DELPHI

P. J. Holt

CERN
On behalf of the DELPHI Collaboration

LEP Jamboree

6 March 2003

Outline

- EW
  - $\sigma(WW)$ and $\sigma(ZZ)$
- QCD/$\gamma\gamma$
  - α_s from event shapes
  - Coherence
- B-physics (LEP I)
  - b branching fractions
  - b-hadron lifetimes
  - B_s^0 oscillations
- Higgs Searches
  - SM Higgs
  - Invisible Higgs
- SUSY/EXOTICA Searches
  - Resonant $\tilde{\nu}$ production
  - $\gamma + \not{E}$
- Unless stated
  - Limits 95% C.L.
  - Results to be published
  - y-axis: Number of event/bin

Status of EW Measurements

DRAFTS

σ(WW) σ(ZZ)

WWγ production

A_{FB}(b) inclusive A_{FB}(b) with leptons

PLANNED

W mass and Width Zγ^*

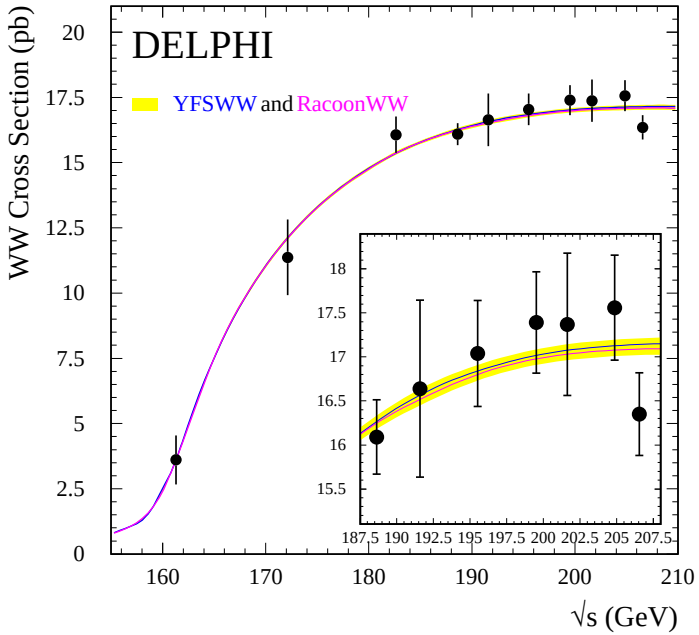
Single-boson production Spin Density Matrix

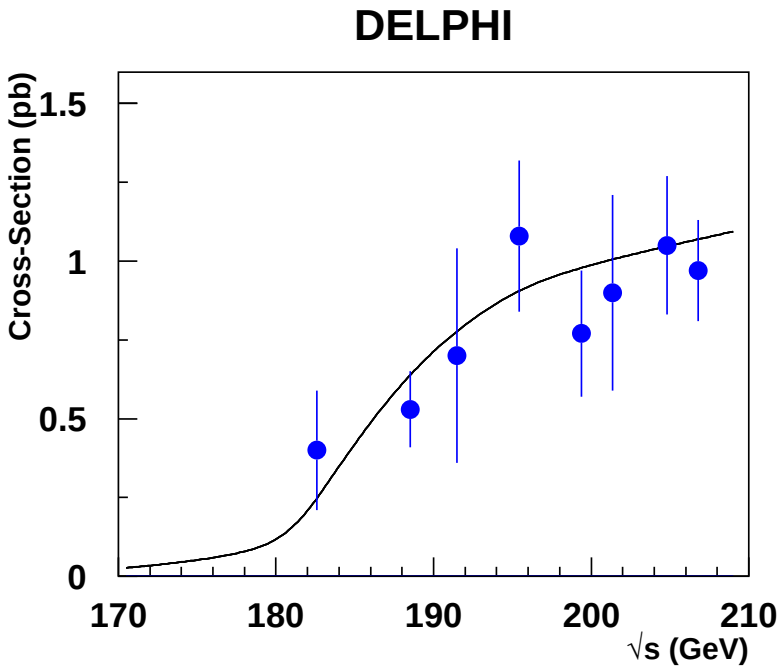
Charged TGCs Neutral TGCs

$f\bar{f}$ production at LEP II $\gamma\gamma$ production at LEP II

$Q\overline{Q}$ production at LEP II

WW/ZZ cross-sections





$$\mathcal{R}_{WW} = 1.001 \pm 0.012(stat) \pm 0.011(syst) \qquad \mathcal{R}_{ZZ} = 0.91 \pm 0.08(stat) \pm 0.02(syst)$$

$$\text{Average over energies } \mathcal{R} = \left\langle \frac{\sigma_{\text{measured}}}{\sigma_{\text{predicted}}} \right\rangle \text{ include correlations}$$

Status of QCD/$\gamma\gamma$ Measurements

PUBLISHED

Energy evolution of event shapes

DRAFTS

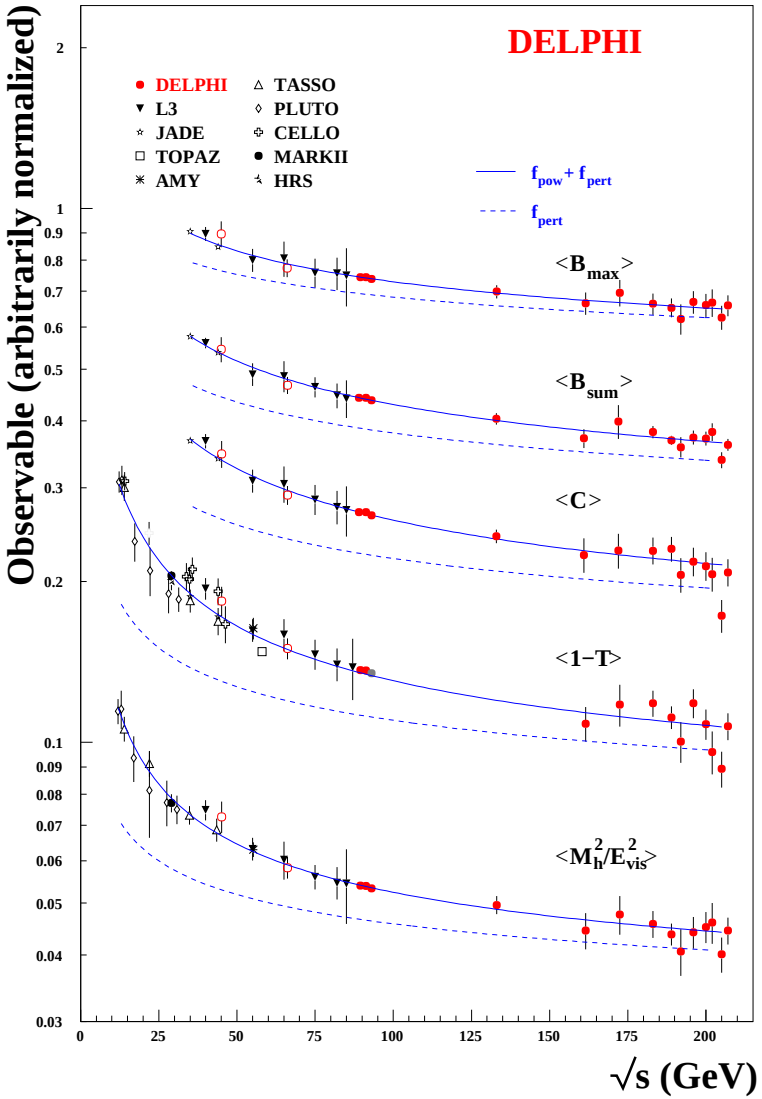
α_s from event shapes	f_1 production	$\Xi^{\pm}$ production
hadr. γ struct. func.	$\gamma\gamma \to J/\psi$	$\gamma\gamma \to \eta_c$

PLANNED

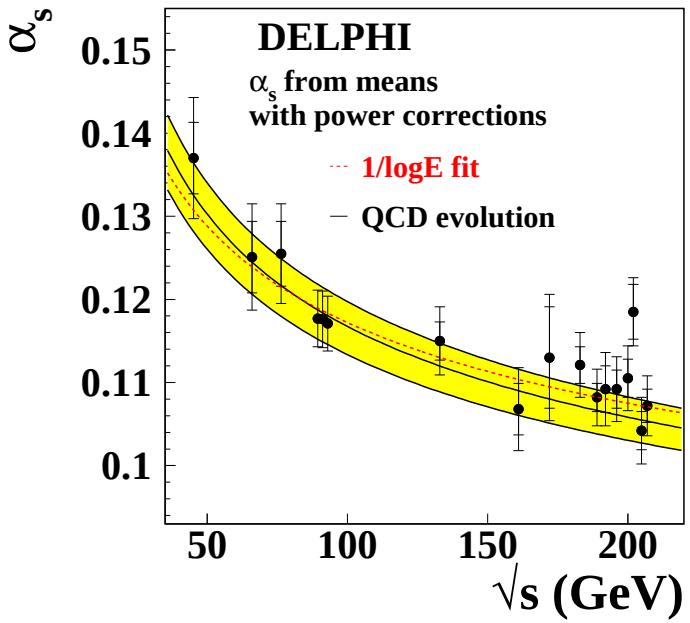
BEC in WW	Mult. in 3-jet events	Running m_b in 4-jet events
CR in WW	Charged part. mult. at 206 GeV	α_s in 4-jets events
Transverse radii in BEC	Mult. in b and light quark events	Angular distr. in 4-jet events
W hadronic decays	Fragm. functions and α_s	Soft photon excess in qq
Gluon fragm.	Running m_b	QCD overview paper
$\gamma\gamma$ σ(total)	$\gamma\gamma \to c\bar{c}/b\bar{b}$	$\gamma\gamma \to \eta_b$
no-tag high-p_t jets	$\gamma\gamma \to \pi\pi/KK$	$\gamma\gamma \to 4\pi$
double-tag σ	$\gamma\gamma \to p\overline{p}$	$\gamma\gamma \to KK\pi$
single-tag σ	$\gamma\gamma \to \rho\rho$	electron struct. func.

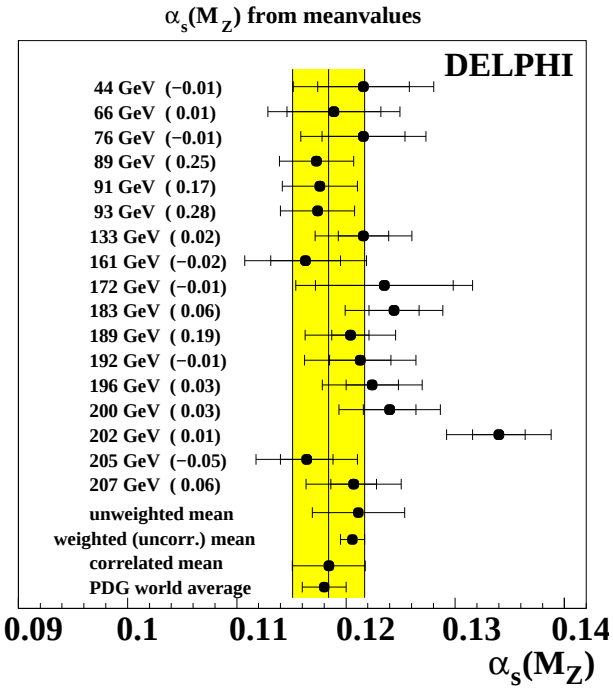
Determination of α_s

- Fit means of 5 event shapes including power corrections
  - Fit means vs $\sqrt{s}$ to obtain non-perturbative contribution to each event shape and $\alpha_s(s)$



Determination of α_s (II)





- Check running of $\alpha_s(s)$
  - Fit $b = \frac{d\alpha_s^{-1}}{d\log\sqrt{s}}$

    $b = 1.11 \pm 0.09(stat) \pm 0.19(syst)$

    [QCD(5 flavours) 1.27]

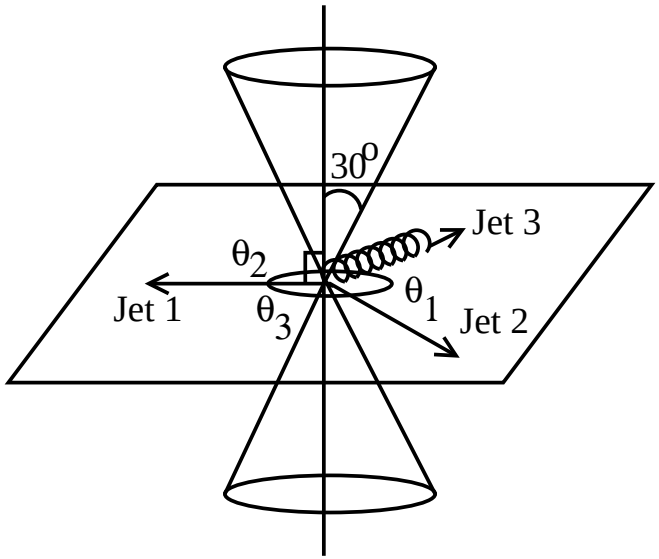
- Extrapolate all measurements to $\alpha_s(\mathrm{M_Z})$

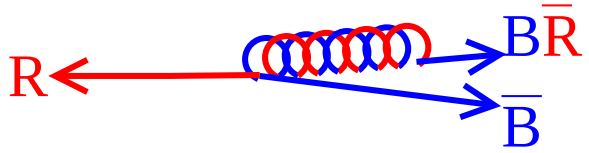
  $\alpha_s(\mathrm{M_Z}) = 0.1184 \pm 0.0004(stat) \pm 0.0033(syst)$

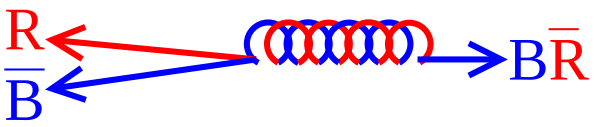
  - LEP II/LEP I weights similar
    LEP II smaller had. and scale errors
  - Scale uncertainty dominates

Coherence

NEW ANALYSIS





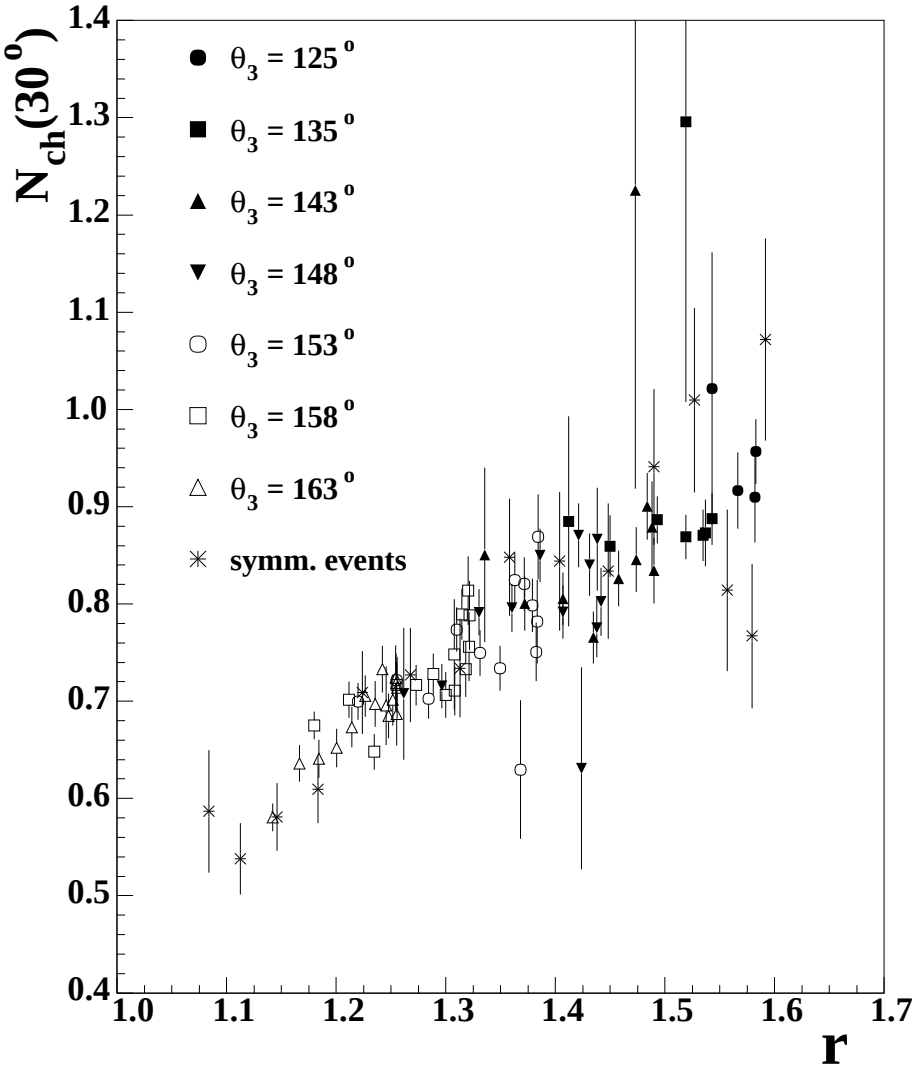


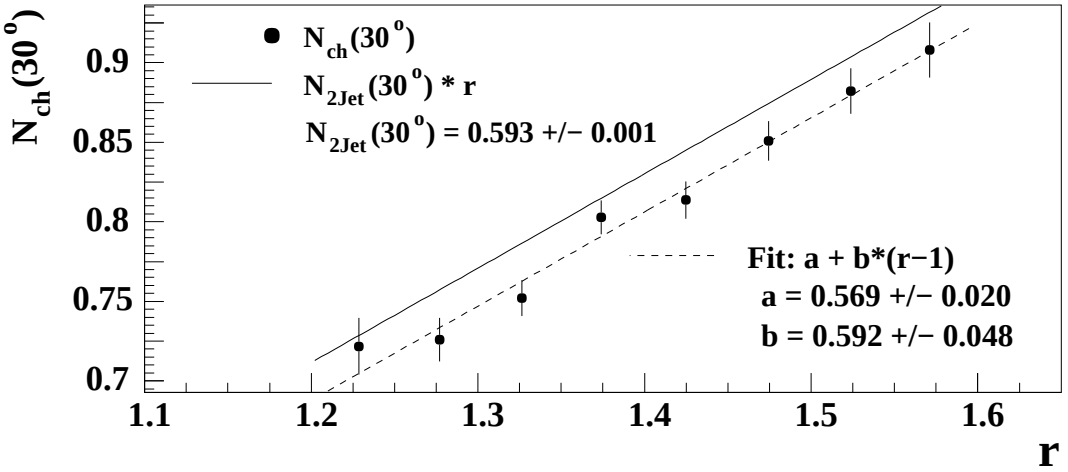
- Test coherence in different topologies of $q\bar{q}g$ events
- Use rate of production of hadrons at 90° to the plane of the $q\bar{q}g$ events
  - Measure $< N_{ch} >$/event in cone at 90°
- Prediction

$$\frac{< N_{ch}(3j) >}{< N_{ch}(2j) >} = r(\theta_2, \theta_3)$$

- 2 jet events
  Gluon soft and collinear
  $r = 1$
- Y-events:
  2 COLOUR – $\overline{\text{COLOUR}}$ sources
  $r = C_a/C_f$

Coherence (II)





- $< N_{ch} >$/event depends only on r
- Slope of $< N_{ch} >$/event vs r as expected

Status of Heavy Flavour Measurements

PUBLISHED

B_s osc. with incl. vertex $b \rightarrow$ wrong sign charm

DRAFTS

b branching fractions **B_s osc. with incl. $l/D_s l$**

B^0/B^+ **lifetimes** Λ_b form factor

B decays V_{cb}

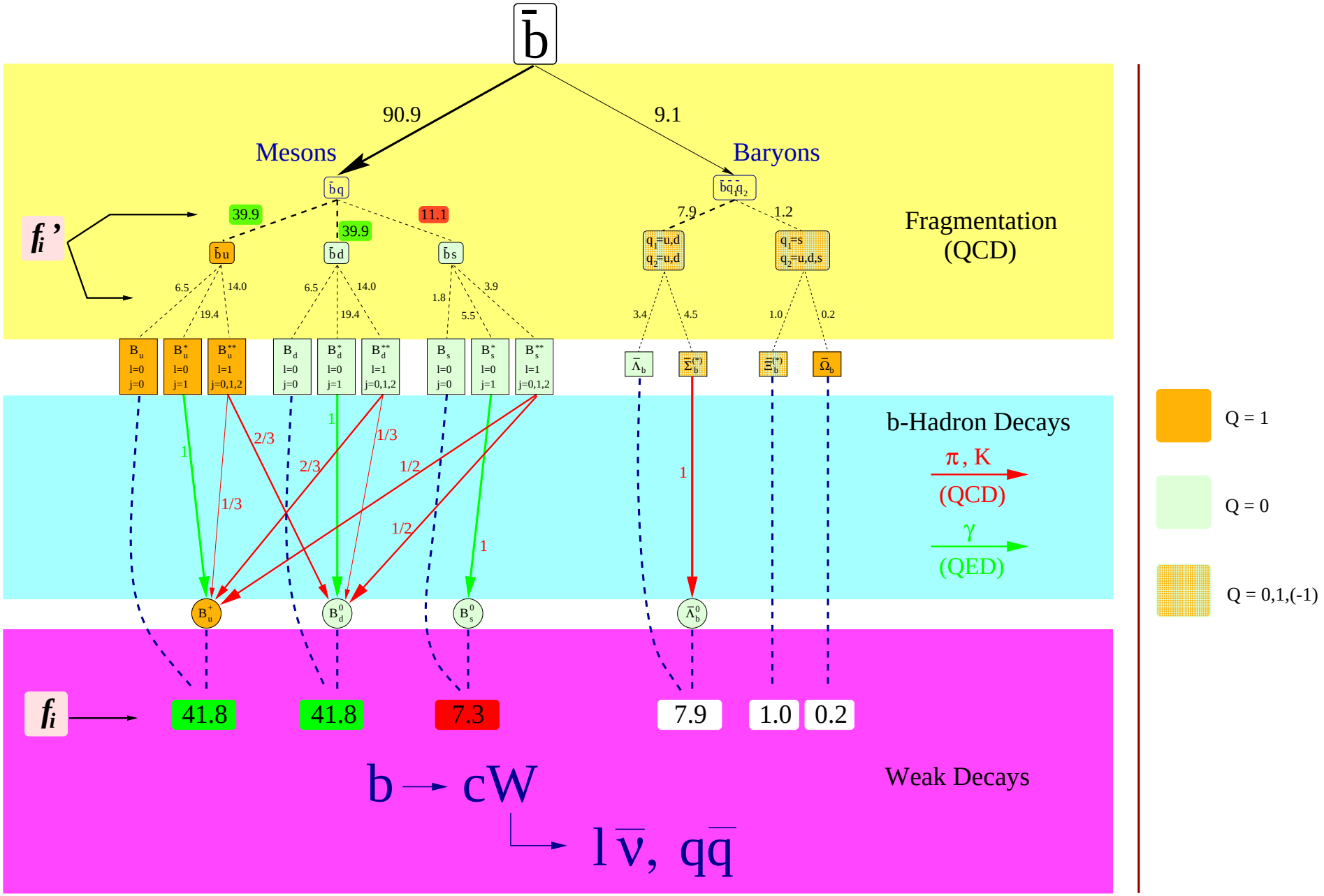
BR($\tau \rightarrow$ had) τ lifetime

$\gamma\gamma \rightarrow \tau^+\tau^-$

PLANNED

b fragmentation Moments analysis

$B^{*(*)}$ Ξ_c



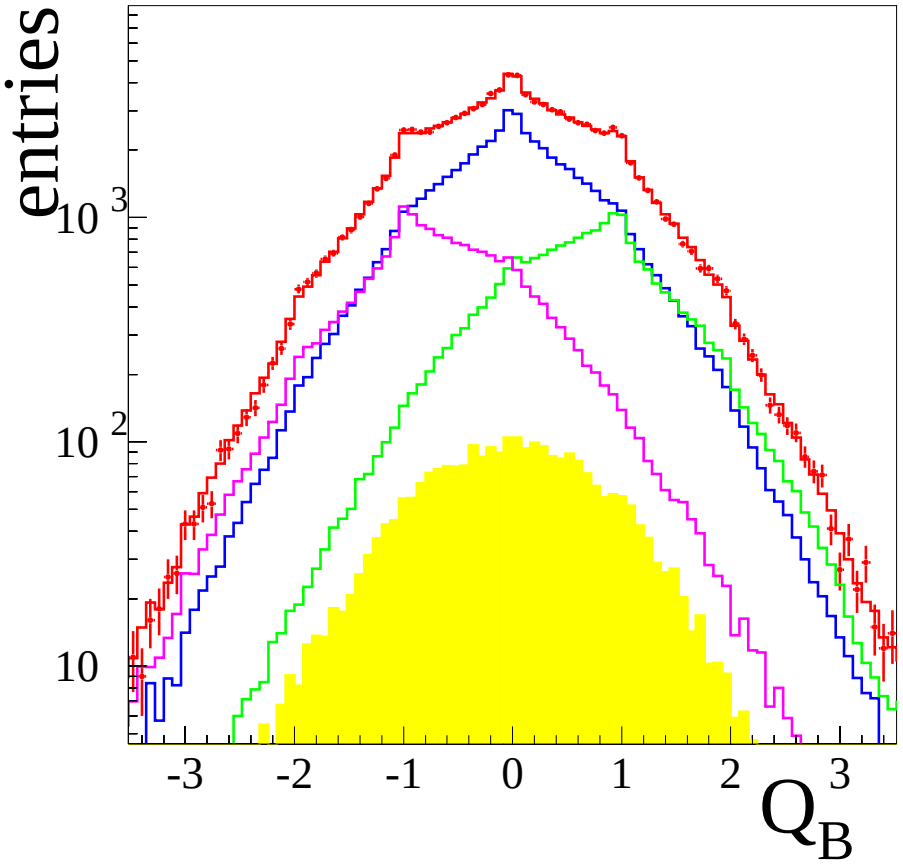
(numbers from simulation)

b branching fractions (II)

- First direct measurement of b fragmentation
  rates into weakly decaying charged and neutral b-hadrons
- Probability that a track comes from a b-decay given by a `Neural Net`
- Compute b hadron charge

$$Q_b = \sum_{hem} Q_i . P_b^i$$

- Calibrate Q_b distributions from data by comparing opposite hemispheres
  - Fraction of events with opposite sign Q_b



b branching fractions (III)

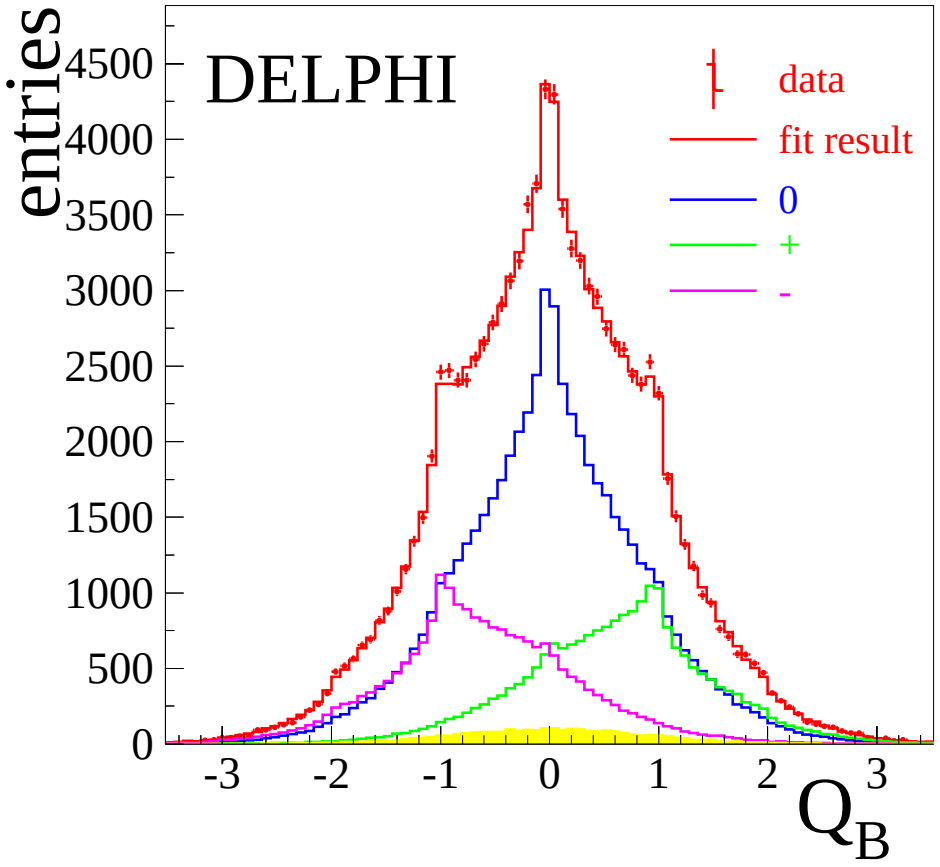
- Fit Q_b in data to expected shapes for charged and neutral b-hads.

  $f^+ = 42.06 \pm 0.81(stat.) \pm 0.91(syst.)\%$

- Subtract b-baryons

  $f_{B_u} = 40.96 \pm 0.81(stat.) \pm 1.14(syst.)\%$

- Dominant systematic comes from calibration of Q_b
- Single most precise measurement of f^+

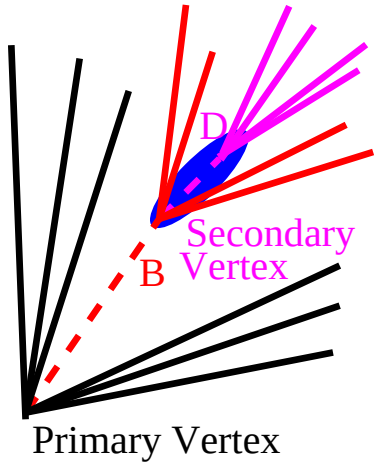


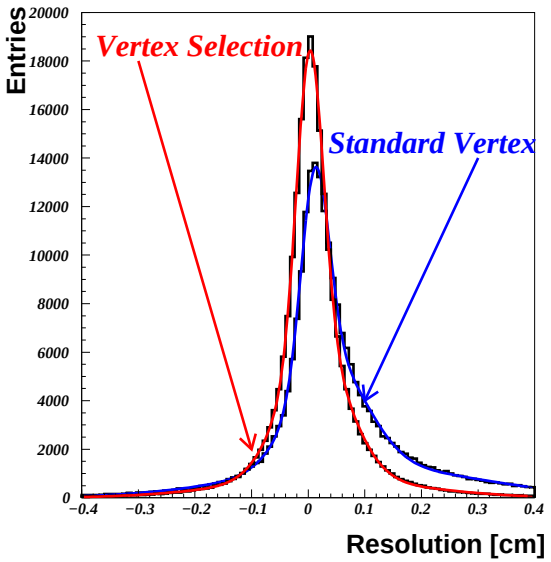
103285 b-hadron candidates

Precise b-hadron lifetimes

- Measure $< \tau_{b-\text{hadron}} >$ and τ_{B^+}, τ_{B^0}
- Reduce bias from cascade D decays
- `Neural Nets` used to
  - Order tracks from B decay/D decay for reconstruction of B vertex
  - Weight tracks from b decays/primary vertex
  - Estimate of the B hadron momentum
  - Select B^0 and B^+ events for τ fits
- Binned χ^2 fit to proper time distribution
- Weight events in MC for, *e.g.*
  - B_s^0 and B^+ fractions

  best model of hadronisation and decays





Precise b-hadron lifetimes (II)

- Reweight MC events for different lifetimes
  - don't need many samples with different lifetimes
- Results

$< \tau_b >$=1.568±0.005±0.009 [ps] (170k b)

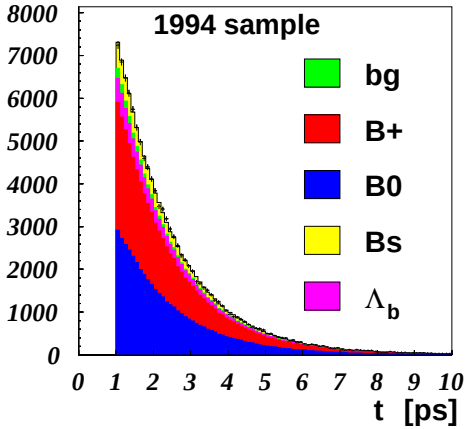
τ_{B^+}=1.625±0.013±0.017 [ps] (54k B^+)

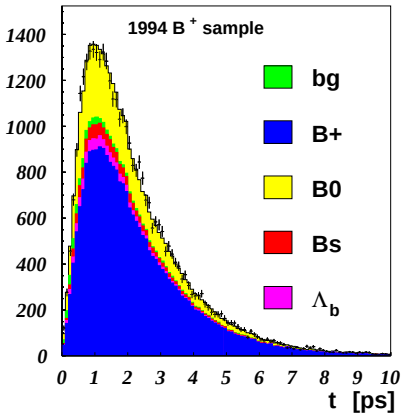
τ_{B^0}=1.543±0.020±0.033 [ps] (16k B^0)

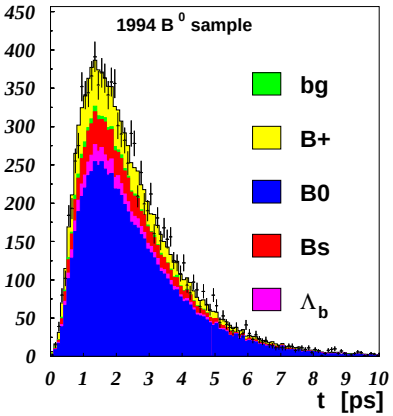
$\frac{\tau_{B^+}}{\tau_{B^0}}$=1.051±0.019±0.024

- Main sources of systematic errors
  - NN cuts to separate B^0/B^+
  - Detector resolution

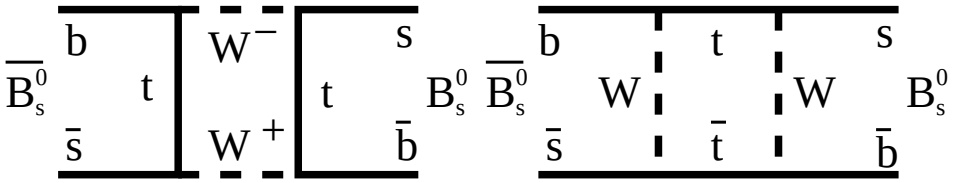
Preliminary





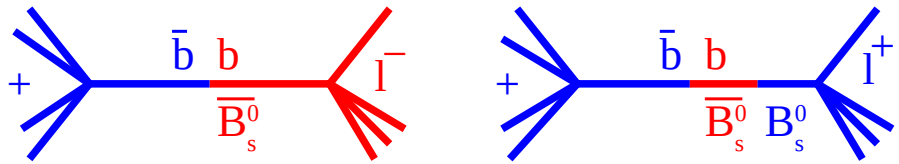


$B_s^0 - \overline{B_s^0}$ Oscillations



- Oscillation

$$\mathcal{P}^{\frac{unmix}{mix}} = \frac{1}{2\tau} e^{-\frac{1}{\tau}} \left[1 \pm \cos(\Delta m_s t)\right]$$



No Oscillation Oscillation

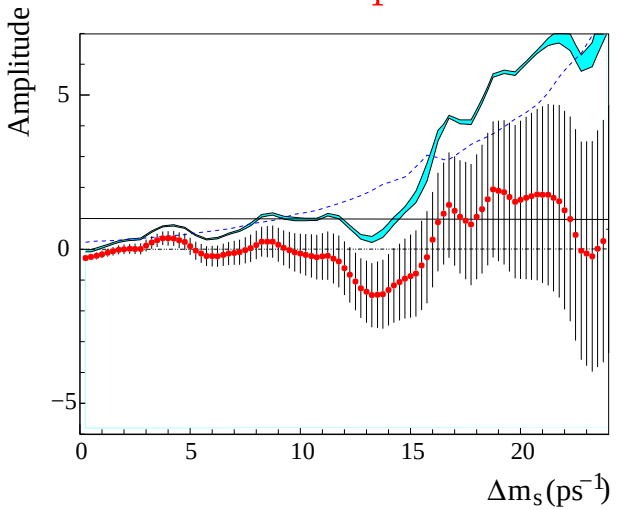
- Fit fractions of *like/unlike-sign* events vs t

- Inclusive leptons *New*
  - High statistics ($\sim 68k$ events)
  - Use NN to improve B_s^0 purity
- D_s-lepton *Update*
  - Exclusive reconstruction of the D_s
  - Low stats (~ 400 events)
  - High B_s^0 purity
- For rapid oscillations (large Δm_s) Need good control of t resolution
  - Separate events with good t resolution
  - Good decay length resolution
  - Good B_s^0 energy resolution

$B_s^0 - \overline{B_s^0}$ Oscillations (II)

- Fit using the *amplitude method*
- $\mathcal{P}^{\frac{unmix}{mix}} = \frac{1}{2\tau} e^{-\frac{1}{\tau}} [1 \pm \mathcal{A} \cos(\Delta m_s t)]$
- $\mathcal{A} = 1 \rightarrow$ mixing at Δm_s
- $\mathcal{A} = 0 \rightarrow$ no mixing at Δm_s

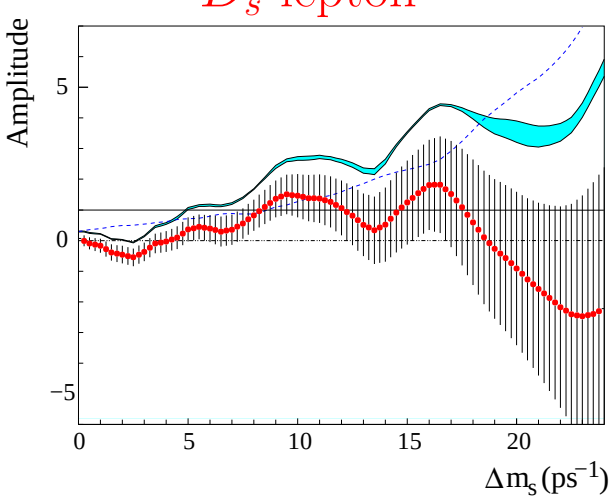
Inclusive leptons



$\Delta m_s > 8.0 \text{ps}^{-1}$

Sensitivity $\Delta m_s = 9.1 \text{ps}^{-1}$

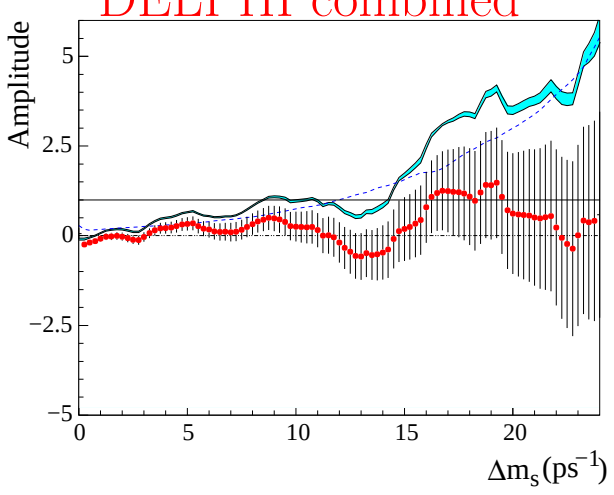
D_s-lepton



$\Delta m_s > 4.9 \text{ps}^{-1}$

Sensitivity $\Delta m_s = 8.6 \text{ps}^{-1}$

DELPHI combined



$\Delta m_s > 8.5 \text{ps}^{-1}$

Sensitivity $\Delta m_s = 12.0 \text{ps}^{-1}$

Status of Higgs Searches

DRAFTS

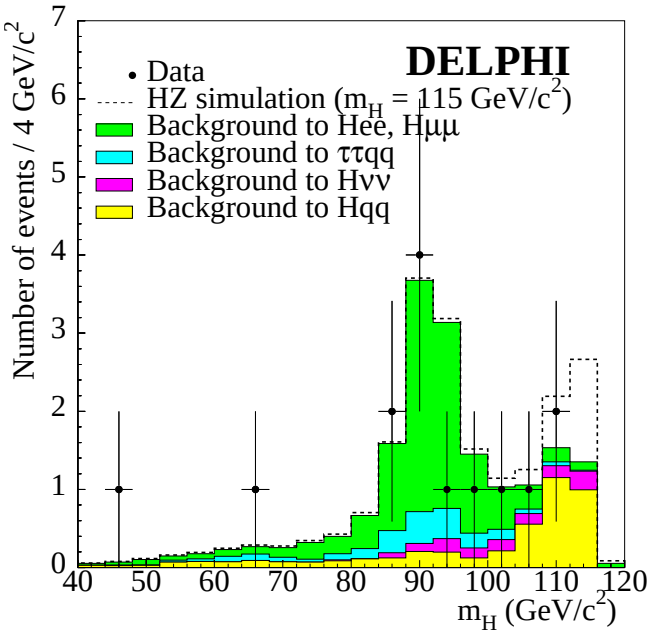
SM+MSSM Neutral Higgs **Invisible Higgs**

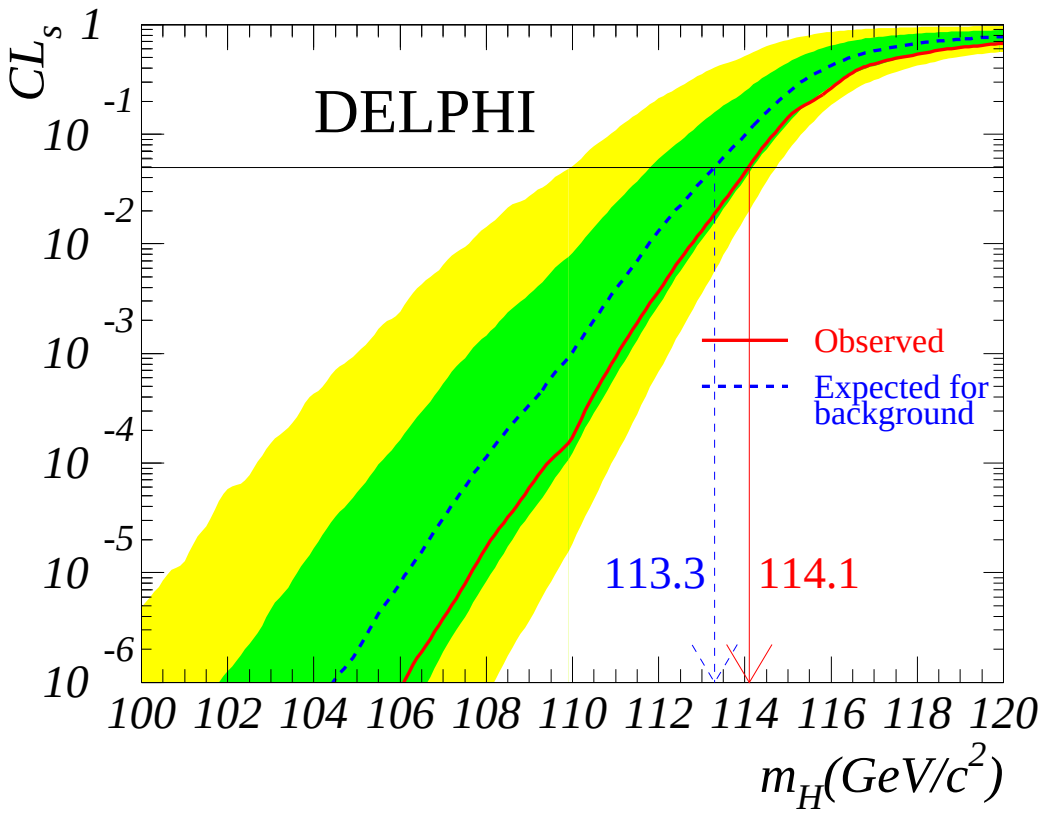
Charged Higgs 2HDM Extended Models

PLANNED

Extensions to the MSSM Neutral Higgs Searches

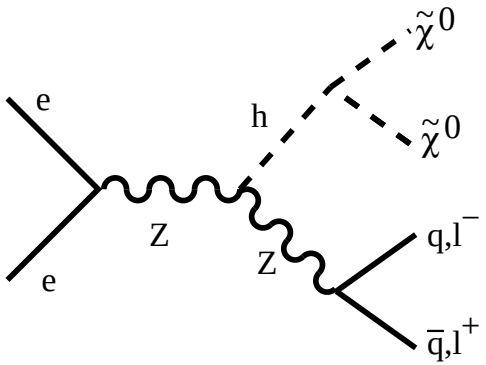
$\mathcal{SM}$ Higgs



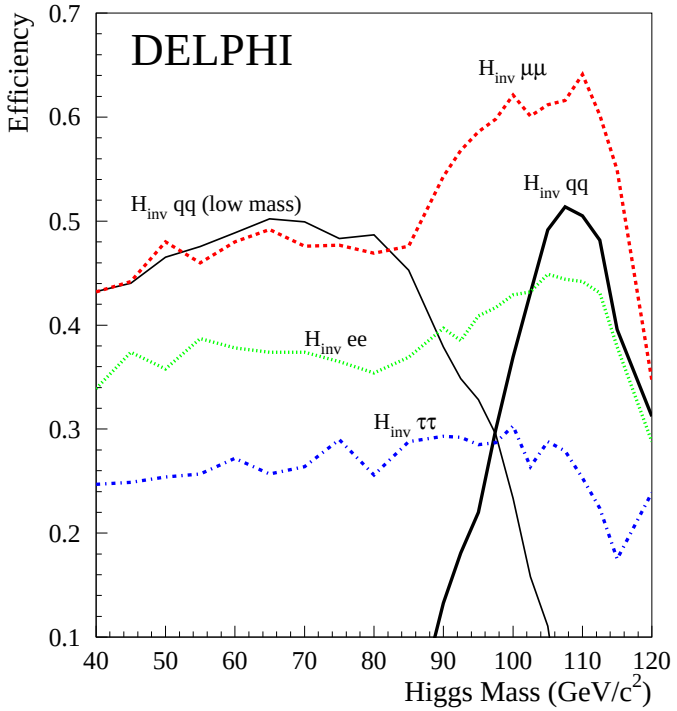


- Result unchanged since summer 2002
- Limit: $M_H > 114.1\,\mathrm{GeV}/c^2$ (expected $113.3\,\mathrm{GeV}/c^2$)
- Paper with EP referee

Invisible Higgs



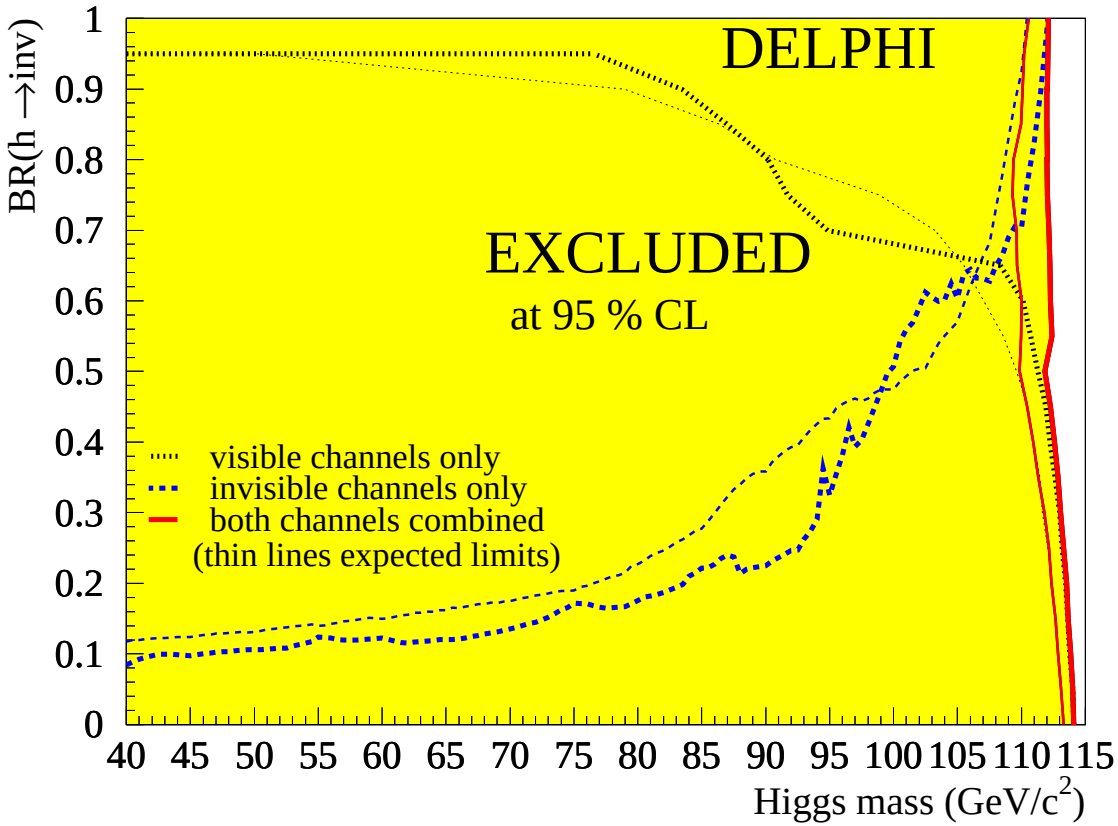
- Signatures: $m_{vis} \sim M_Z$; $\not{E}$
- 5 search channels
  - $q\bar{q}$: high Higgs mass; low Higgs mass
    use IDA tuned for different M_H
  - l^+l^-: e^+e^- $\mu^+\mu^-$ $\tau^+\tau^-$
    use cuts ; no overlap in samples



Channel	Obs	Expected
$q\bar{q}$(high)	153	160.6±8.1
$q\bar{q}$(low)	213	226.8±5.6
$\mu^+\mu^-$	18	25.7±0.9
e^+e^-	20	29.7±1.1
$\tau^+\tau^-$	37	43.9±1.6

Invisible Higgs (II)

- Limit BR(h→inv)=1
  $M_H > 112.1\,\mathrm{GeV}/c^2$
  (expected 110.5 GeV)
- Combine with SM Higgs search
  $M_H > 112.0\,\mathrm{GeV}/c^2$
  For any BR(h→inv)



Status of SUSY and Exotica searches

PUBLISHED

Resonant $\tilde{\nu}$ production Doubly charged Higgs,
Gluino as LSP GMSB
SUGRA

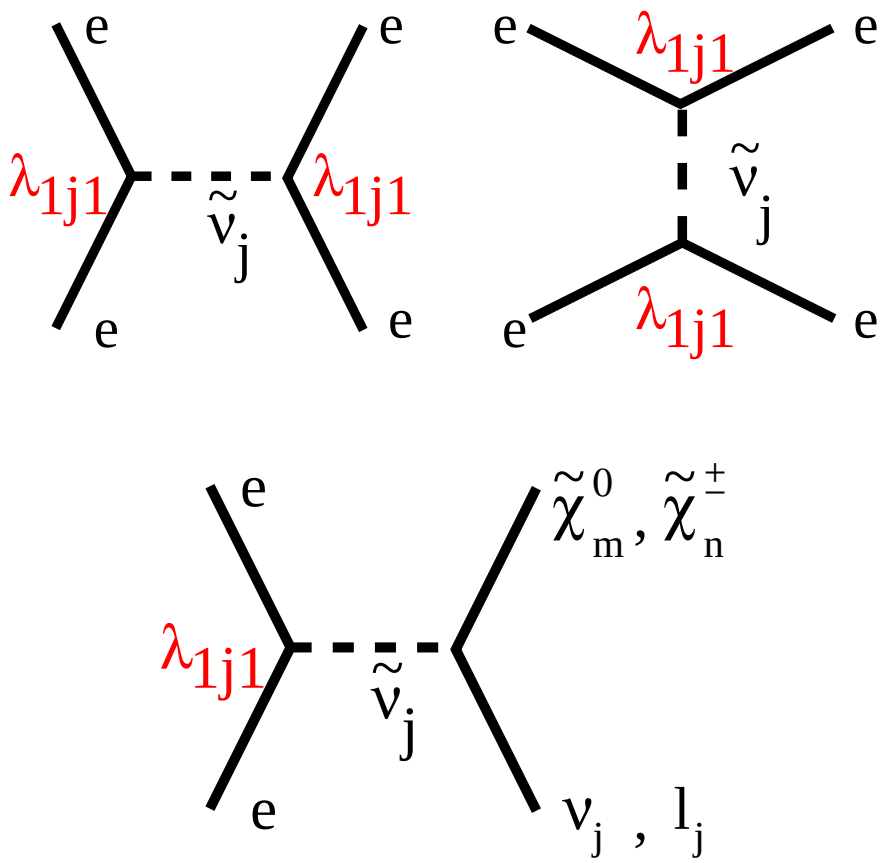
DRAFTS

AMSB RPV
$\gamma \not{E}$ Single top via FCNC

PLANNED

2HDM SUSY Searches Flavour indep. Higgs
Single top production Single top via contact int.
Leptoquarks Fermiophobic Higgs
Excited leptons b'

Resonant $\tilde{\nu}$ Production

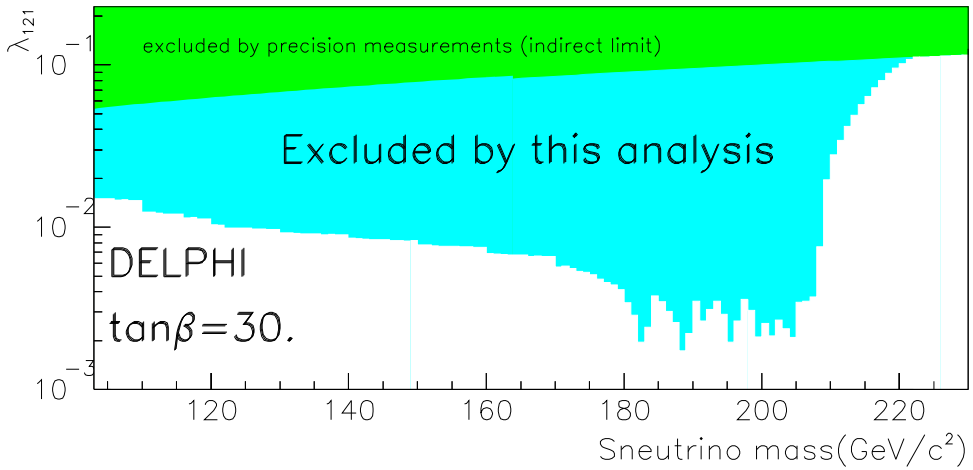


- $\not{R}$- superpotential $\lambda_{ijk} L_i L_j \overline{E}_k$
- For $M_{\tilde{\chi}} < M_{\tilde{\nu}}$ indirect decay of $\tilde{\nu}$ possible
- For small λ may dominate over direct decay
  - $\sigma \sim \Gamma(ee)\Gamma(X)$
  - Direct decay $\sim \lambda^4_{1j1}$
  - Indirect decay $\sim \lambda^2_{1j1}$
- 3 topologies - depending on $\tilde{\chi}$ decay modes
  - 2 leptons + $\not{E}$
  - 4/6 leptons with/without $\not{E}$
  - $\geq$ 2 leptons + $\geq$ 2 jets
  - Semi-leptonic analyses different for $j = 2, 3$ due to l_j

Resonant $\tilde{\nu}$ Production (II)

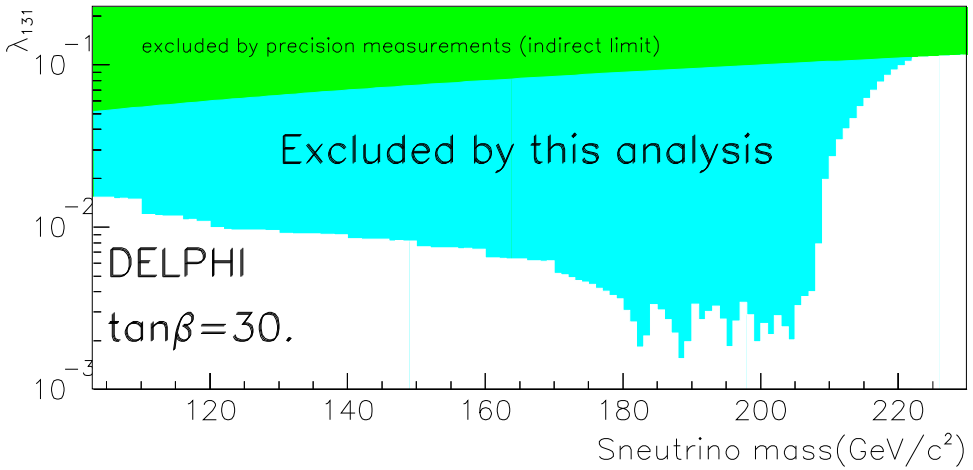
FINAL RESULT

λ_{121}



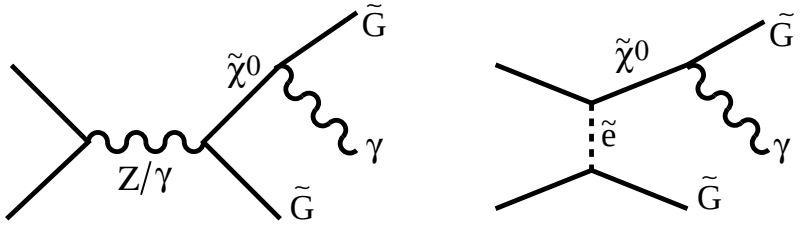
Total expected 155.6 ± 1.6 events
Total observed 150 events
Limits for $\Gamma_{\tilde{\nu}} = 150$ MeV

λ_{131}

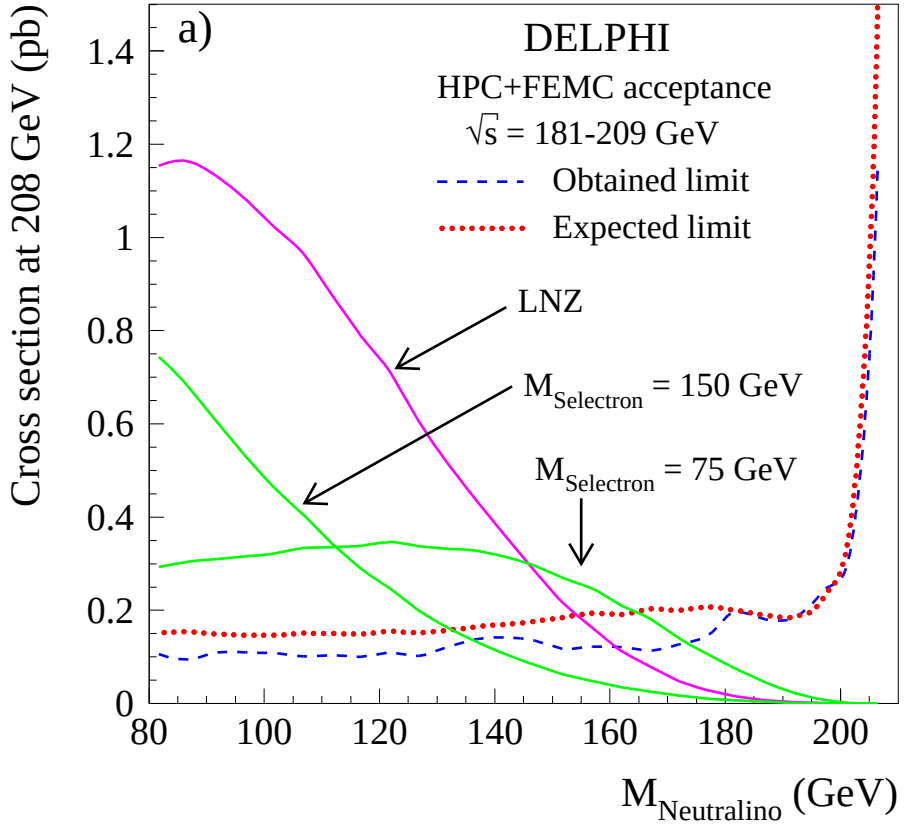


Total expected 154.3 ± 1.6 events
Total observed 129 events
Limits for $\Gamma_{\tilde{\nu}} = 150$ MeV

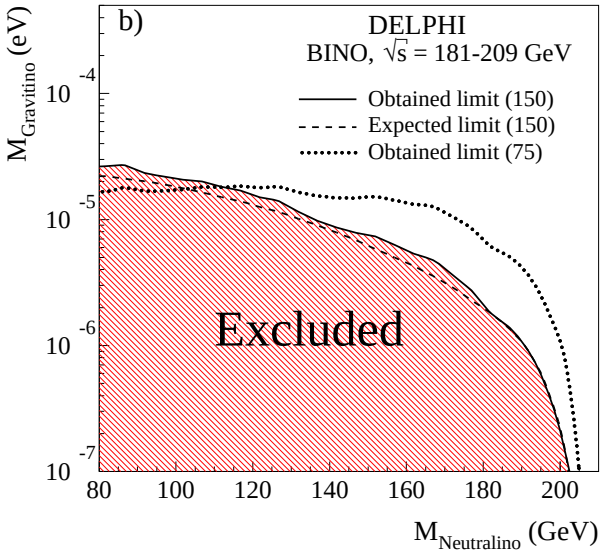
$\gamma + \not{E}$

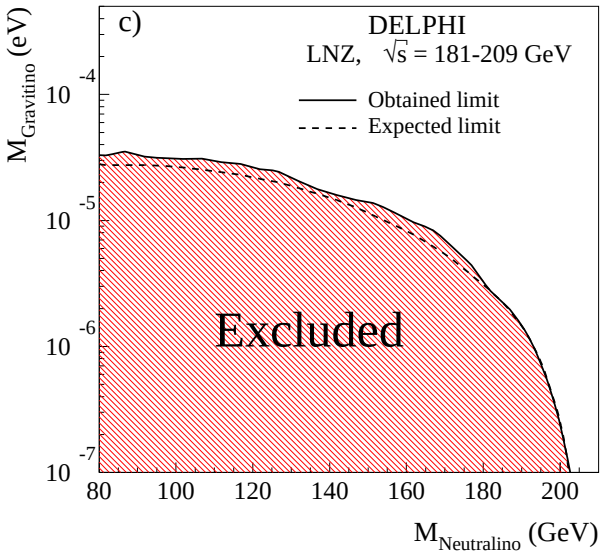


- Cross-section depends on
  - Composition of the $\tilde{\chi}^0$
  - $M_{\tilde{\chi}}$ and $M_{\tilde{G}}$
  - $M_{\tilde{e}}$
- Obtain σ limits at 208 GeV vs $M_{\tilde{\chi}}$
  - $\sqrt{s}$ and $\cos\theta_\gamma$ dependence of limits only weakly model dependent



$\gamma + \not{E}$ (II)

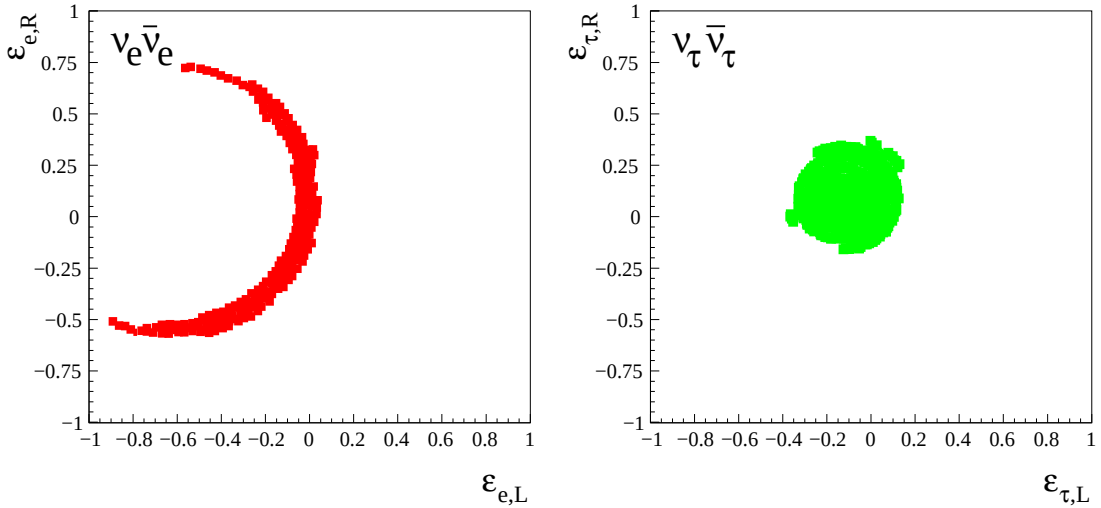


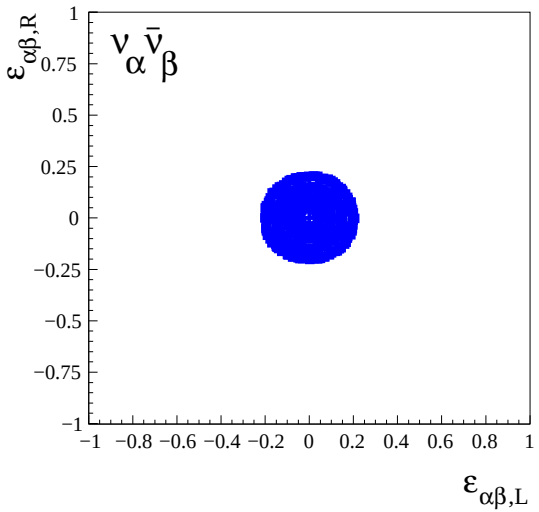


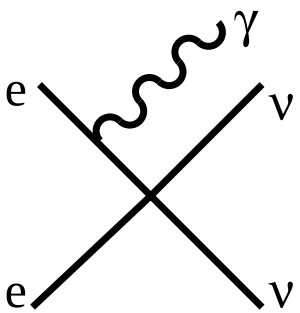
- For $\tilde{\chi}^0$ bino-like, obtain limits on $M_{\tilde{\chi}}$ vs. $M_{\tilde{G}}$
  - for given $M_{\tilde{e}}$

- LNZ model of SUSY breaking only 2 free parameters $M_{\tilde{G}}$ and $M_{\tilde{\chi}}$
  - These fix the composition of the $\tilde{\chi}^0$
  - Favourable for significant σ

$\gamma + \not{E}$ (III)







- Search for C.I. between e and υ
- Put limits on $\epsilon_{L/R} = g^2_{L/R}/\Lambda^2_{L/R}$
- 3 different interpretations
  Consider coupling to
  - $\nu_e\overline{\nu_e}$ - interf. with s/t-chan. SM
  - $\nu_\mu\overline{\nu_\mu}/\nu_\tau\overline{\nu_\tau}$ - interf. with s-chan. SM
  - $\nu_\alpha\overline{\nu_\beta}$ $(\alpha \neq \beta)$ - no interf. with SM

Data archiving: a reminder

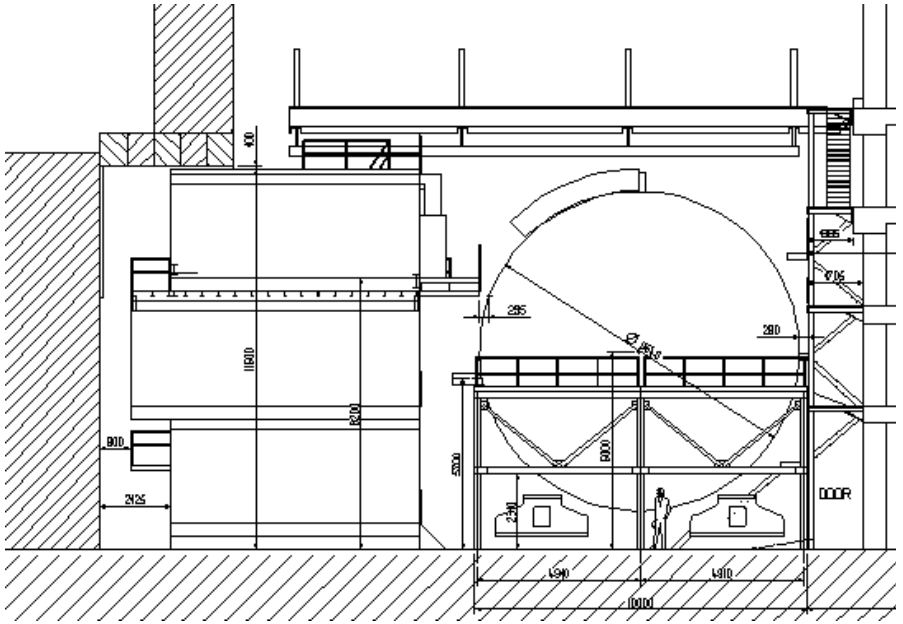
- Data are stored in `/castor`
  - To allow access to low level information
    in case features need to be investigated in detail

- Raw data from the pit:	6003 GB	in	58186 files
- Real data DSTs:	7370 GB	in	76292 files
- MC DSTs:	10043 GB	in	215915 files

- We have produced a CD with all DELPHI analysis software
- Would like longterm support for `FORTRAN`
- Have developed an `OO` framework for data access
  - Less well used/tested within DELPHI
- Starting internal discussion about who will be given access to data
  - Existing collaboration members only
    ↓
  - The whole world

Status of DELPHI

- Dead - but not buried
- DELPHI will be reopened to the general public in Summer
  - Thanks to our friends on LHCb
- DELPHI has been moved to rear/side of UX8
- Civil engineering
  - Erection of a platform
  - Discussing creation of extra elevator stop



Conclusions

- Status of Physics Analysis
  - Since July 2002 Published 8 papers
  - Currently 28 drafts in circulation
  - Expect to produce $\sim$ 30 additional publications
  - *i.e.* $\sim$ 60 publications to come
- Support now will ensure
  - High quality final publications on complete DELPHI data set
  - Combination of results between LEP experiments
  - Maximising the scientific return on the total investment in DELPHI and LEP