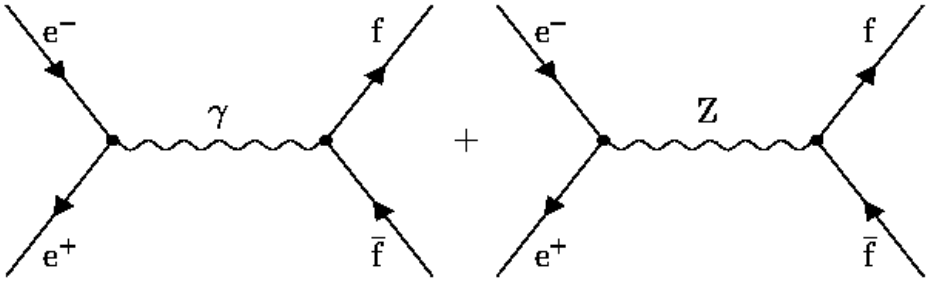
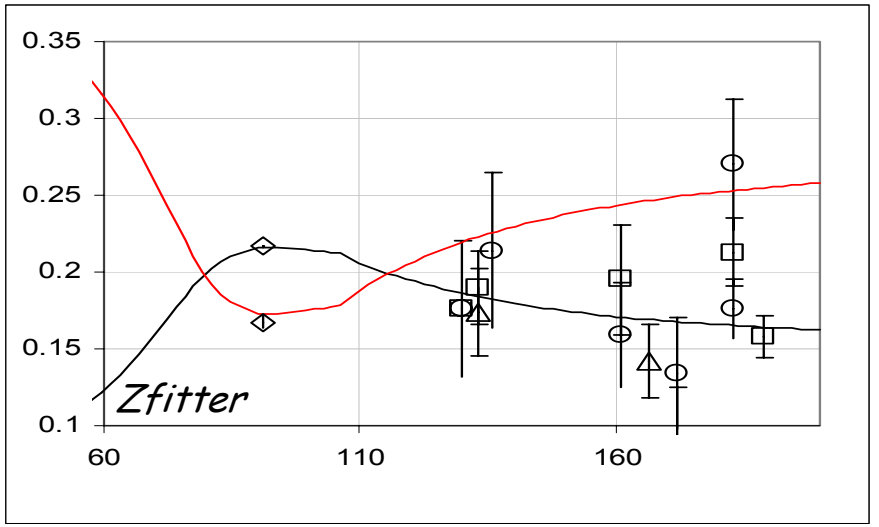
R_b @ LEP2

Yoram Rozen – Technion, Israel
for the OPAL Collab.

Rb@LEP2

$$R_b = \frac{\sigma\left[e^+e^- \to b\bar{b}\right]}{\sigma\left[e^+e^- \to q\bar{q}\right]}$$



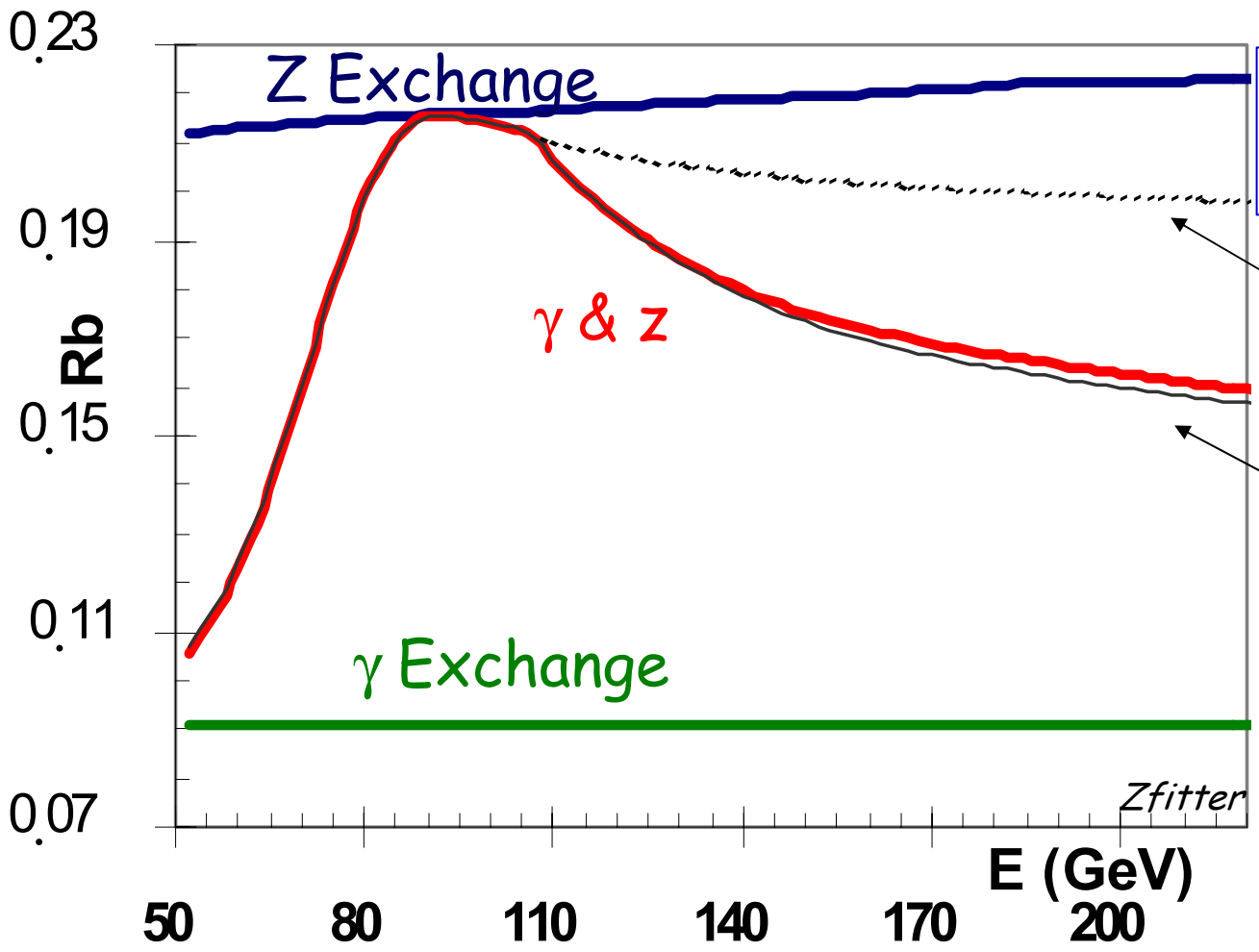


- Experimental parameter
- SM check "Nice to have" Precision

- s dependence "Need to have" Precision
- Probe the top, Higgs sector
- Z-γ interference

Rc Rb
□ OPAL ○ ALEPH
△ DELPHI ◇ Avg. LEP1

Rb-Theoretical prediction



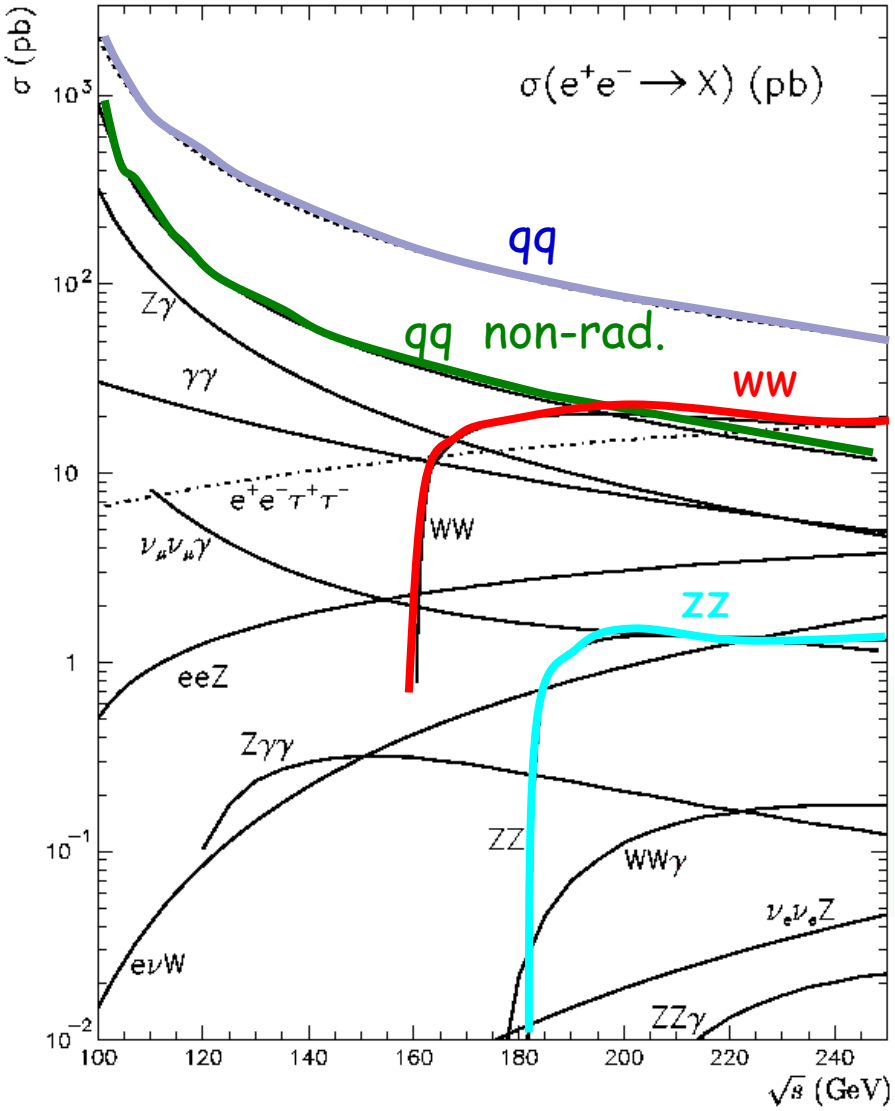
$$R_b \approx \frac{C_V^{b2} + C_A^{b2}}{\sum_{i=u\ldots t}\left(C_V^{i2} + C_A^{i2}\right)} \approx 0.22$$

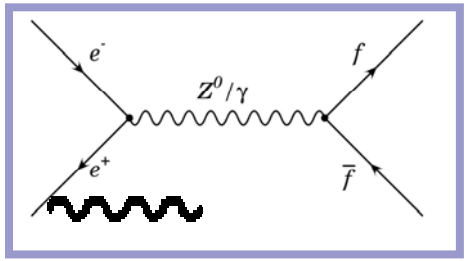
Including radiative events

Without Z/γ interference

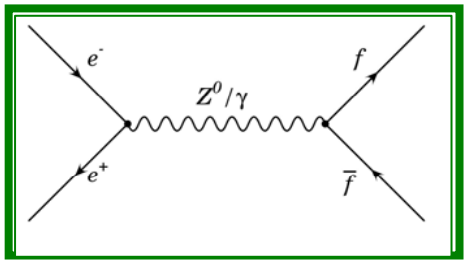
$$R_b \approx \frac{q_b^2}{\sum_{i=u\ldots t} q_i^2} = \frac{1}{11} \approx 0.091$$

LEP2 cross sections

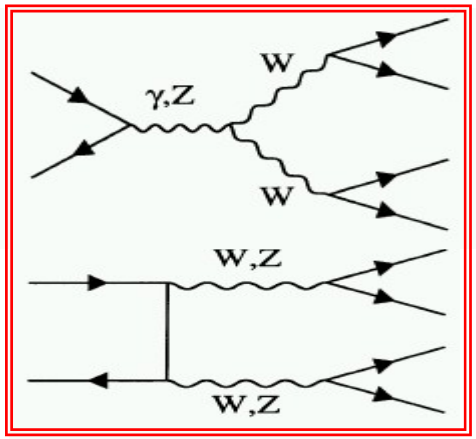




radiative

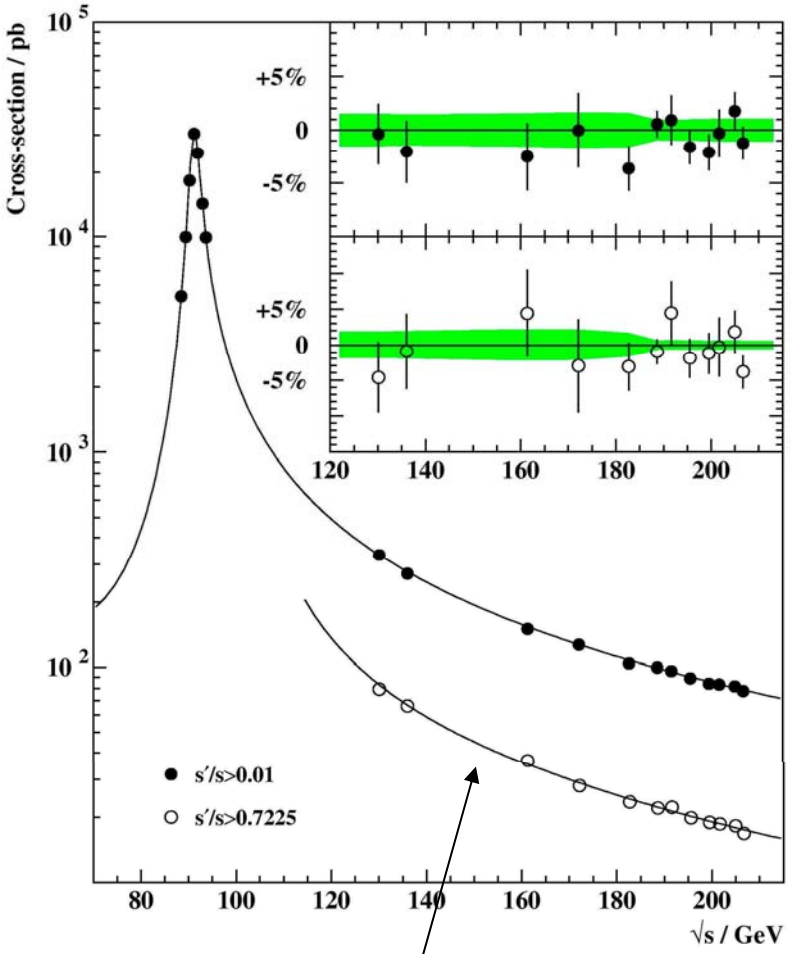


Fermion pair (non-radiative)

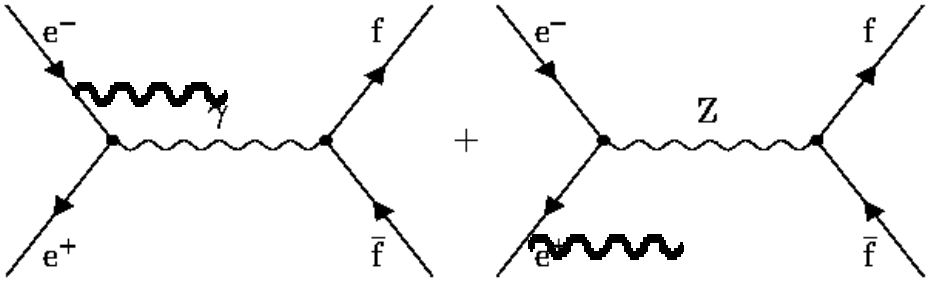


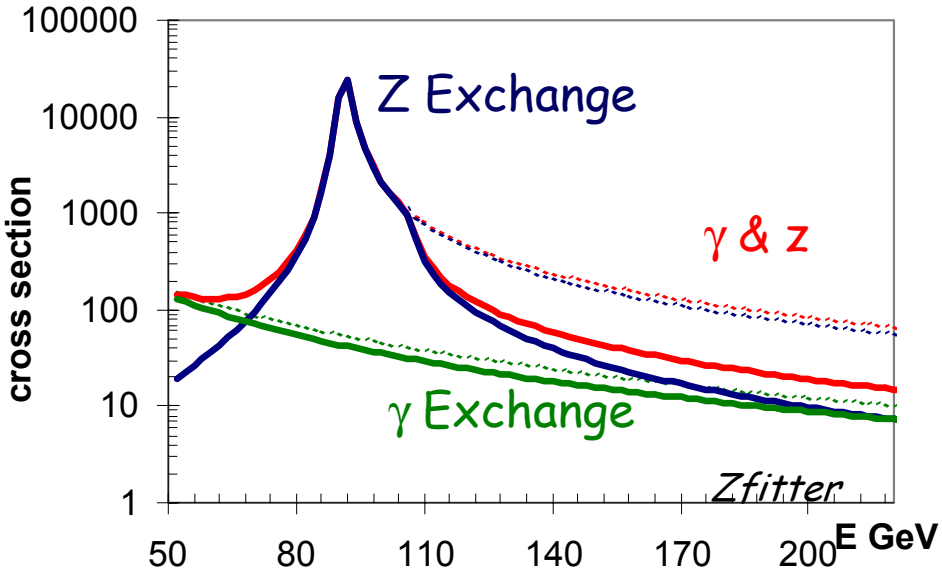
4 fermions (4f)

LEP Fermion Pair Production None Radiative Cross Section



non-rad events





$$R_b = \frac{\frac{N_{tag}}{N_{qq}} - \varepsilon_c R_c - \varepsilon_{uds}(1 - R_c)}{\varepsilon_b - \varepsilon_{uds}}$$

1. Estimate hadronic events, make corrections → N_{qq}
   - select hadronic events
   - reject radiative events
   - reject 4-fermions events
   - subtract remaining 4f and radiative events

2. Estimate bb events, make corrections → N_{tag}

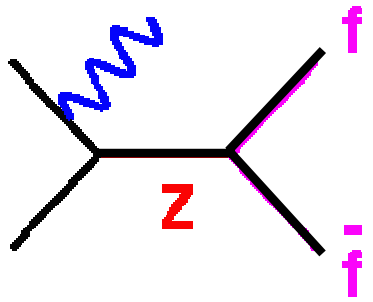
3. Estimate remaining background → ε_c, ε_{uds}

4. Tagging efficiency → ε_b

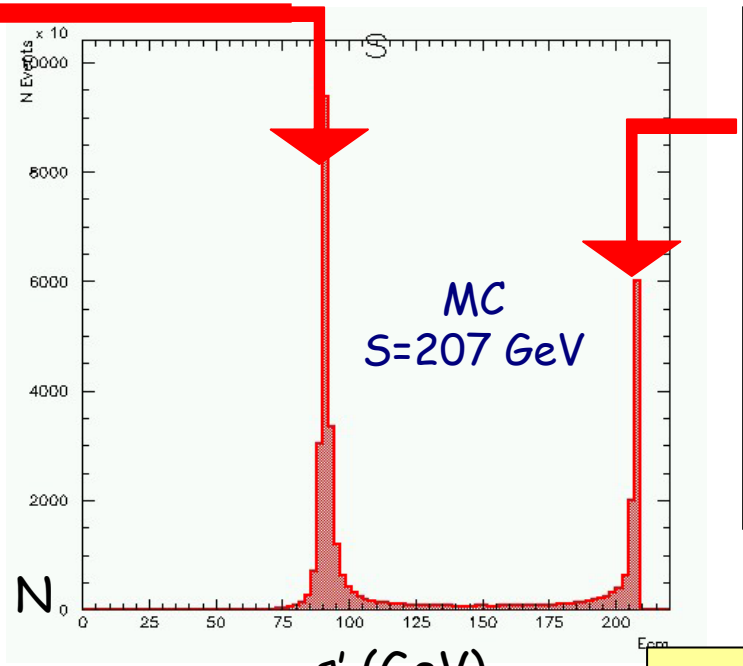
Radiation of an initial state photon decreases effective collision energy to $\sqrt{s'}$

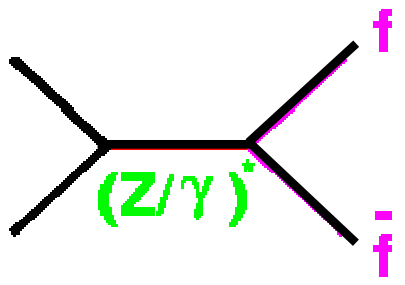
If $\sqrt{s'}$ close to Z peak⇒more likely to interact⇒enhancement of CS

Radiative return to the Z



$\sqrt{s'} < \sqrt{s}$





Full energy events

$\sqrt{s'} = \sqrt{s}$

LEP signal definition:

- $s' > 0.85 * s$,
- $\sqrt{s'}$ =mass of propagator,
- ISR-FSR interference subtracted

missing energy
⇒ fake lower s'

4f veto

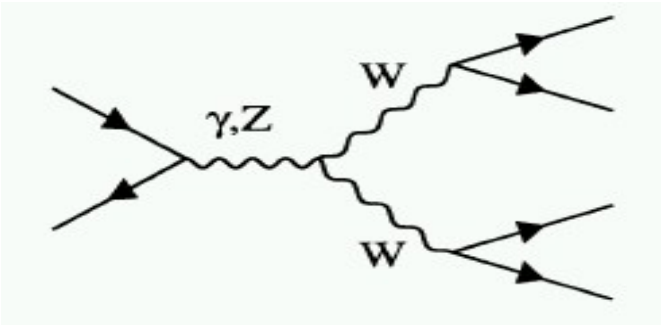
Reject events with 'other' topologies:

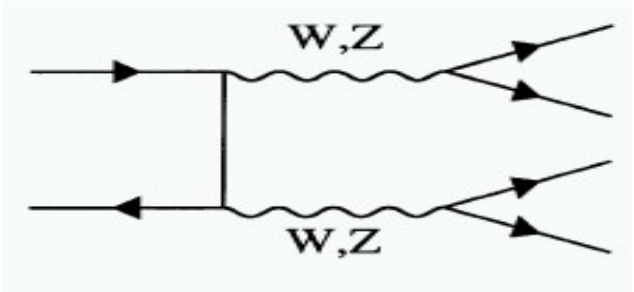
$e^+e^- \to W^+W^- \left(\sqrt{s} > 161GeV\right)$
$e^+e^- \to ZZ \left(\sqrt{s} > 183GeV\right)$

ww→qqqq (46%)
- Four jets
- No missing momentum

ww →qqlν (43%)
- Two jets.
- Isolated lepton
- Missing momentum

ε_{qq}=94%
ε_{4f}=5 %
ε_{4f}'=0.3 %





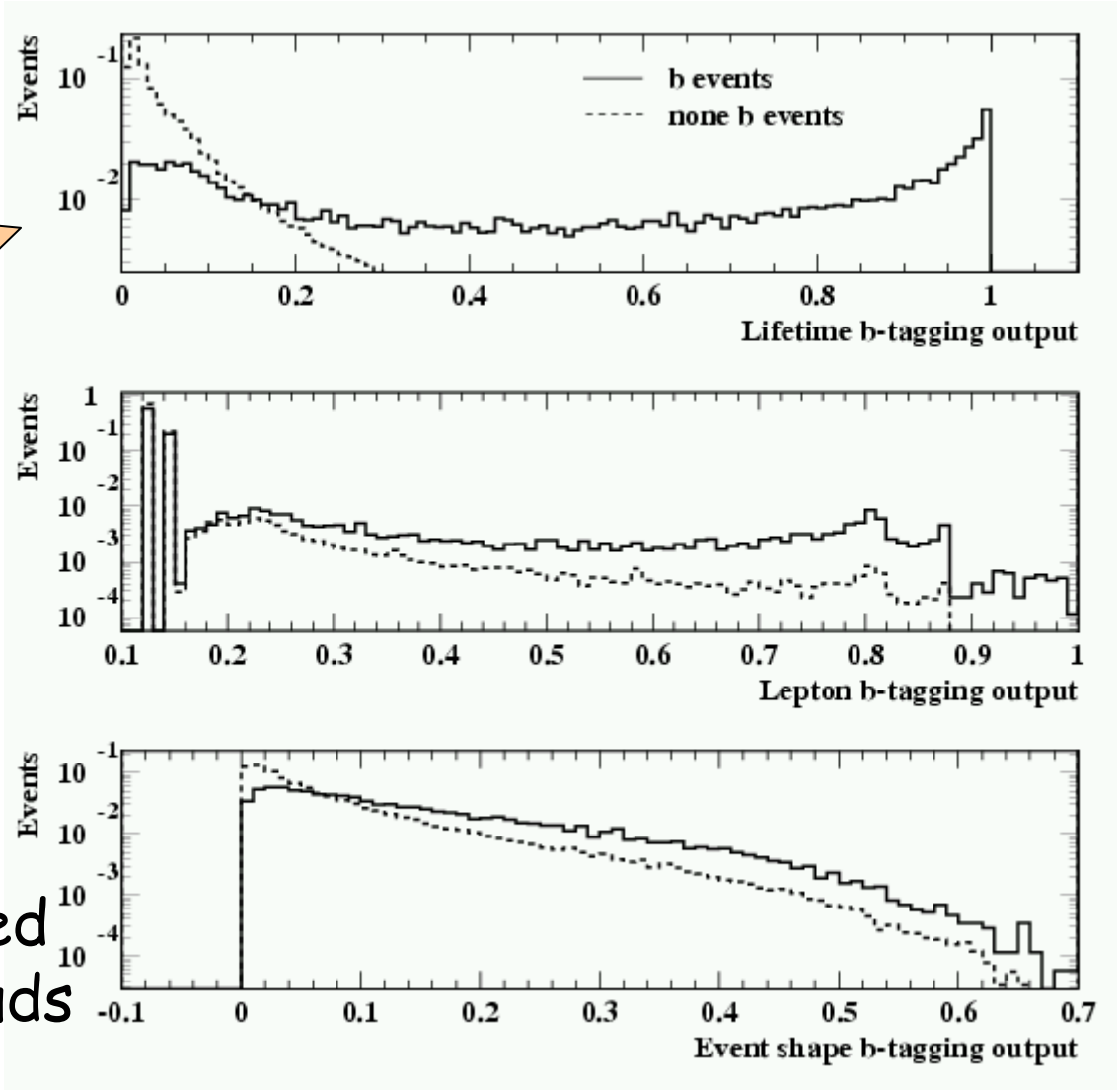
ww →lνlν (11%) [ee,μμ,ττ,eμ, eτ,μτ]
- Two leptons
- Missing energy

B tagging

b-ness from three independent sources:

- Lifetime information
- Lepton Pt
- Kinematic variables

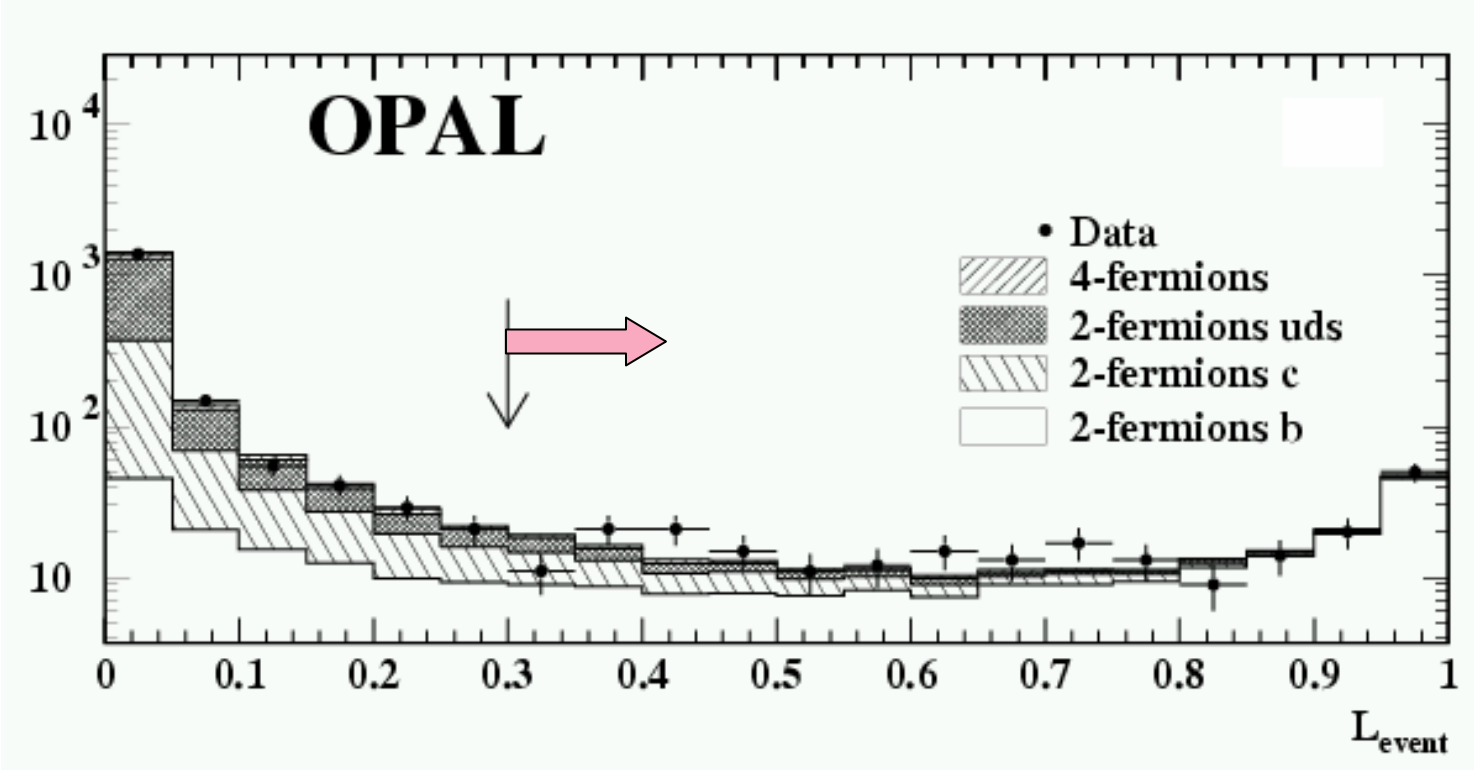
each source gives ANN
The 3 ANNs are combined into a likelihood for b,c,uds



B tagging

- Each event is divided to hemispheres
- The lb algorithm is applied to each hemisphere
- Each event is given a b-being likelihood L:

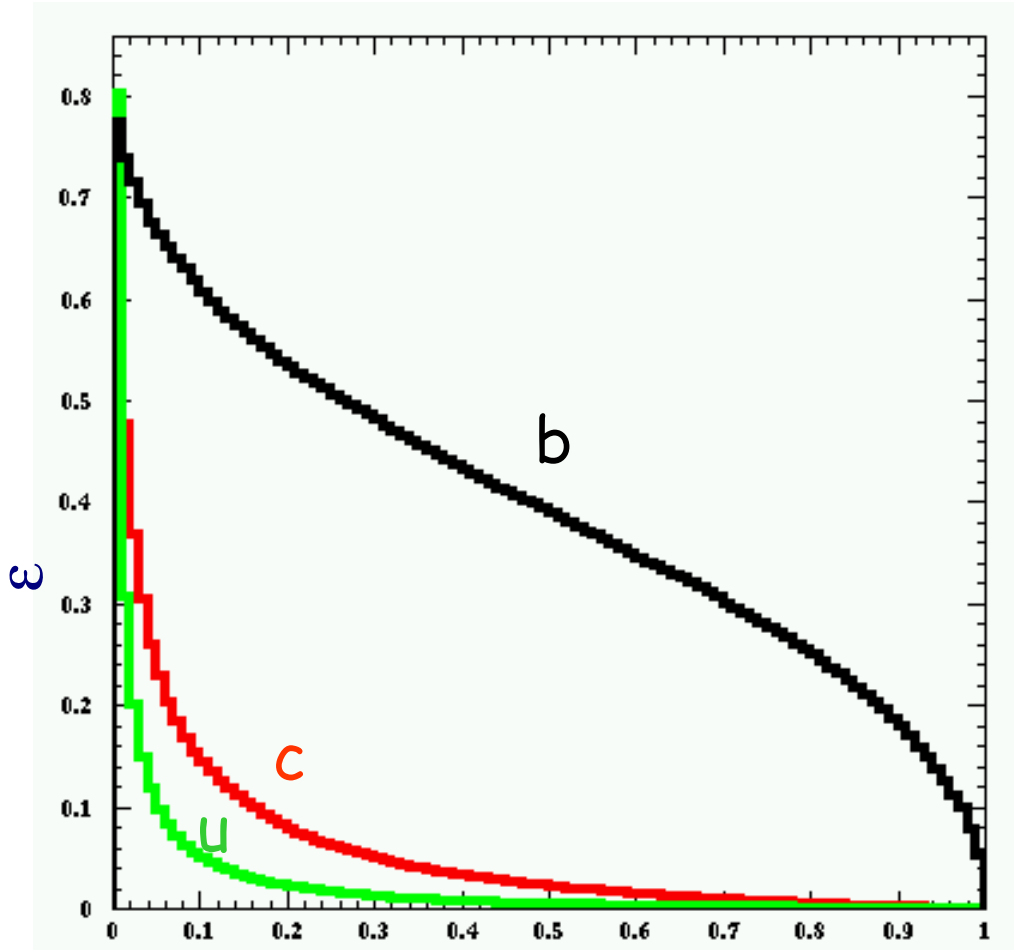
$$L_{event} = \frac{r_b L_{b1} L_{b2}}{r_b L_{b1} L_{b2} + r_c L_{c1} L_{c2} + r_{uds} L_{u1} L_{u2}}$$



Efficiency

%	b	c	uds	4f
s'+ Event selection	84	86	87	16
4f veto	77	80	80	0.5
B-tagging @0.3	48	5	1.2	0.03

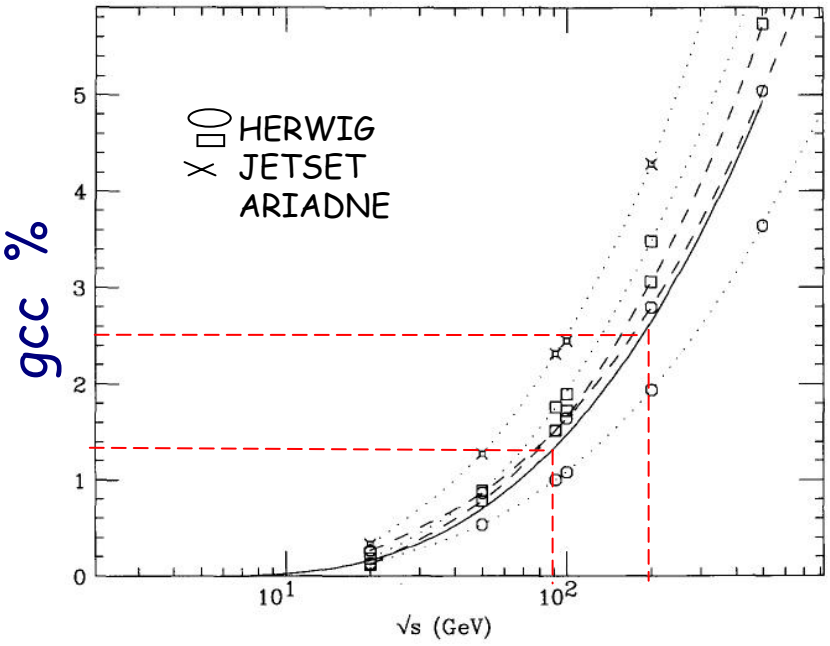
Including a cut on $\cos(\theta_{thr})$

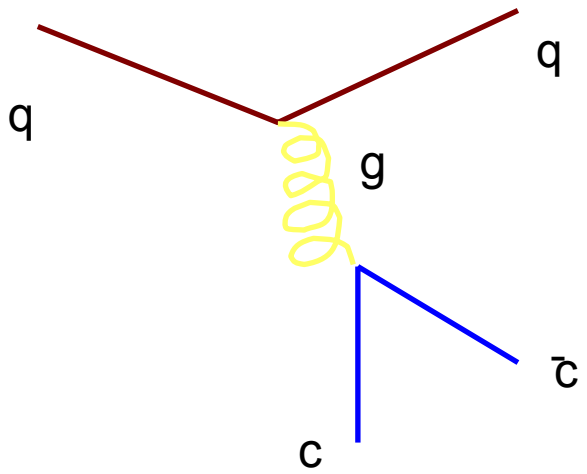


lb cut

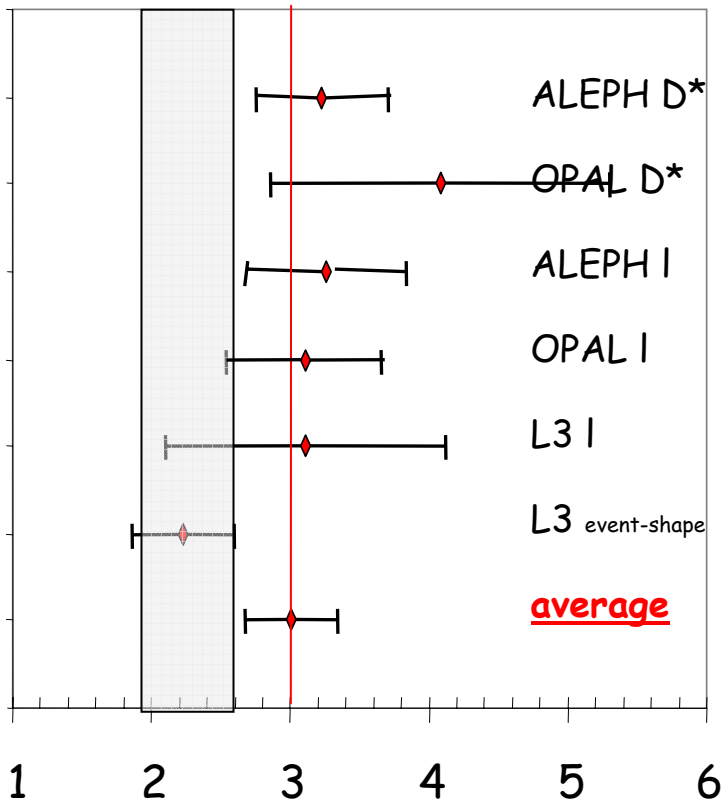
g_{cc}

gcc Predictions





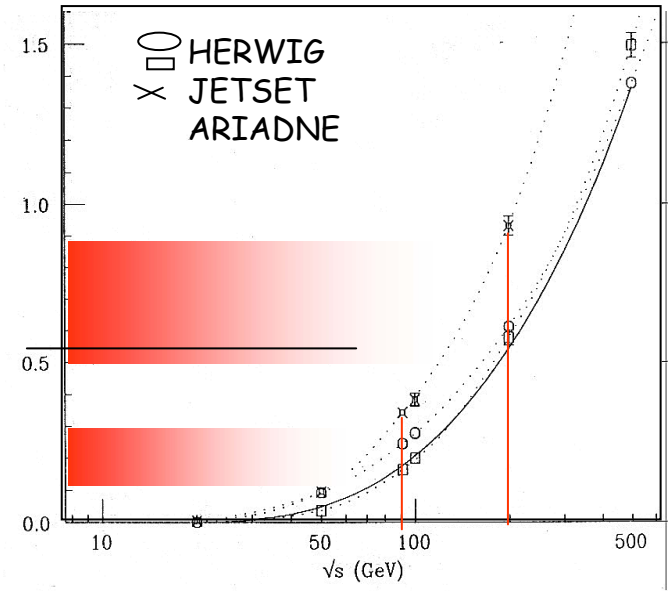
gcc results 90GeV

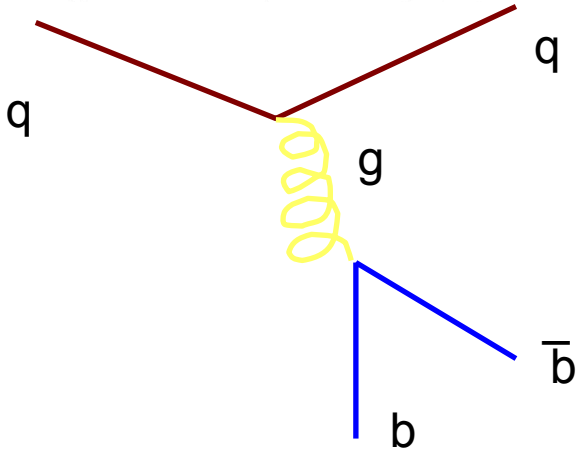


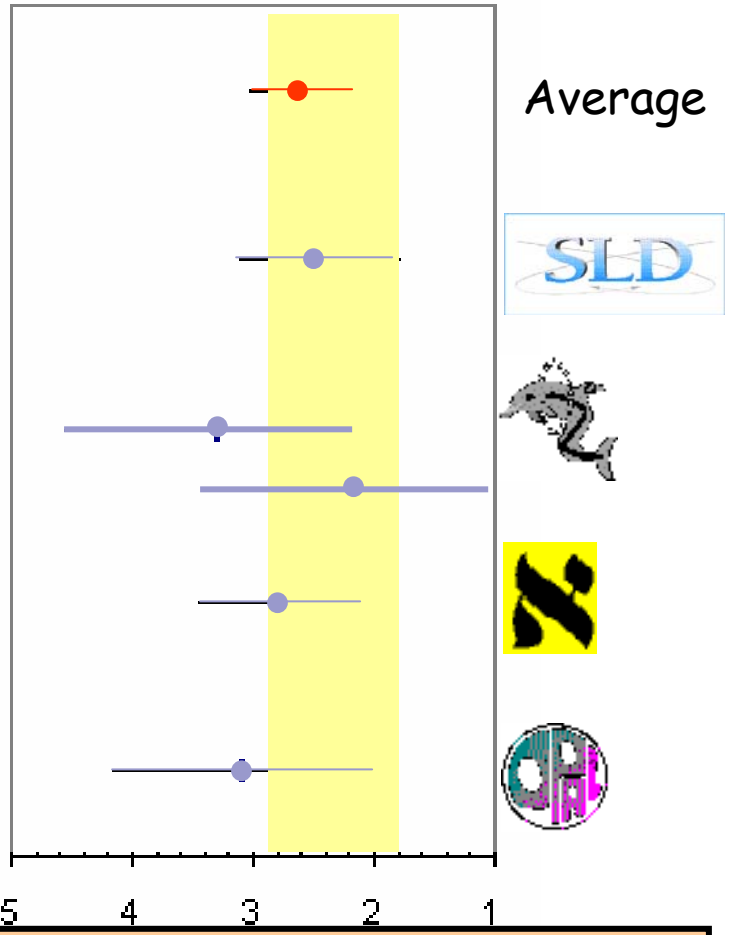
90 GeV : Analytical result	~	1.4%
90 GeV : Measured	~	3.0%
200GeV: Analytical result	~	2.6%
200GeV: "Measured"	~	5.6%

g_{bb}

gbb Predictions







90 GeV : Analytical result	~ 0.18%
90 GeV : Measured	~ 0.25%
200GeV: Analytical result	~ 0.52%
200GeV: "Measured"	~ 0.72%

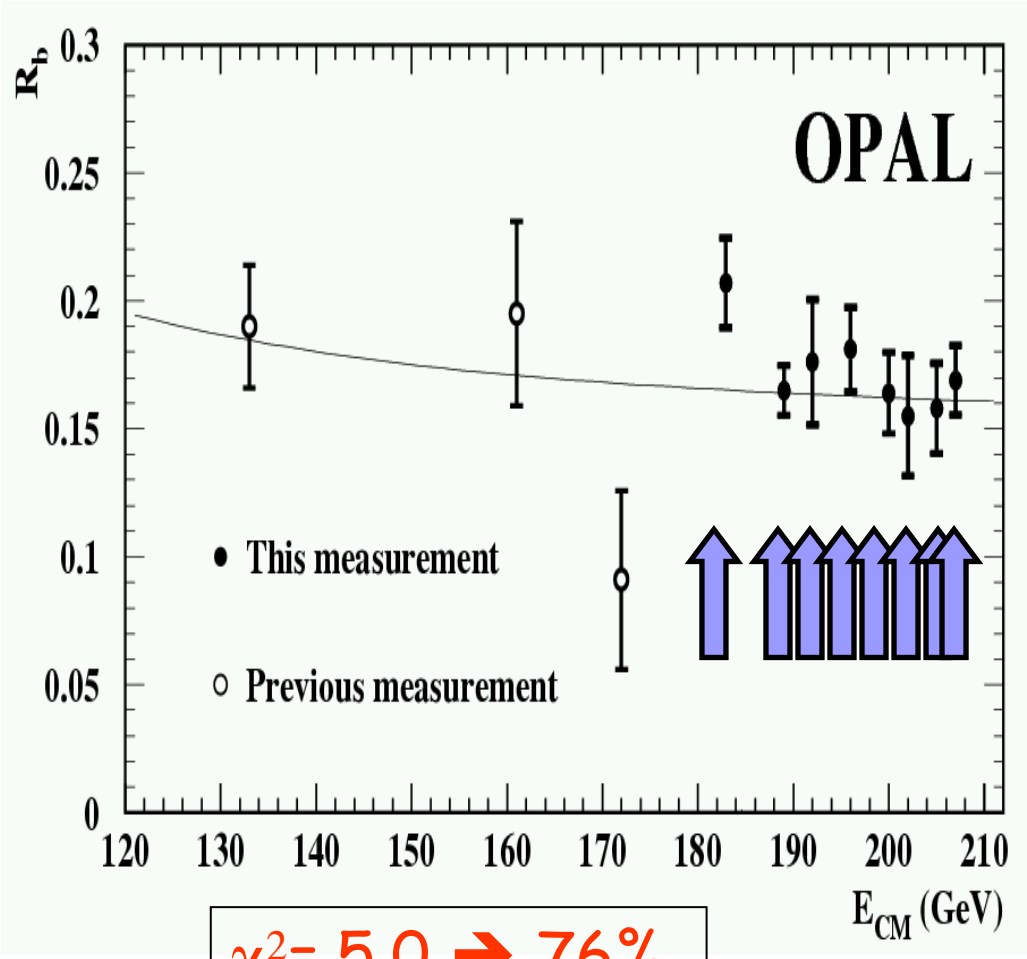
Systematics (207 GeV)

Source	$\Delta R_b/R_b$
Track reconstruction	3.2%
MC stat	0.6 %
S'	0.1 %
Lepton ID	0.5%
Total detector effects	3.3%

Source	$\Delta R_b/R_b$
b,c physics modelling	1.3%
K^0, Λ rate	0.2 %
Interference	0.3 %
gcc gbb	0.1% 0.1%
4f background	0.1%
Total physics modelling	1.3%

Total systematic uncertainty = 3.5%

Results



χ^2= 5.0 ➔ 76%

E (GeV)	Rb ± sys ± stat
183	0.207 ± 0.018 ± 0.007
189	0.165 ± 0.010 ± 0.006
192	0.174 ± 0.025 ± 0.006
196	0.181 ± 0.017 ± 0.006
200	0.164 ± 0.016 ± 0.006
202	0.154 ± 0.024 ± 0.005
205	0.158 ± 0.018 ± 0.006
207	0.169 ± 0.014 ± 0.006

Conclusion

- Rb was measured by OPAL at 8 new energy points (183-207 GeV)

Using a highly efficient and background-free B-tagger.

- These measurements are consistent with the SM prediction:

$$\frac{R_b^{OPAL}}{R_b^{SM}} = 1.055 \pm 0.031 \pm 0.037$$

Thanks

- To the organizers for the great snow/food/program
- To my daughter for sitting so quietly
- To Hagar Landsman for all the help throughout