OPAL Experimental Program

at the University of Victoria

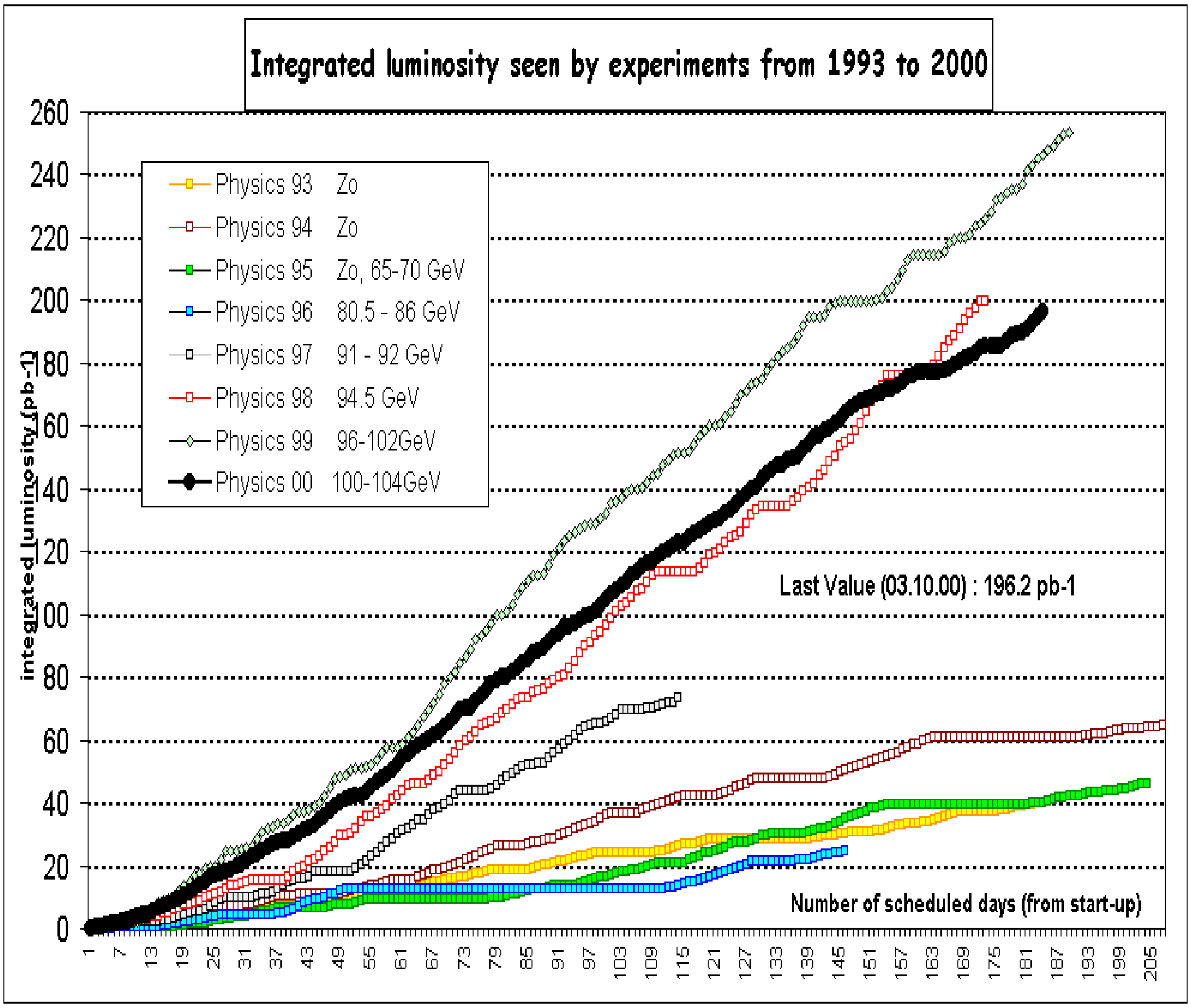
NSERC Site Visit

16 October 2000

- The LEP Program
- Current Personnel and Activities
- Responsibilities
  - Zed Chambers
  - Online Data Reconstruction
- Selected UVic Physics Topics
  - τ Branching Ratios
  - τ Asymmetries
  - FCNC: Single top quark production
  - Vector Boson (Anomalous) Couplings
  - $\gamma + \not{E}_T$: Low scale gravity?
  - $\ell^+\ell^-\gamma$: Excited Lepton Searches
  - SUSY Searches
- Future Plans

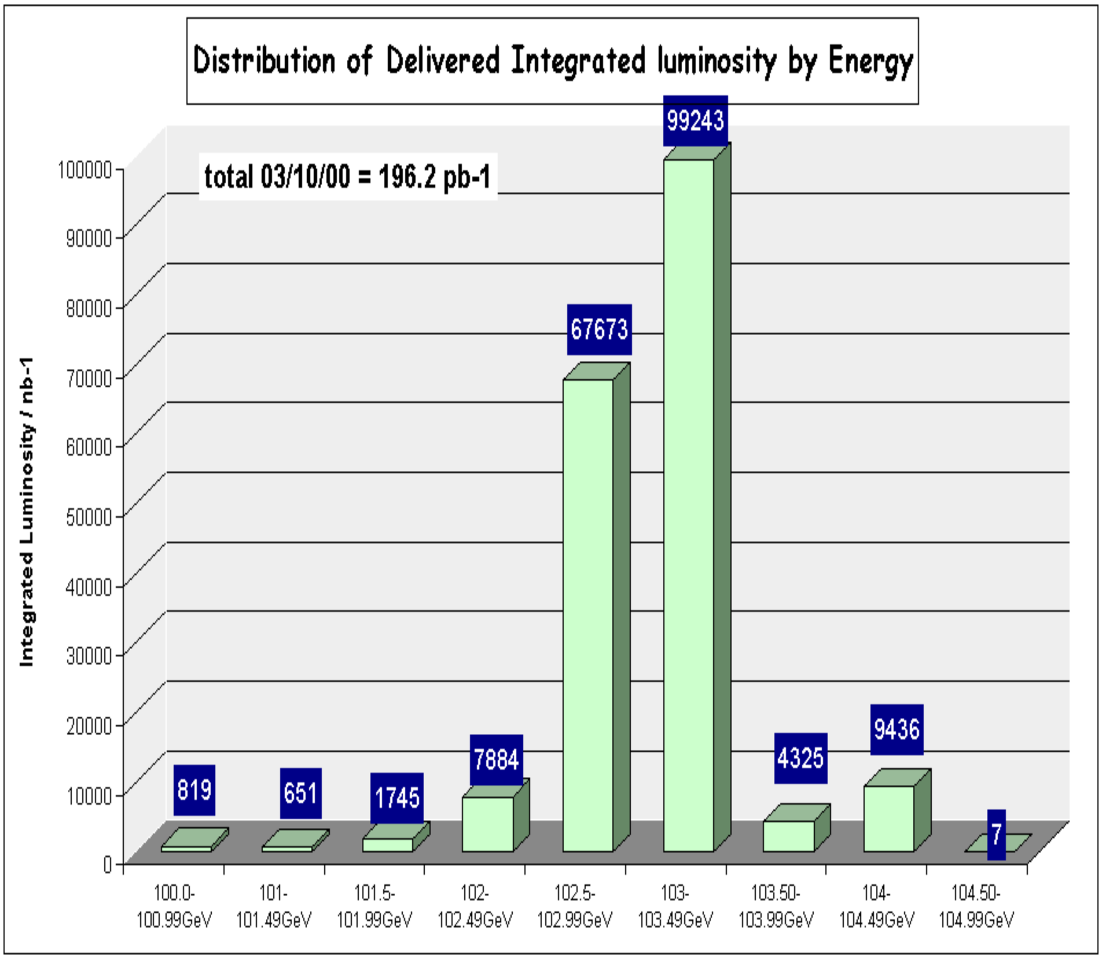
The LEP Program

Stage	$\sqrt{s}$	Year	Luminosity
LEP 1	$\approx$ 91 GeV	1989-1995	175 pb^{-1}
LEP 1.5	130-140 GeV	1995	5 pb^{-1}
LEP 2	161 GeV	1996	10 pb^{-1}
	172 GeV	1996	10 pb^{-1}
	183 GeV	1997	55 pb^{-1}
	189 GeV	1998	180 pb^{-1}
	192–202 GeV	1999	230 pb^{-1}
	200–209 GeV	2000	$>$190 pb^{-1}



Year 2000 Run

- Many measurements (*eg.* M_{W}) near systematic limit
- "Discovery Mode"
  - Run at highest achievable energy
  - Give up some luminosity
  - Increase $\sqrt{s}$ as beam current decreases



- Fast "online" analyses
- Detailed combinations and cross-checks with other experiments

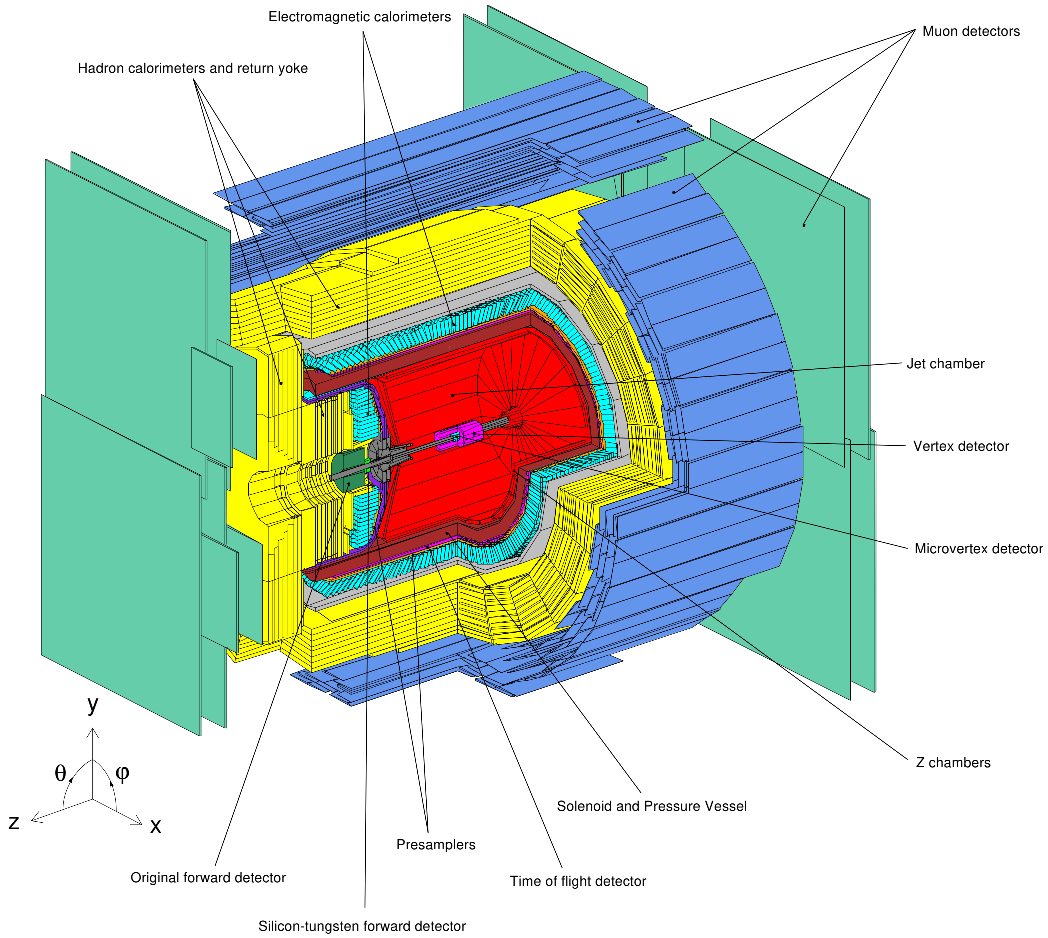
Current Personnel and Activities

- Faculty and Adjunct
  - Keeler
    τ-physics, W-physics, Administration
  - Kowalewski
    FCNC
  - McPherson
    Beyond SM searches, Coordination
    Zed Chamber DAQ and Coordination
    Overall OPAL Physics Coordinator 2001
  - Roney
    τ-physics
  - Sobie
    τ-physics, Coordination
- Research Associates
  - Long
    Photonic Events
    Online Event Reconstruction
  - Sbarra
    W-physics
    Online Event Reconstruction
- Current Students
  - Bailey (Keeler)
    W-physics
  - Graham (Roney)
    τ Asymmetry
  - Stumpf (Sobie)
    $\tau \rightarrow \mu$ BR
  - Vachon (McPherson,Sobie)
    Excited Lepton Searches
    Online Event Reconstruction

Responsibilities: Zed chambers

- Large area drift chambers
- Typically 1 mm z-coordinate resolution
- 1152 flash ADC channels

  100 MHz, 6 true bits (10 effective bits)
- Read out with VME-based system



McPherson :

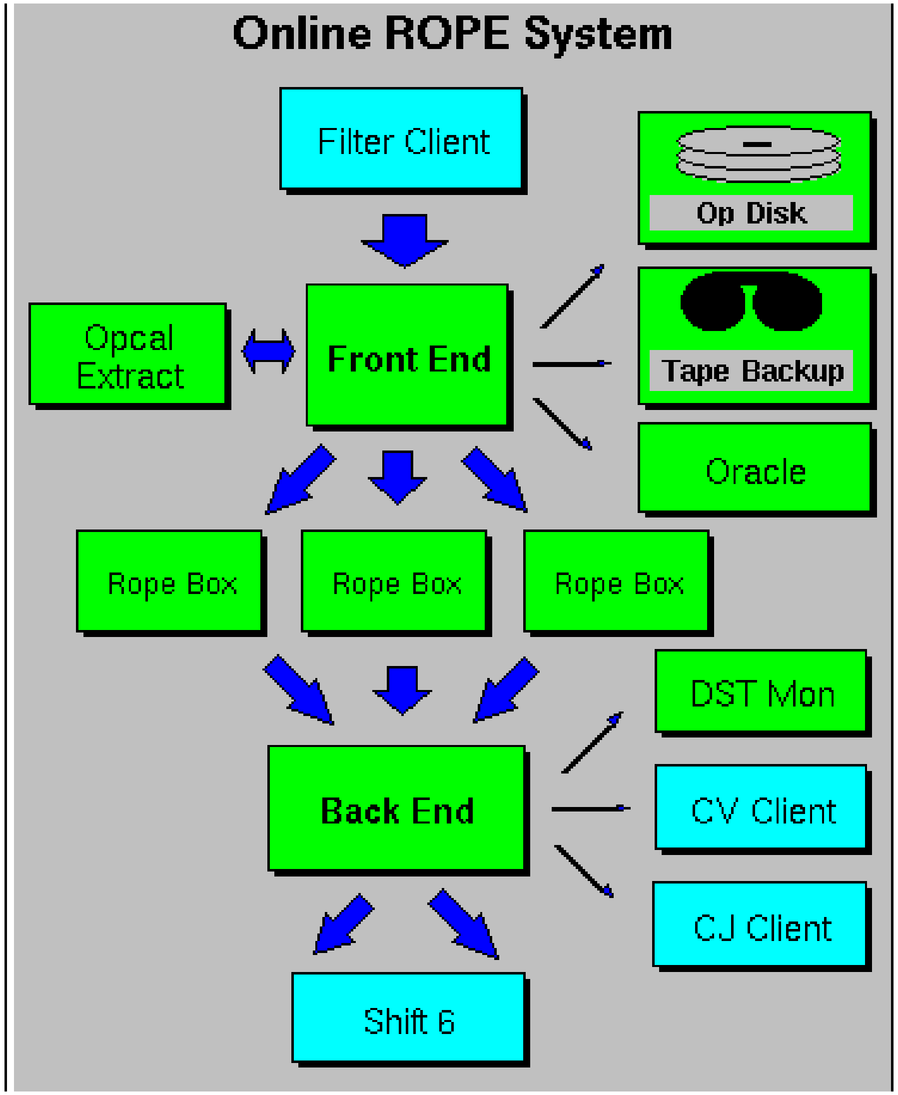
- DAQ maintenance, repairs
- Oncall during data taking
- Coordination of DAQ and detector coverage, daily checking shifts, calibration

Responsibilities: Online event processing

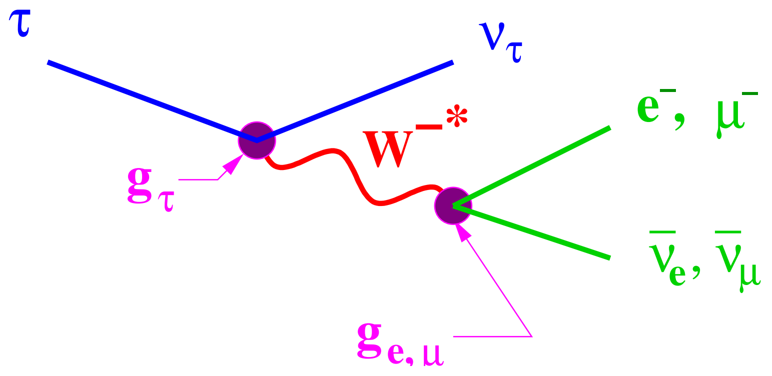
- Receives data from central OPAL DAQ
- Writes to optical disk and tape
- Full OPAL reconstruction
- Online detector calibration
- Available for analysis in $\sim$ 1 hour

- Also used for offline “re-reconstruction”
  i.e. after the end of data taking

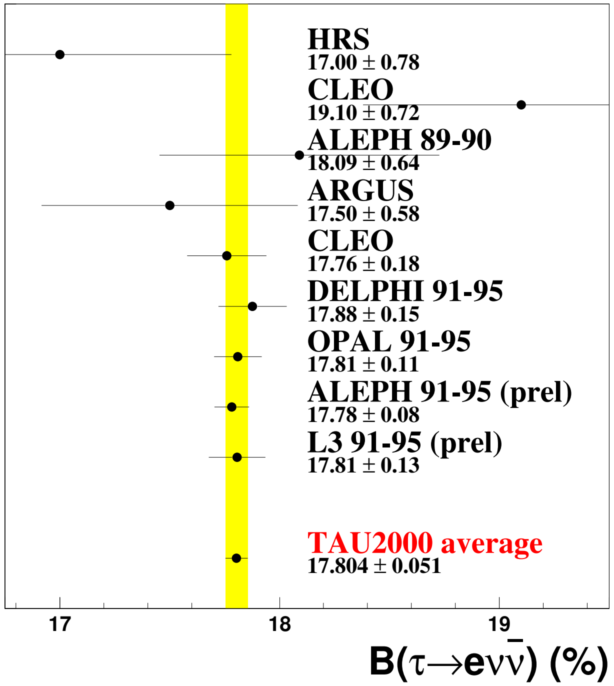
- Developed by Victoria with UBC
- Run by **Long**, **Sbarra**, **Vachon**
  (McPherson)
- Oncall during (and after) data taking

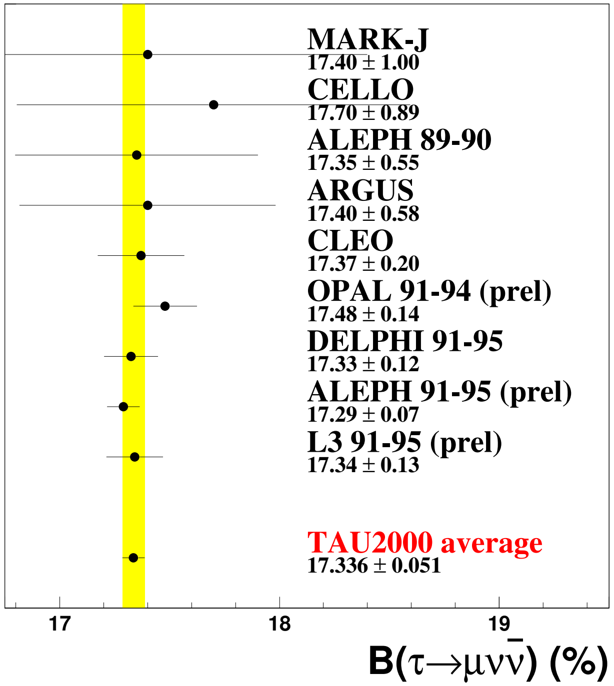


$\tau^- \longrightarrow \ell^- \bar{\nu}_\ell \nu_\tau$ Branching Ratios



$\Rightarrow \dfrac{g_\mu}{g_e}$





$\tau^- \longrightarrow \mu^-\bar{\nu}_\mu\nu_\tau$ Branching Ratio

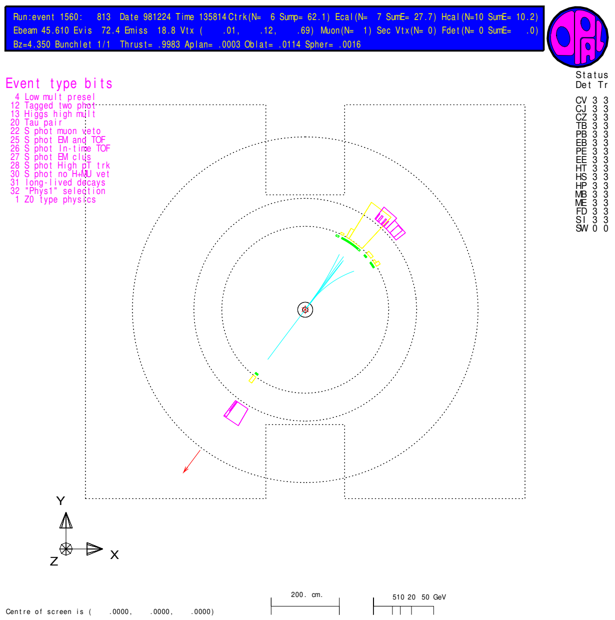
L. Stumpf *Ph.D. Research* **(Sobie)**

- OPAL Published 1990-1992: BR = (17.36 ± 0.27)%
- OPAL Prelim. 1991-1994: BR = (17.48 ± 0.14)%
- Best Published: BR = $(17.31 \pm 0.11 \pm 0.05)$%

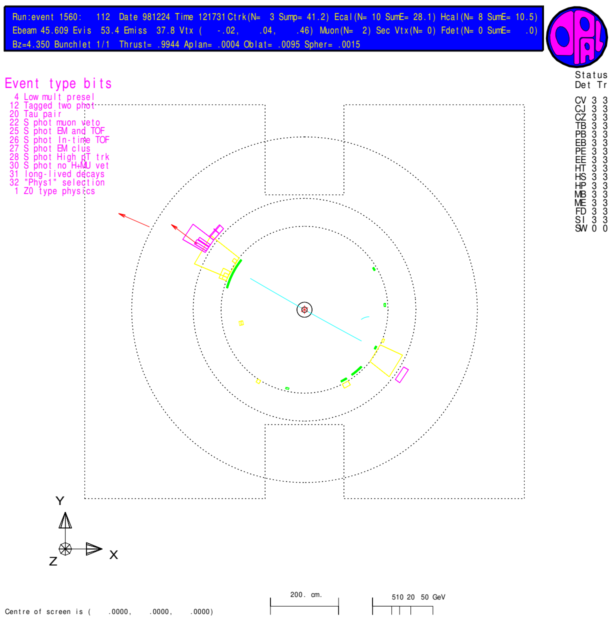
This work:

- Use full OPAL data sample
- Extended $\cos\theta$ coverage
- Goal: ± 0.09% (stat), ± 0.12%(total)

Signal ($\tau^- \longrightarrow \mu^-\bar{\nu}_\mu\nu_\tau$)



Background ($\tau^- \longrightarrow \rho^-\nu_\tau$)



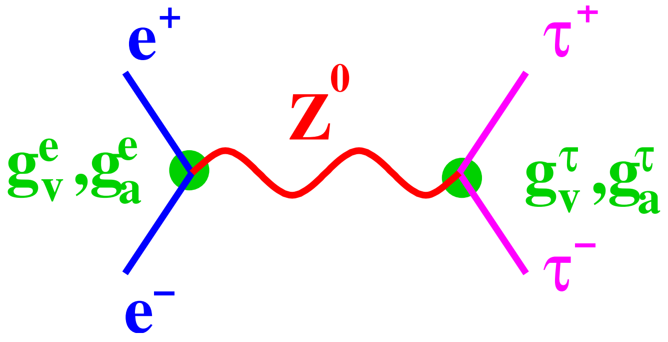
Preliminary results:

$$B(\tau^- \rightarrow \mu^-\bar{\nu}_\mu\nu_\tau) = (17.39 \pm 0.09_{\mathrm{stat}})\%$$

$$g_\mu/g_e = 1.002 \pm 0.005$$

$e^+e^-Z^0 \longrightarrow \tau^+\tau^-$ Asymmetries

K. Graham *Ph.D. Research* **(Roney)**

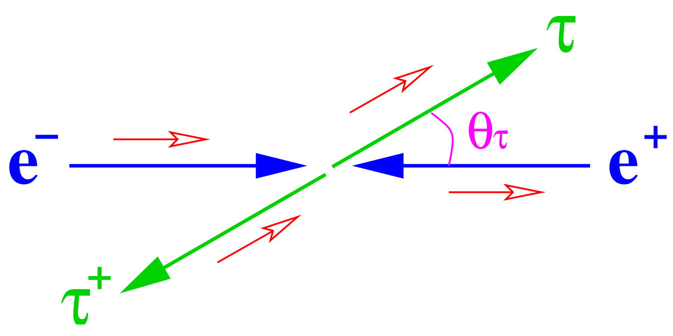


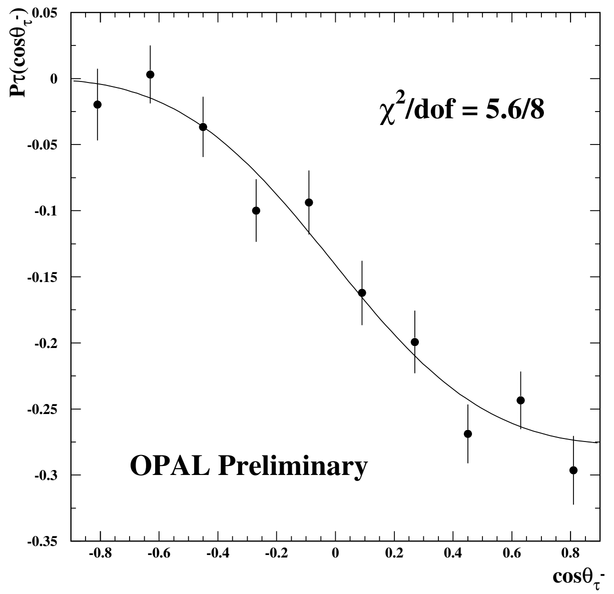
Measure: $\frac{d\sigma_+}{d\cos\theta_{\tau^-}}, \frac{d\sigma_-}{d\cos\theta_{\tau^-}}, P_\tau(\cos\theta_{\tau^-})$

Extract: $< P_\tau >, \mathrm{A_{FB}}, \mathrm{A^{FB}_{pol}}$

And then: $\mathrm{A}_\tau, \mathrm{A_e}$

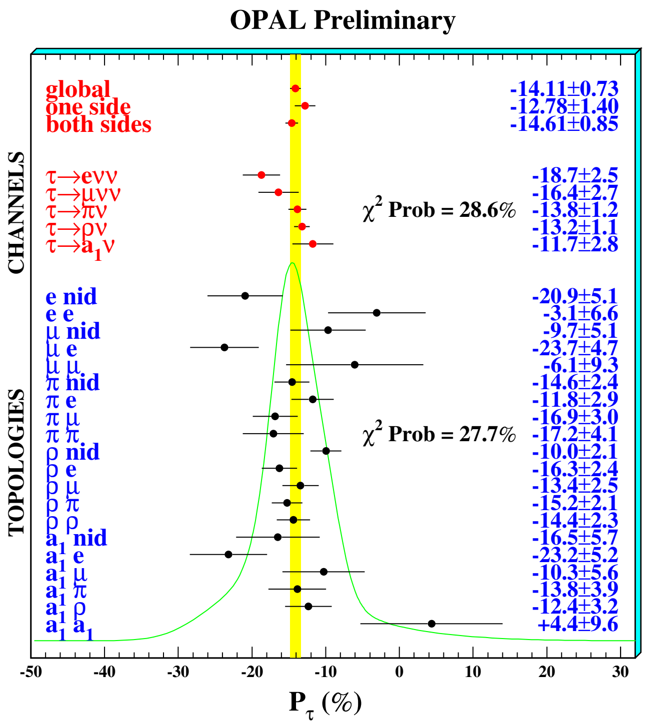
$\Rightarrow$ **Lepton Universality Test,** $\sin^2\theta^{lept}_{\mathrm{eff}}$

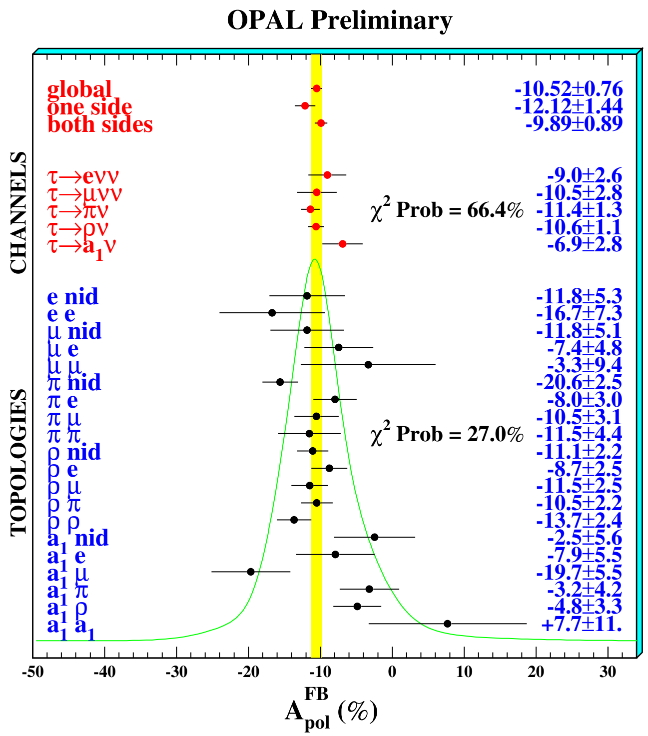




$Z^0 \longrightarrow \tau^+\tau^-$ Asymmetries

Do all channel combinations, correct for correlations:





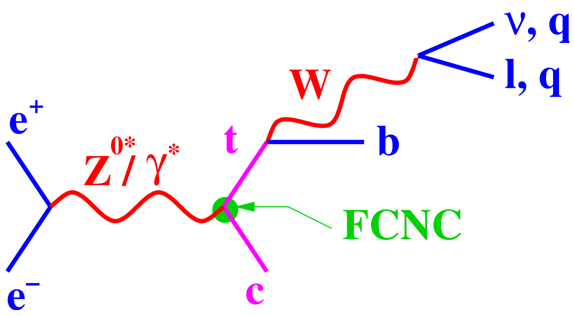
$$\mathcal{A}_\tau = \mathbf{0.1446 \pm 0.0075 \pm 0.0057}, \; \mathrm{A_e} = \mathbf{0.1456 \pm 0.0103 \pm 0.0034}$$

$$\sin^2 \theta^{lept}_{\mathrm{eff}} = \mathbf{0.23170 \pm 0.00089}$$

(LEP best τ Asymmetry measurements)

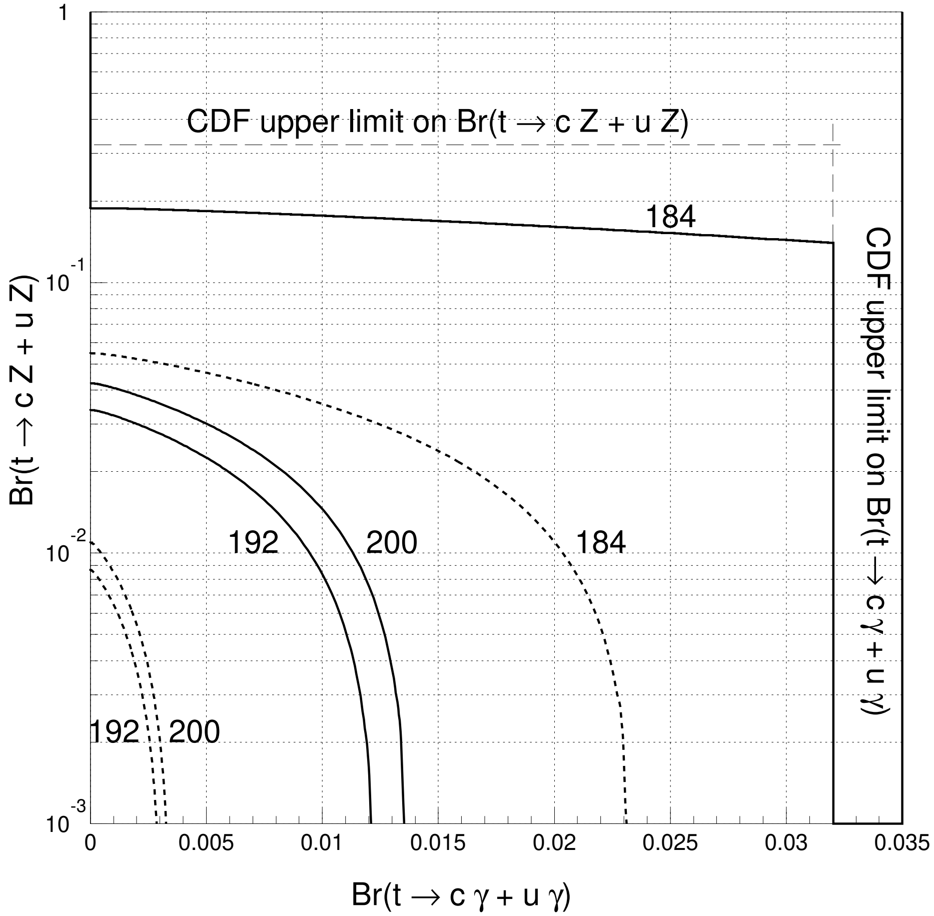
FCNC: Single Top

R. Kowalewski



- Soft c-quark jet
- b-tag
- Hadronic or leptonic W-decay

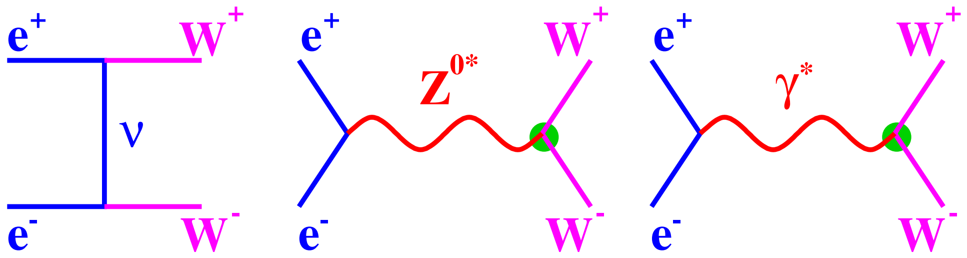
Exclude: $\sigma(\mathrm{tc}) >\sim$ 0.3 pb^{-1}



⇒ Strong Constraints when LEP combines all $\sqrt{s}$ points

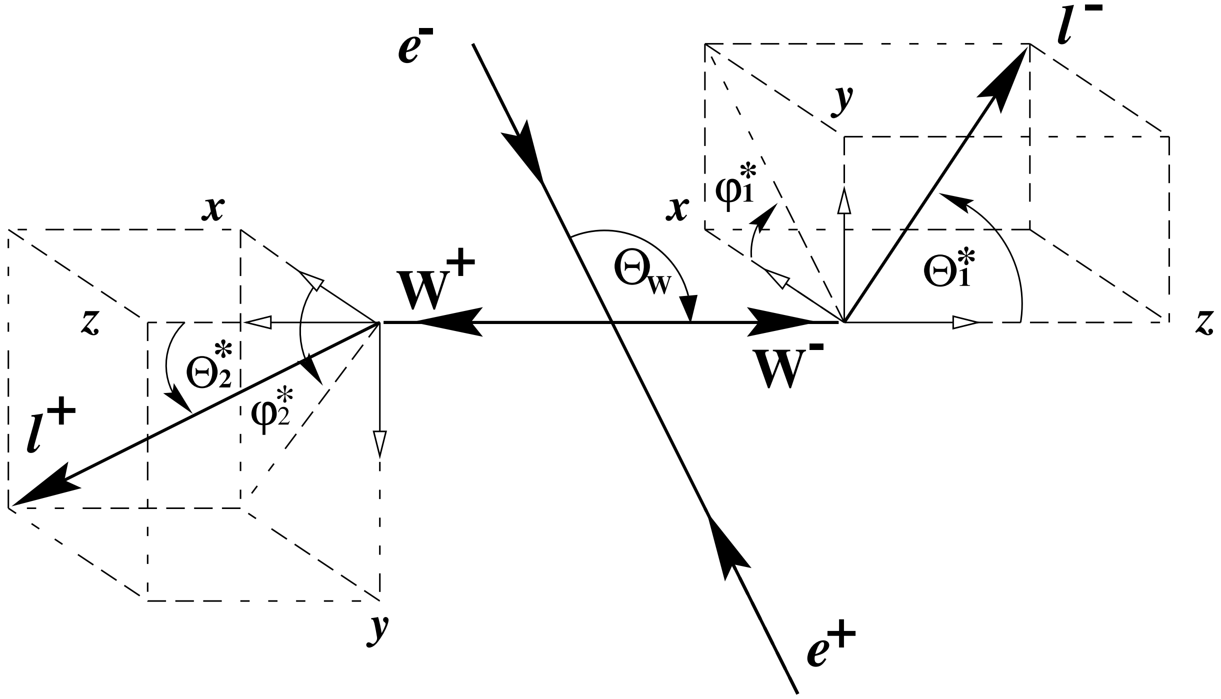
Triple Gauge Couplings

C. Sbarra, I. Bailey (Keeler)



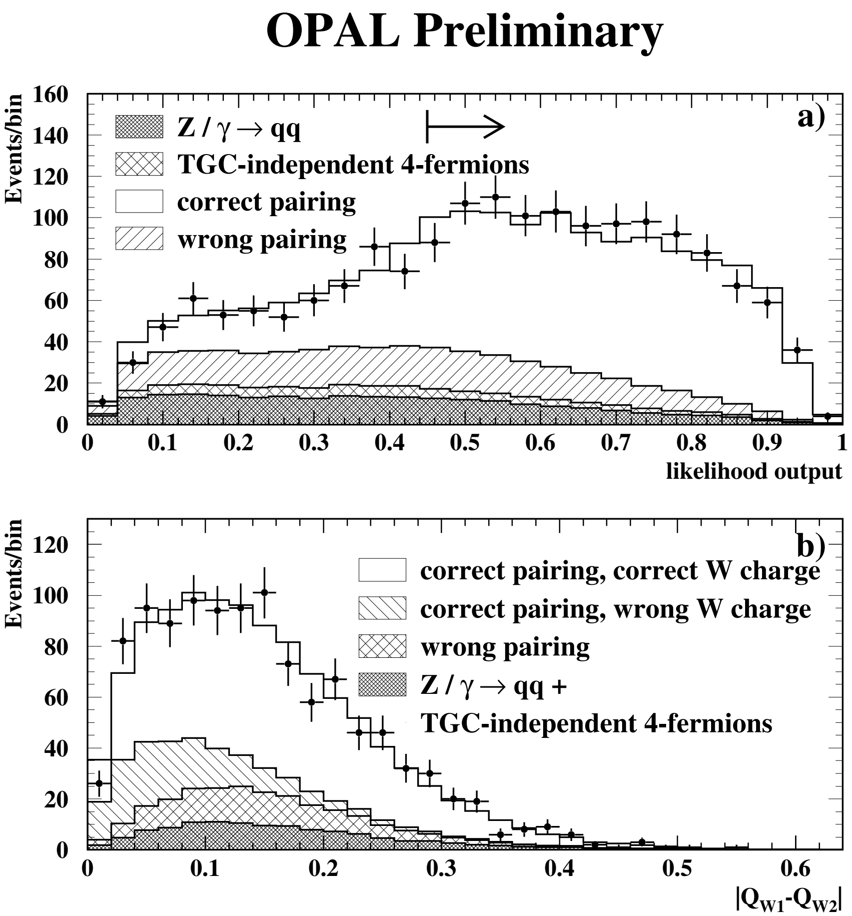
Sensitive variables:

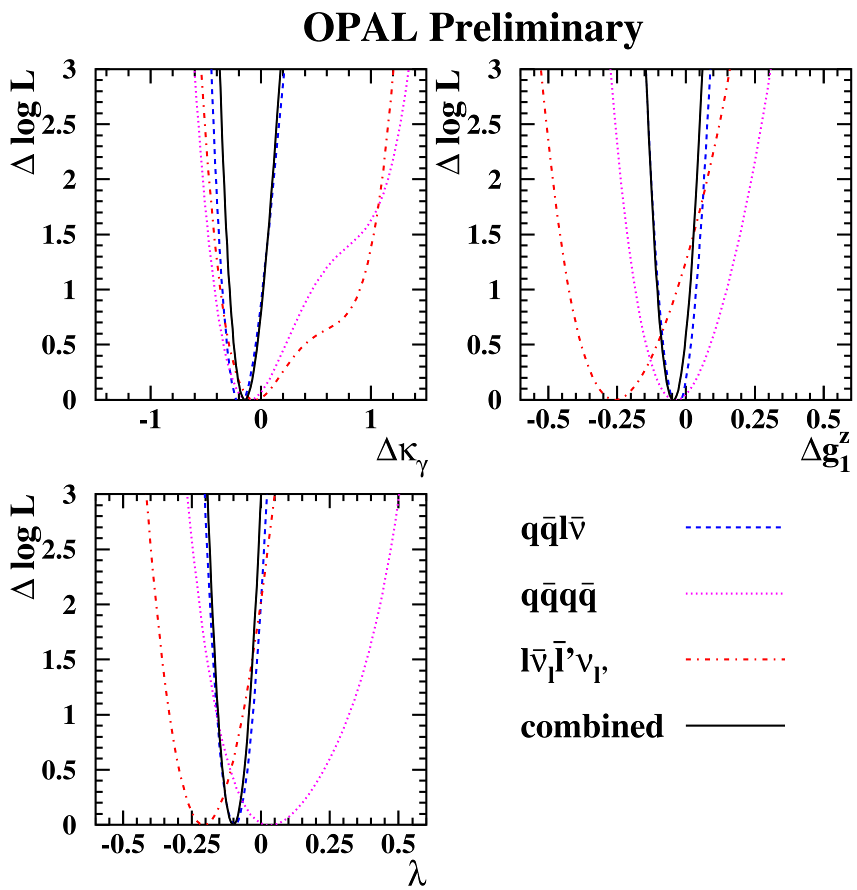
- Total $\mathrm{e^+e^-} \rightarrow \mathrm{W^+W^-}$ cross-section
- Angular distributions



- “Easy” : $\mathrm{W^+W^-} \rightarrow \mathrm{q\bar{q}}\ell^\pm\nu$
- But also : $\mathrm{W^+W^-} \rightarrow \mathrm{q\bar{q}q\bar{q}}$?

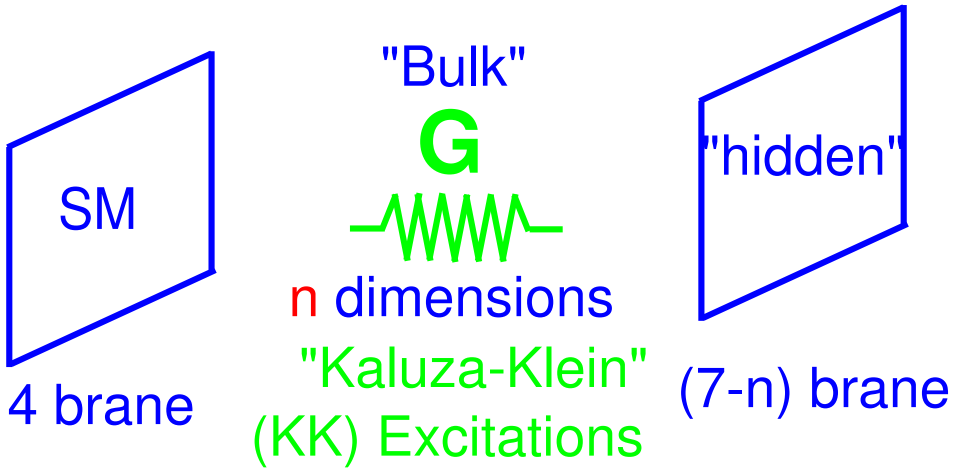
TGC's from $W^+W^- \longrightarrow q\bar{q}q\bar{q}$



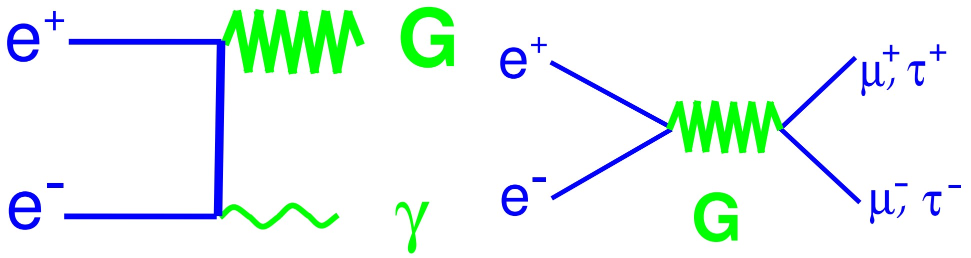


$\gamma + \not{E}_T$ *eg.* Low scale gravity

<u>Overall Picture</u>



<u>Can affect Measurable Phenomena</u>



<u>WHY??</u>

- Gravity "diluted"
  $\Rightarrow$ "M_{planck}"$= M_D = M_{\mathrm{EW}}$
- No hierarchy problem

$$M_{Pl}^2 = R^n \times {M_D}^{n+2}$$

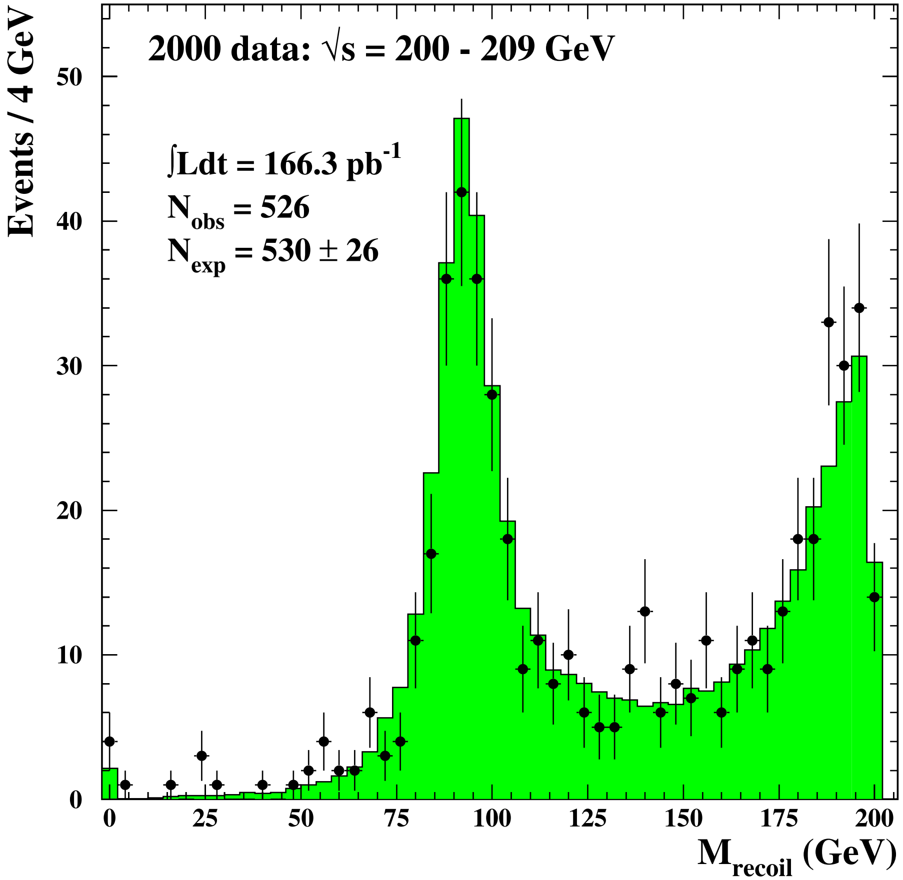
R : Extra dim. Compactification Radius

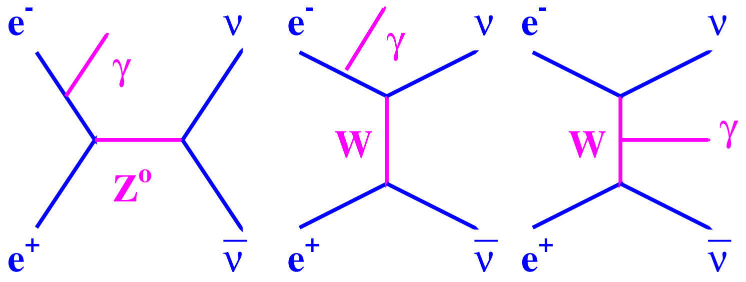
n : Number of large dim., $1 < R < 7$

n	R	Possible?
1	10^{13} cm	Excluded
2	1 mm	Not excluded!!
7	1 fm	Not excluded

$e^+e^- \longrightarrow \nu\bar{\nu}\gamma$

G. Long (Honma, McPherson)





OPAL 189 GeV

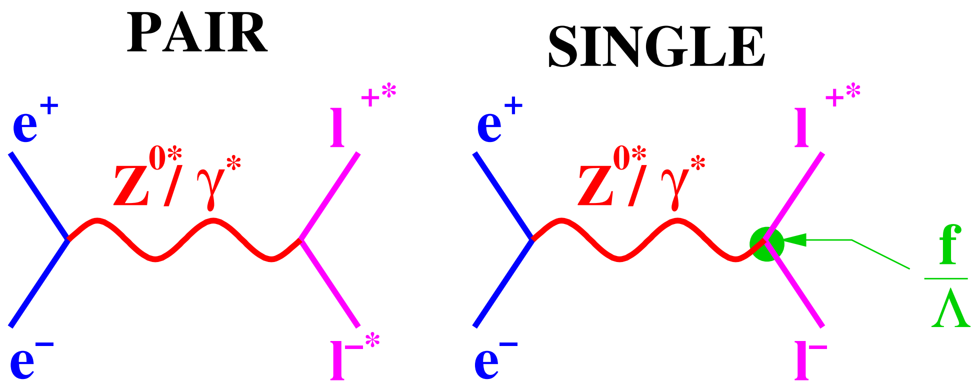
n	M_D Lower Limit (GeV) 95%C.L.
2	1086
3	862
4	710
5	605
6	528
7	470

Also used for: $e^+e^- \longrightarrow \gamma\tilde{G}$, $\tilde{\chi}_2^0\tilde{\chi}_1^0 \longrightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0\gamma$, $\nu^*\nu \longrightarrow \nu\nu\gamma$, SM $\nu\nu\gamma$ cross-section

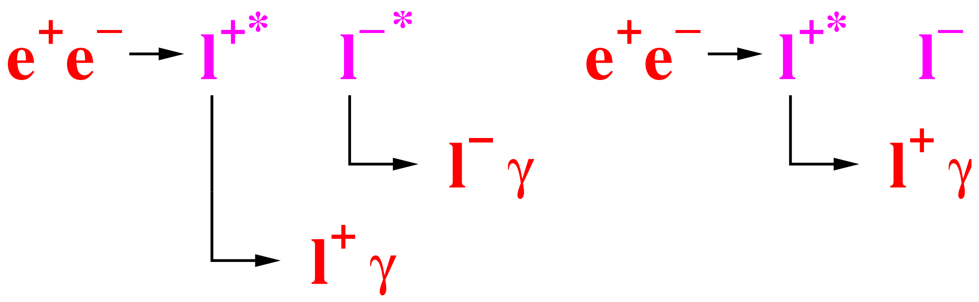
$\ell^+\ell^-\gamma$ *eg.* Excited Lepton Searches

B. Vachon *Ph.D.* Research (McPherson)

Compositeness Models $\Rightarrow$ q^*, ℓ^*



Experimentally:

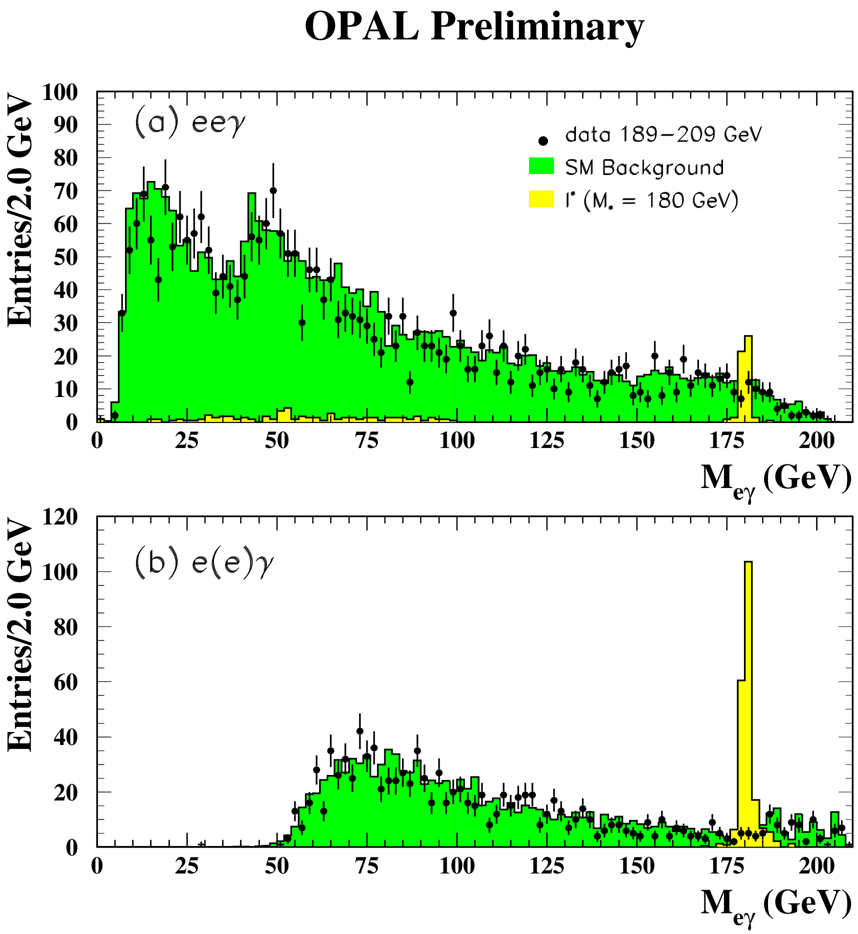


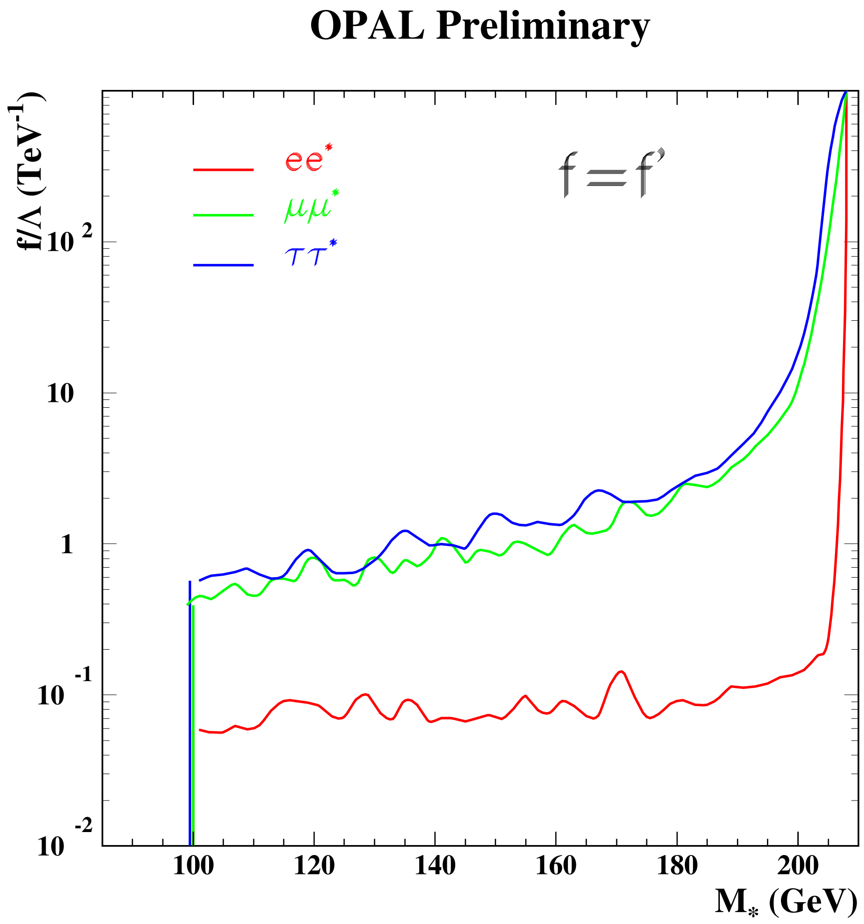
- General section of events with leptons and photons
- Looks for $\ell - \gamma$ mass peaks
- Kinematic fits $\Rightarrow$ $M_{\ell\gamma}$ Resolutions

  e,μ: $\sigma(M_{\ell\gamma}) \sim$ 0.3 GeV

  τ: $\sigma(M_{\ell\gamma}) \sim$ 1 GeV

$\ell^*\ell \longrightarrow \ell^+\ell^-\gamma$





$\Rightarrow$ Can use same selections for $Z^0 - \gamma$ coupling constraints, Quartic Gauge Couplings, ...

SUSY Searches: *eg.* GMSB

- SUSY breaking mechanism unknown:
- Assume mediation method:

Hidden

~~**SUSY**~~

$\sqrt{F} \sim \sqrt{\frac{M}{G_F^{1/2}}}$

M

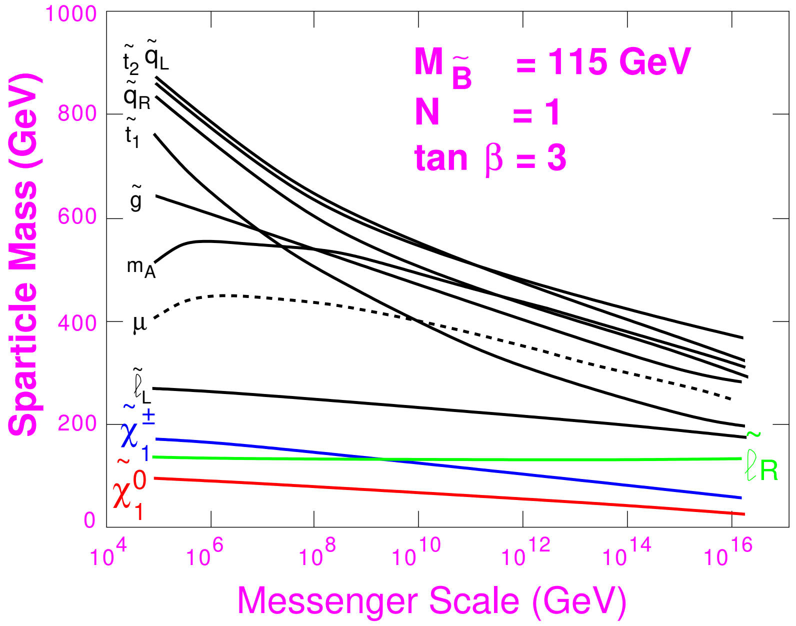
Visible

$e, \mu, \tau, \ldots, W^{\pm}, Z^0$

$\tilde{e}, \tilde{\mu}, \tilde{\tau}, \ldots, \tilde{\chi}^{\pm}, \tilde{\chi}^0$

Gravity	Gauge
$M \sim M_P \sim 10^{18}$ GeV	$10^3 < M < 10^{15}$ GeV
$\sqrt{F} \sim 10^{11}$ GeV	$10^3 < \sqrt{F} < 10^{10}$ GeV
But: FCNC	**No FCNC**
	Spectrum: $\Lambda = k\frac{F}{M}$
$M_{\tilde{G}} \sim 2.5$ TeV	$M_{\tilde{G}} < 1$ GeV $\Rightarrow$ LSP

Example GMSB mass spectra
(Dimopoulos *et al.*, hep-ph/9609434):



NLSP

$\tilde{\chi}_1^0 \to \gamma \tilde{G}$

$\tilde{\ell}_R^{\pm} \to \ell^{\pm} \tilde{G}$

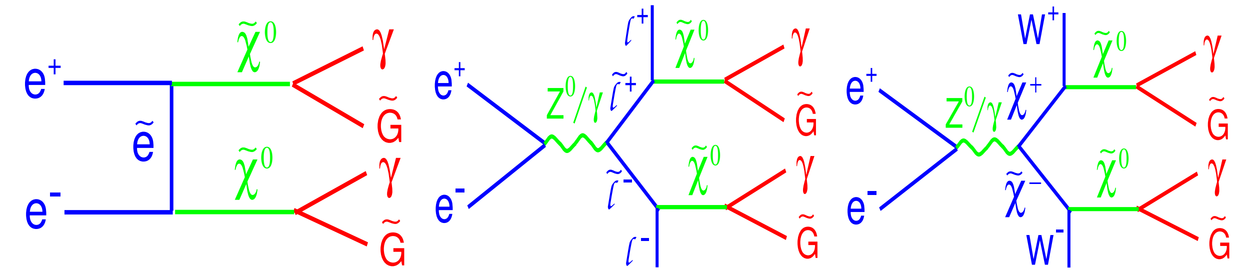
NLSP $c\tau =$

1 μm–10^{11} km

Minimal Model: $F,\ \Lambda,\ M,\ N,\ \tan\beta$ and $\mathrm{sign}(\mu)$

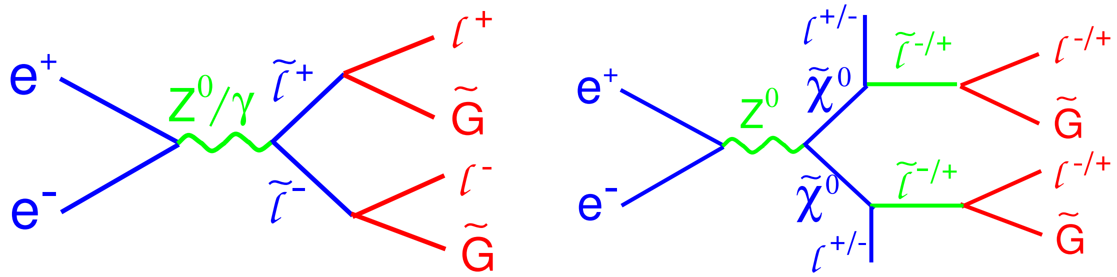
GMSB Searches

$\tilde{\chi}_1^0$ NLSP



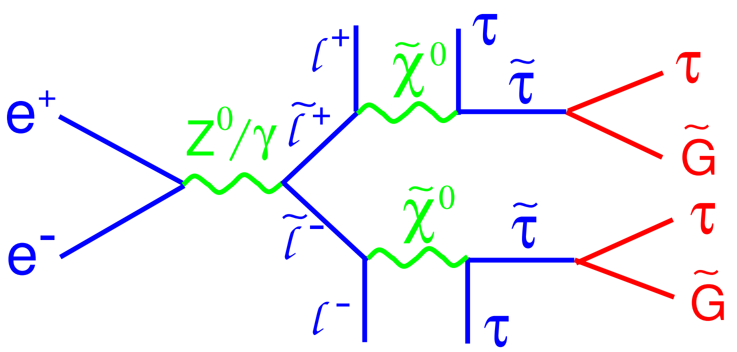
$c\tau \sim 0:$	$\gamma\gamma + \not\!\!E_T$	$\ell^+\ell^-\gamma\gamma + \not\!\!E_T$	$\gamma\gamma + \mathrm{jets}/\ell^\pm + \not\!\!E_T$
$0 < c\tau < \infty:$	$\gamma + \not\!\!E_T$	$\ell^+\ell^-\gamma + \not\!\!E_T$	$\gamma + \mathrm{jets}/\ell^\pm + \not\!\!E_T$
$c\tau \sim \infty:$	$\not\!\!E_T$	$\ell^+\ell^- + \not\!\!E_T$	$\mathrm{jets}/\ell^\pm + \not\!\!E_T$

$\tilde{\ell}^\pm$ NLSP



$c\tau \sim 0:$	$\ell^+\ell^- + \not\!\!E_T$	$4 \times \ell^\pm + \not\!\!E_T$
$0 < c\tau < \infty:$	$2 \times$ Kinked Tracks	$2 \times \ell^\pm + 2 \times$ Kinked Tracks
$c\tau \sim \infty:$	$2 \times$ Stable Charged	$2 \times \ell^\pm + 2 \times$ Stable Charged

$\tilde{\tau}^\pm$ NLSP ($\tan\beta > 10$)

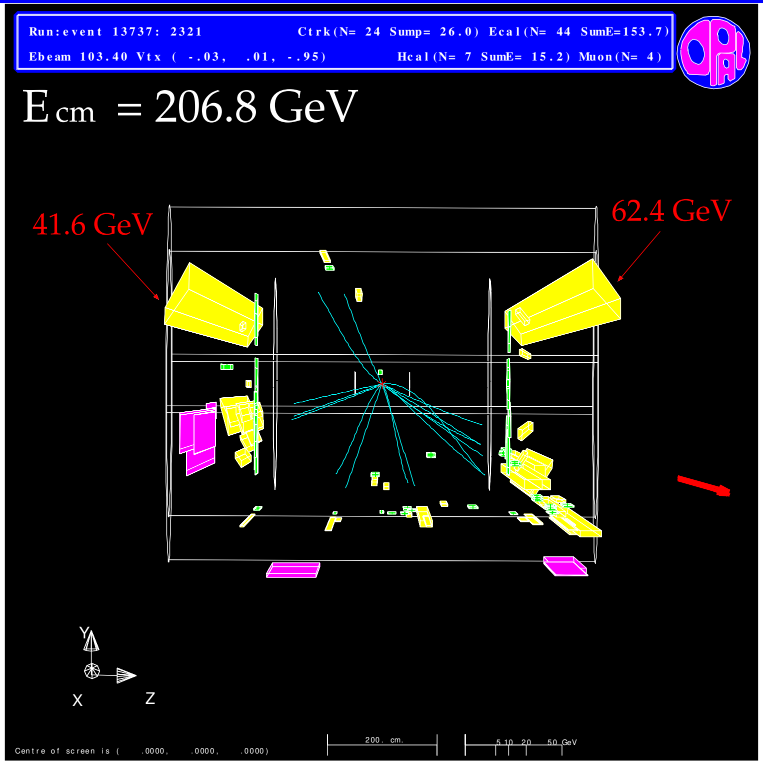


$c\tau \sim 0:$	$\tau^\pm\tau^\pm + (\ell^\pm\tau^\mp\ell^\pm\tau^\mp)$
$0 < c\tau < \infty:$	Kinked Tracks $+ (\ell^\pm\tau^\mp\ell^\pm\tau^\mp)$
$c\tau \sim \infty:$	Stable Charged $+ (\ell^\pm\tau^\mp\ell^\pm\tau^\mp)$

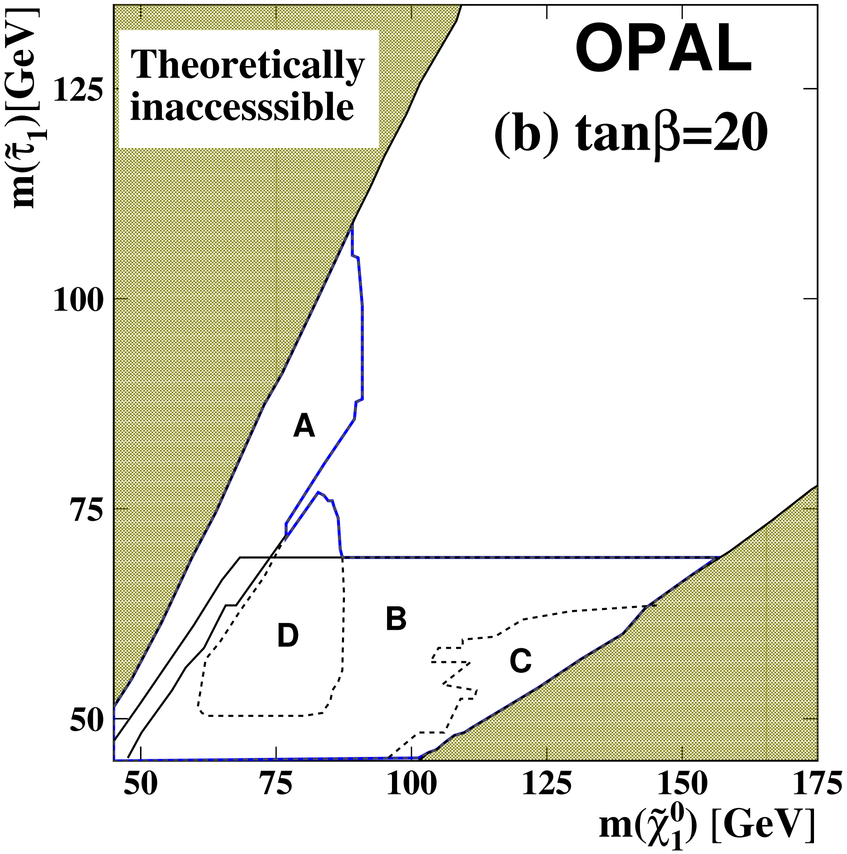
SUSY Search Results: $X + \gamma(\gamma) + \not{E}_T$

N. Kanaya, ***Ph.D.*** **Research (McPherson)**

Channel	$1\,\gamma$		$2\,\gamma$	
OPAL Y2K	Bkg	Data	Bkg	Data
Low Mult	12.9	13	2.2	1
High Mult	22.6	30	7.3	12



Limits on Model Parameters

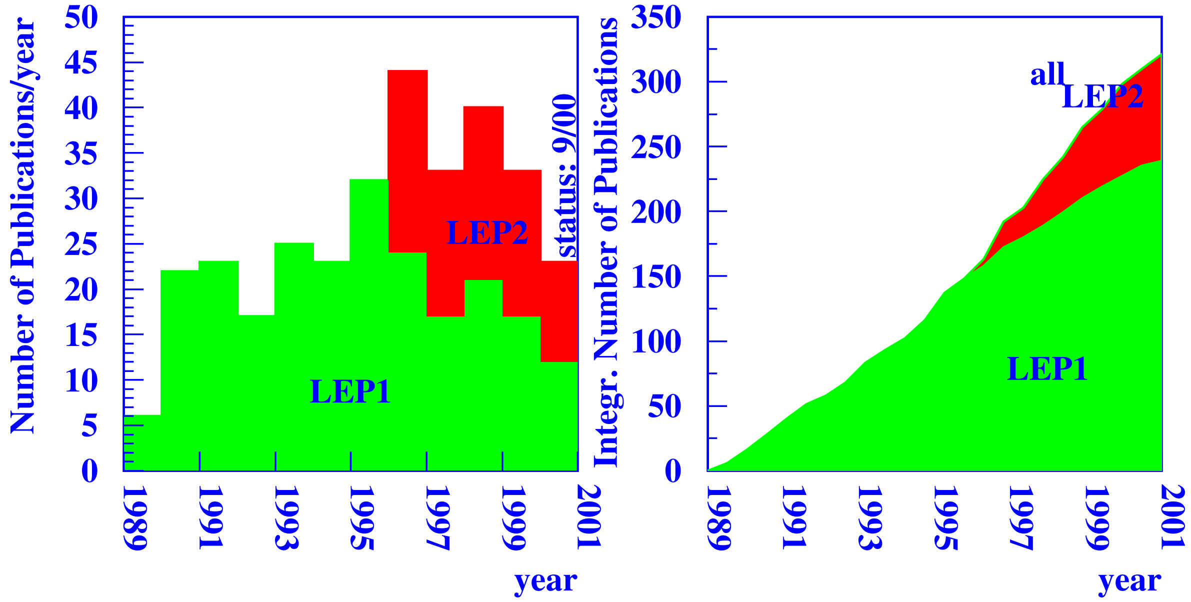


Future Plans

Running and data processing:

- Y2K Run extended to 2 November
- Dismantling currently scheduled to start 8 November
- If *a good chance of transforming a significant signal of new physics into a discovery*

  2001 Run?? (contingency under consideration)
- **Y2K data reprocessing: until $\sim$ June 2001**



- Still new LEP1 results 5 years after end of data taking
- Expect first “final” OPAL LEP2 papers $\sim$ summer 2001
- Precision LEP2 measurements?

  Some OPAL papers $\sim$ summer 2002

  Many $\sim$ summer 2003
- LEP combined final results

  Higgs, SUSY, other searches by 2002

  M_{W}, TGC’s, *etc.* in 2003 (maybe later)
- OPAL has *more than half* of our LEP2 data set still to be analyzed in many channels!

  Best LEP physics is yet to come...