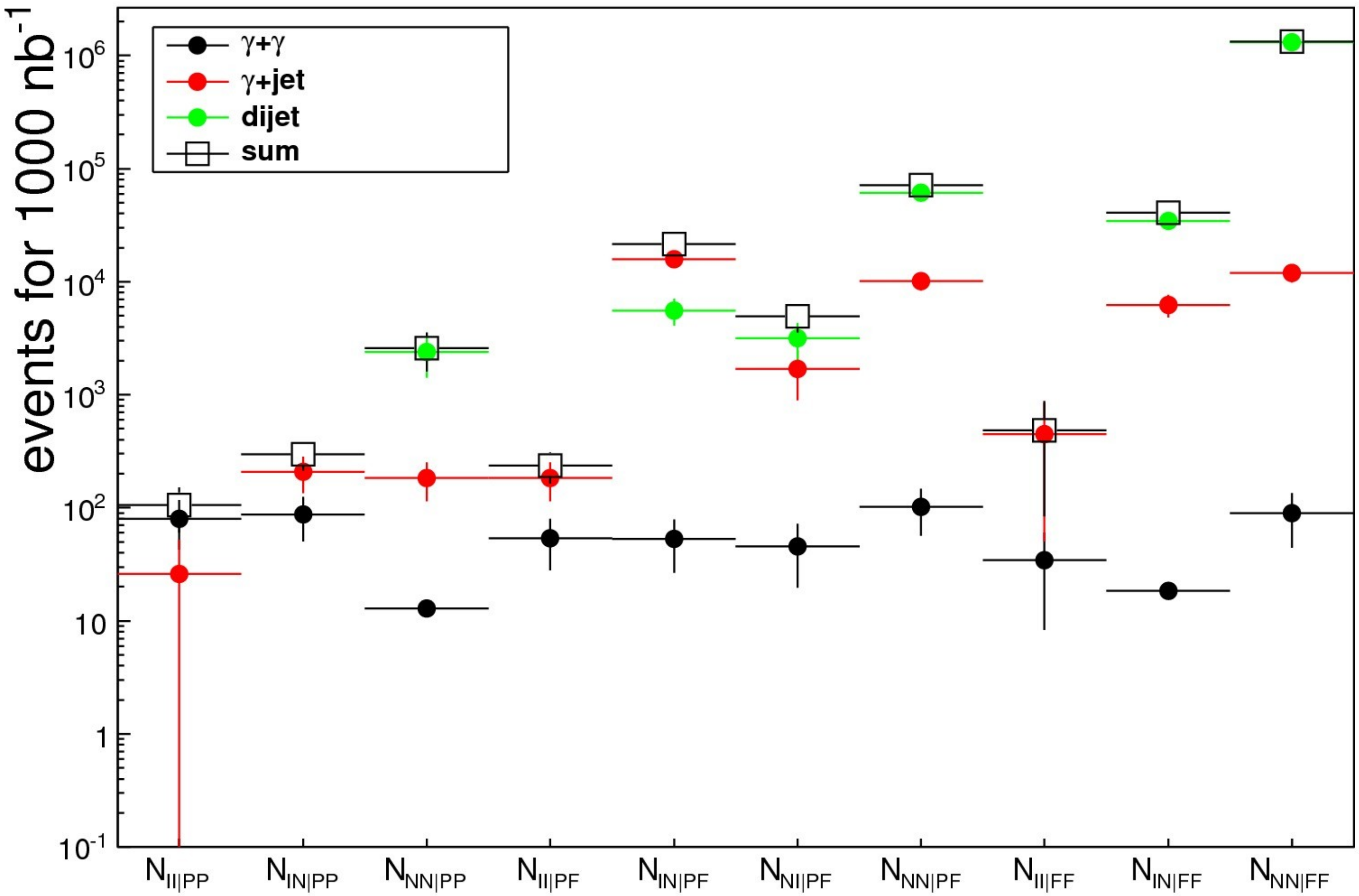
- **Are at the fake rates similar for different truth scenarios?**



- **Difference between effiencies from all photons and the efficiencies from diphoton pairs need to be understood**
- **Part of the effect due to two candidates from 1 jet (see ΔR plot for MB)**

First tests

- Yields for 1 pb^{-1} for the 10-row vector N of events passing certain combinations of cuts (see slide 7)



First tests

- Matrix as calculated from MC
- Efficiencies for prompt photons are taken from γγ
- Fake rates are treated differently for γ+jet an filtered MB

0.0945	0.0005	0.0000
0.1369	0.0060	0.0001
0.0496	0.0041	0.0006
0.1011	0.0220	0.0003
0.1878	0.2801	0.0037
0.0732	0.0187	0.0007
0.1360	0.2080	0.0462
0.0271	0.0116	0.0002
0.1005	0.1712	0.0262
0.0933	0.2778	0.9223

- Differences w.r.t. true matrix

0.0438	0.0000	-0.0000
0.0149	-0.0016	-0.0001
-0.0272	-0.0002	0.0011
-0.0074	-0.0181	-0.0003
-0.0961	0.0587	0.0002
0.0060	0.0174	0.0016
0.0401	0.0081	-0.0031
0.0327	-0.0020	-0.0002
-0.0688	-0.0389	-0.0020
0.0621	-0.0235	0.0026

- Matrix elements are in the same order
- Differences are quite large for some entries
- One possible origin: different efficiencies for bremsstrahlung & hard γ

First tests

- Took the efficiencies from $\gamma\gamma$ and perform a (χ^2)-fit (Minuit):
  - Free parameters: W($\gamma\gamma$), W(γ+jet), W(jet+jet), the 6 fake rates
  - $$\chi^2 = \sum_{i=1}^{10} \frac{\left(N_i - N_i^{\text{estimate}}(\text{parameters})\right)^2}{N_i^{\text{estimate}}(\text{parameters})}$$

	Output from method			Truth
W($\gamma\gamma$)	755.2	+-	1369.5	576.8
W(γ+j)	79794.7	+-	26361.4	46888.4
W(j+j)	1397939.7	+-	11054.4	1428750.0

- Agreement is not very bad, but errors are large...
- χ^2 ~ 4500 … :-(

Summary:

- Revisited CDF analyses for the diphoton cross-section (1993)
- Proposed an extended matrix method
- Yields estimated from MC have large errors
- However, study may be feasible with a few 1 pb^{-1}
- Showed first tests with the method
- Uncertainties from the fit are large, though …

Outlook:

- Efficiencies need to be understood
- Investigate fit in more detail
- Then: study different sets of cuts, apply to data, investigate systematics, ...

BACKUP

Matrix can be decomposed into 1 for each cut

$$\mathbf{N} = E \cdot \mathbf{W} = E_{\text{isolation}} \cdot E_{\text{quality}} \cdot \mathbf{W} = E_{\text{isolation}} \cdot \mathbf{N}' = E_{\text{isolation}} \cdot \begin{pmatrix} N'_{\text{PP}|\gamma\gamma} \\ N'_{\text{PF}|\gamma\gamma} \\ N'_{\text{FF}|\gamma\gamma} \\ N'_{\text{PP}|\gamma j} \\ N'_{\text{PF}|\gamma j} \\ N'_{\text{FP}|\gamma j} \\ N'_{\text{FF}|\gamma j} \\ N'_{\text{PP}|jj} \\ N'_{\text{PF}|jj} \\ N'_{\text{FF}|jj} \end{pmatrix}$$

$$E_{\text{quality}} = \begin{pmatrix} \epsilon \cdot \epsilon & 0 & 0 \\ 2 \cdot \epsilon \cdot (1-\epsilon) & 0 & 0 \\ (1-\epsilon) \cdot (1-\epsilon) & 0 & 0 \\ 0 & \epsilon \cdot f_{\gamma j} & 0 \\ 0 & \epsilon \cdot (1 - f_{\gamma j}) & 0 \\ 0 & (1-\epsilon) \cdot f_{\gamma j} & 0 \\ 0 & (1-\epsilon) \cdot (1 - f_{\gamma j}) & 0 \\ 0 & 0 & f_{jj} \cdot f_{jj} \\ 0 & 0 & 2 \cdot f_{jj} \cdot (1 - f_{jj}) \\ 0 & 0 & (1 - f_{jj}) \cdot (1 - f_{jj}) \end{pmatrix}$$

Proposal of an extended matrix method

$$
\begin{aligned}
E_{\mathrm{isolation}} = & \begin{pmatrix}
\hat{\epsilon}_P \cdot \hat{\epsilon}_P & 0 & 0 & \hat{\epsilon}_P \cdot \hat{f}_{\gamma j,P} & 0 & 0 & 0 & \hat{f}_{jj,P} \cdot \hat{f}_{jj,P} & 0 & 0 \\
2 \cdot \hat{\epsilon}_P \cdot (1-\hat{\epsilon}_P) & 0 & 0 & \hat{\epsilon}_P \cdot (1-\hat{f}_{\gamma j,P}) + (1-\hat{\epsilon}_P) \cdot \hat{f}_{\gamma j,P} & 0 & 0 & 0 & 2 \cdot \hat{f}_{jj,P} \cdot (1-\hat{f}_{jj,P}) & 0 & 0 \\
(1-\hat{\epsilon}_P) \cdot (1-\hat{\epsilon}_P) & 0 & 0 & (1-\hat{\epsilon}_P) \cdot (1-\hat{f}_{\gamma j,P}) & 0 & 0 & 0 & (1-\hat{f}_{jj,P}) \cdot (1-\hat{f}_{jj,P}) & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \\
& + \begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & \hat{\epsilon}_P \cdot \hat{\epsilon}_F & 0 & 0 & \hat{\epsilon}_P \cdot \hat{f}_{\gamma j,F} & \hat{\epsilon}_F \cdot \hat{f}_{\gamma j,P} & 0 & 0 & \hat{f}_{jj,P} \cdot \hat{f}_{jj,F} & 0 \\
0 & \hat{\epsilon}_P \cdot (1-\hat{\epsilon}_F) & 0 & 0 & \hat{\epsilon}_P \cdot (1-\hat{f}_{\gamma j,F}) & (1-\hat{\epsilon}_F) \cdot \hat{f}_{\gamma j,P} & 0 & 0 & \hat{f}_{jj,P} \cdot (1-\hat{f}_{jj,F}) & 0 \\
0 & (1-\hat{\epsilon}_P) \cdot \hat{\epsilon}_F & 0 & 0 & (1-\hat{\epsilon}_P) \cdot \hat{f}_{\gamma j,F} & \hat{\epsilon}_F \cdot (1-\hat{f}_{\gamma j,P}) & 0 & 0 & (1-\hat{f}_{jj,P}) \cdot \hat{f}_{jj,F} & 0 \\
0 & (1-\hat{\epsilon}_P) \cdot (1-\hat{\epsilon}_F) & 0 & 0 & (1-\hat{\epsilon}_P) \cdot (1-\hat{f}_{\gamma j,F}) & (1-\hat{\epsilon}_F) \cdot (1-\hat{f}_{\gamma j,P}) & 0 & 0 & (1-\hat{f}_{jj,P}) \cdot (1-\hat{f}_{jj,F}) & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0
\end{pmatrix} \\
& + \begin{pmatrix}
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
0 & 0 & \hat{\epsilon}_F \cdot \hat{\epsilon}_F & 0 & 0 & 0 & \hat{\epsilon}_F \cdot \hat{f}_{\gamma j,F} & 0 & 0 & \hat{f}_{jj,F} \cdot \hat{f}_{jj,F} \\
0 & 0 & 2 \cdot \hat{\epsilon}_F \cdot (1-\hat{\epsilon}_F) & 0 & 0 & 0 & \hat{\epsilon}_F \cdot (1-\hat{f}_{\gamma j,F}) + (1-\hat{\epsilon}_F) \cdot \hat{f}_{\gamma j,F} & 0 & 0 & 2 \cdot \hat{f}_{jj,F} \cdot (1-\hat{f}_{jj,F}) \\
0 & 0 & (1-\hat{\epsilon}_F) \cdot (1-\hat{\epsilon}_F) & 0 & 0 & 0 & (1-\hat{\epsilon}_F) \cdot (1-\hat{f}_{\gamma j,F}) & 0 & 0 & (1-\hat{f}_{jj,F}) \cdot (1-\hat{f}_{jj,F})
\end{pmatrix}
\end{aligned}
$$

First tests

- **Assumed that not all fake rates differ → reduced to 3 fake rates, hence 6 parameters remain**

$$\chi^2 = \sum_{i=1}^{10} \frac{\left(N_i - N_i^{\text{estimate}}(\text{parameters})\right)^2}{N_i^{\text{estimate}}(\text{parameters})}$$

	Output from method			Truth
W(γγ)	5916.8	+-	7993.7	576.8
W(γ+j)	54923.2	+-	30799.0	46888.4
W(j+j)	1418787.2	+-	15821.5	1428750.0

- **Errors become much larger...**
- **χ^2 ~ 47500 … :-(**
- **Even worse...**