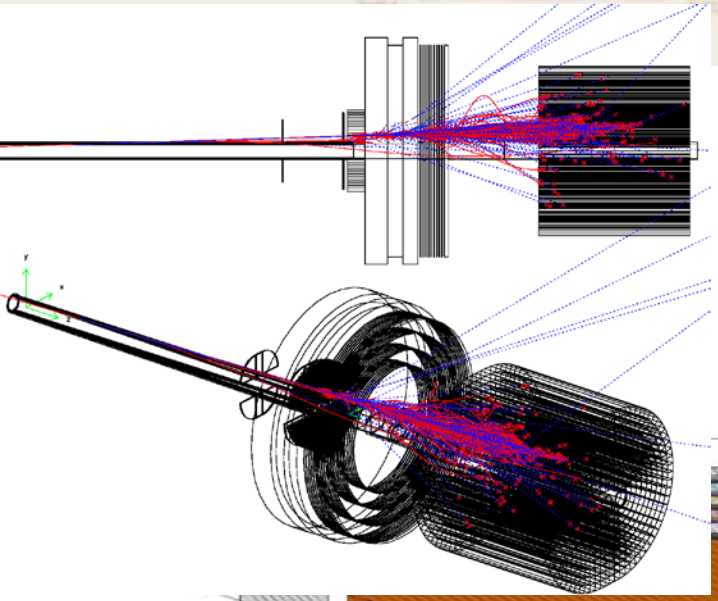
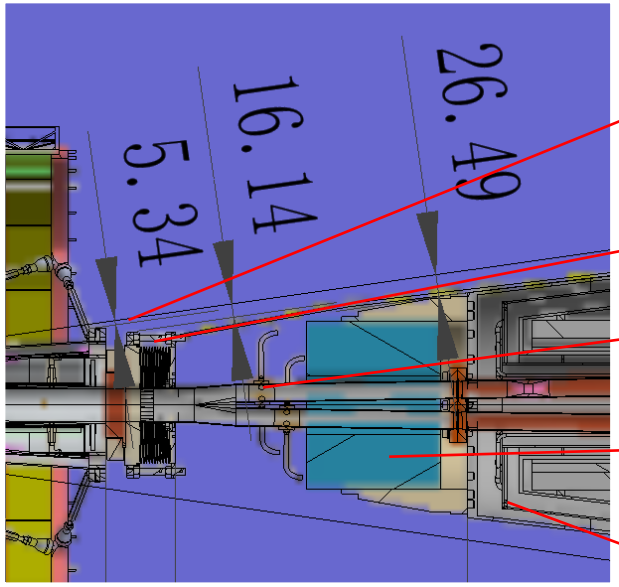
LumiCal, electron tagging for two-photon heavy flavor production

Suen Hou 侯書雲
Academia Sinica
suen@sinica.edu.tw





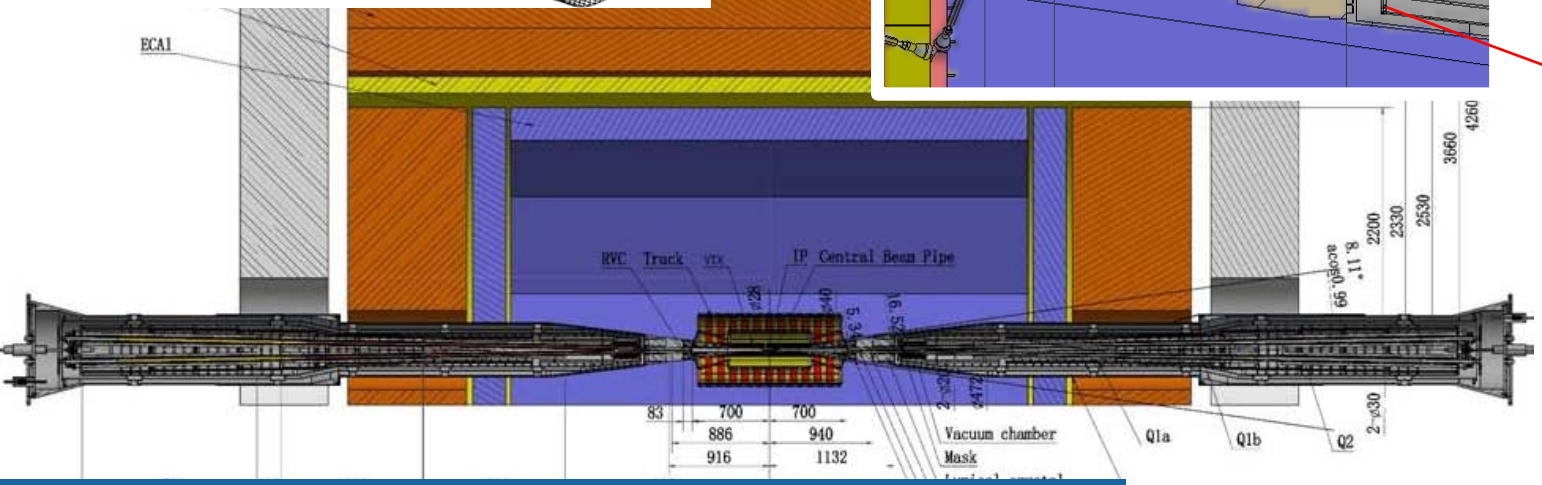
IP chamber flange

RVC

BPM & cable

Lumical& support

Cryostat



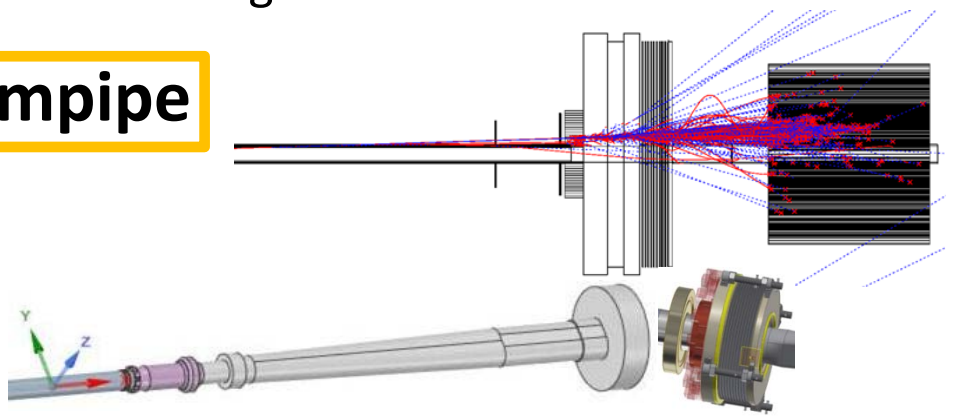
LumiCal: Luminosity 10^{-4} precision

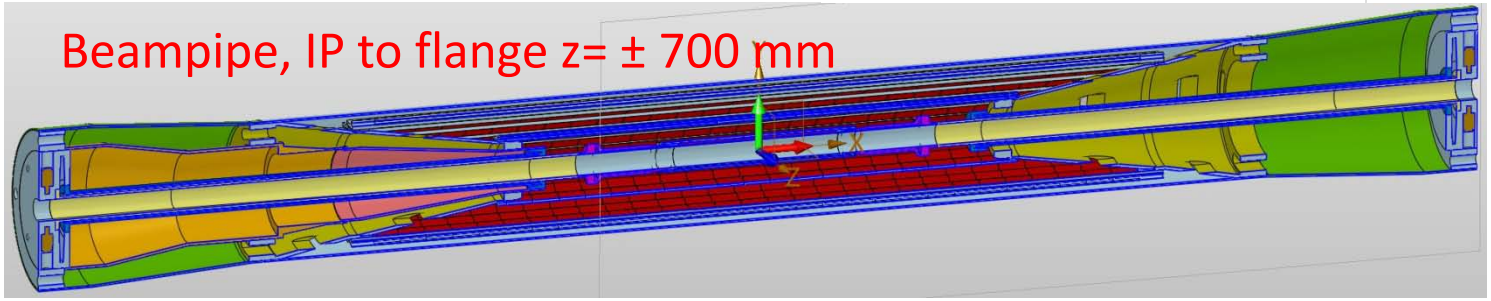
- 2x10^{36} luminosity at Z-pole, goal is for ***10^{-4}*** systematics
- **ø** 20 mm racetrack beampipe beam crossing at 33 mRad

ø 20 mm racetrack beampipe

- **Bhabha fiducial acceptance**
  large X-section with **lower θ_{min}**
- **Electro IP** tracking
  minimal beam-pipe thickness
  1.5 mm Be window
- **error on-mean** on fiducial edge
  for Bhabha event counting

$< \delta\theta_{min} > \rightarrow 10^{-4}$





MDI configurations: LumiCal

CEPC Accelerator parameters to LumiCal Bhabha detection

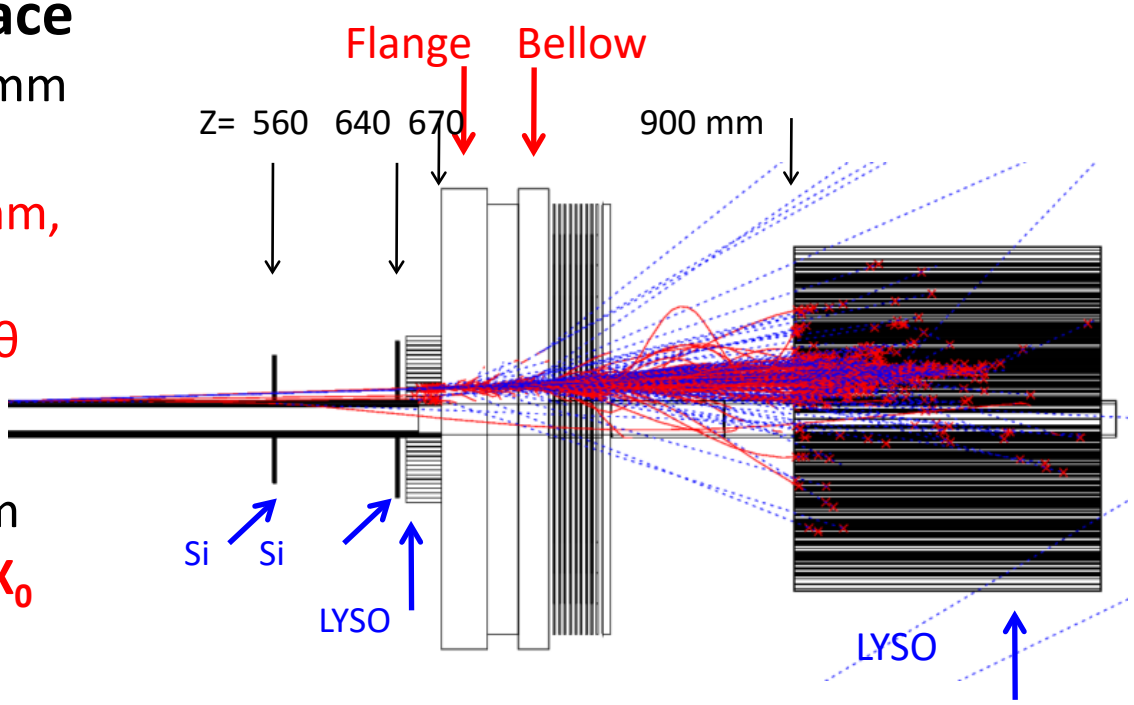
- beam-crossing: **33 mRad**
- IP beam bunch @ Z-pole: ***σ_x σ_y σ_z = 6 μm, 35 nm, 9 mm***
- Bunch crossing: ***23 ns***
- Luminosity: $cm^{-2}s^{-1}$: ***2×10^{36}***

Beam-pipe materials & Space

- **Before Flange:** z = 560~700 mm
  r=10mm, thickness = 1mm
  @20 mRad traversing = 50 mm,
  = 0.14 X_0 (Be), 0.56 X_0 (Al)
- **Two Si-wafers** for $e^{\pm}$ impact θ
- **$2X_0$ LYSO** = 23 mm

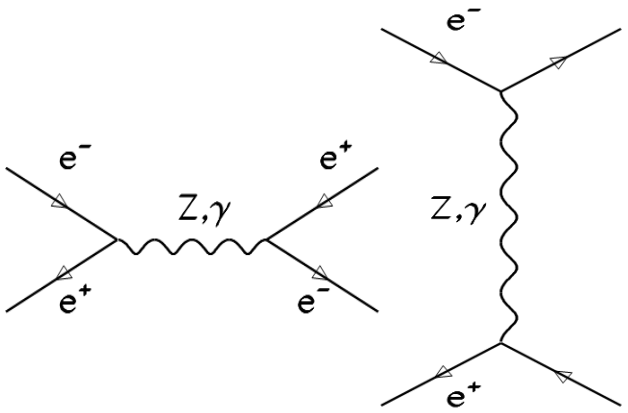
Behind bellow: 900~1100 mm

- **Flange+Bellow : ~60 mm, 6 X_0**
- **17 X_0 LYSO 200 mm**
  for $e^{\pm}$ shower

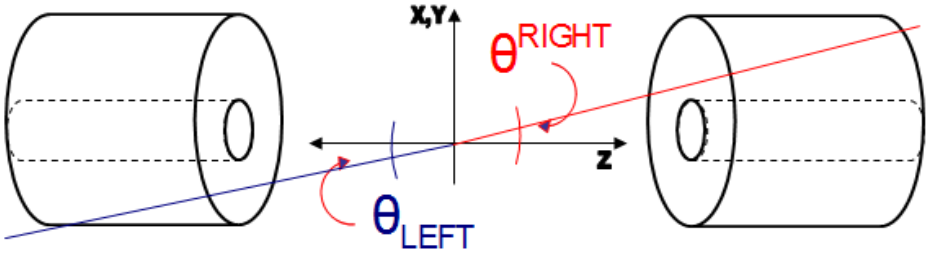


Luminosity by Bhabha elastic scattering

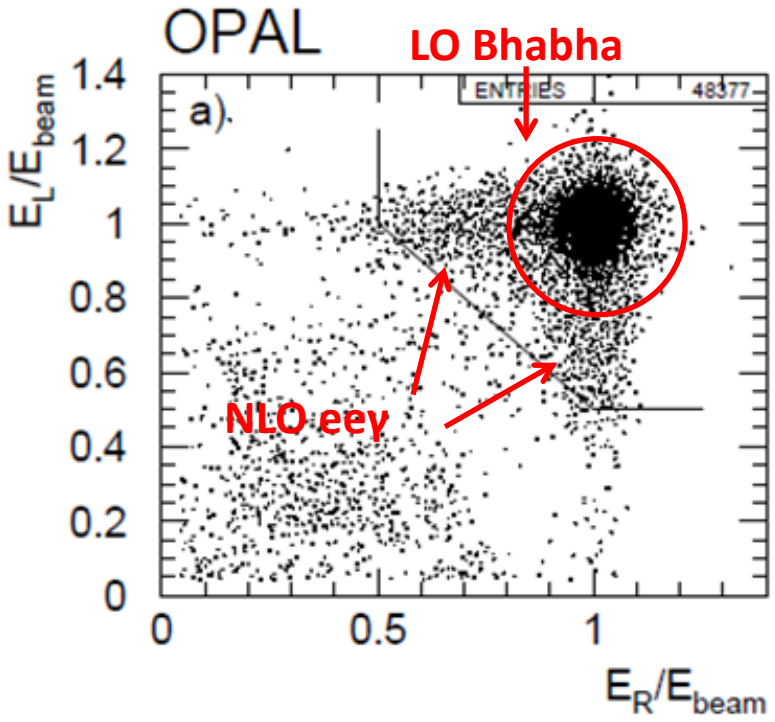
- ***Physics events, e.g. Z-pole,***
  $N = \sigma \cdot \int L$ ***L: Luminosity of e^+e^- collisions***
- ***Luminosity* by counting Bhabha events**
  $e^+e^- \rightarrow e^+e^-(\gamma)$ QED *theo. precision < 0.1%*
  1. ***a pair of electrons,*** $E(e^{\pm}) = E_{beam}$ ***back-to-back***
  2. ***precision ϑ of e, e(γ)***
  3. ***within fiducial region***



$$\sigma = \frac{16\pi\alpha^2}{s}\left(\frac{1}{\theta^2_{min}} - \frac{1}{\theta^2_{max}}\right)$$



$$\Delta\theta \equiv \theta_{RIGHT} - \theta_{LEFT}$$



Bhabha luminosity precision

Luminosity= counting Bhabha events

In a *fiducial ϑ region*

systematic error :

$\delta L/L \sim 2\,\delta\vartheta/\vartheta_{min}$

$$\sigma = \frac{16\pi\alpha^2}{s}\left(\frac{1}{\theta^2_{min}} - \frac{1}{\theta^2_{max}}\right)$$

$$\mathcal{L} = \frac{1}{\varepsilon}\frac{N_{\rm acc}}{\sigma^{\rm vis}}$$

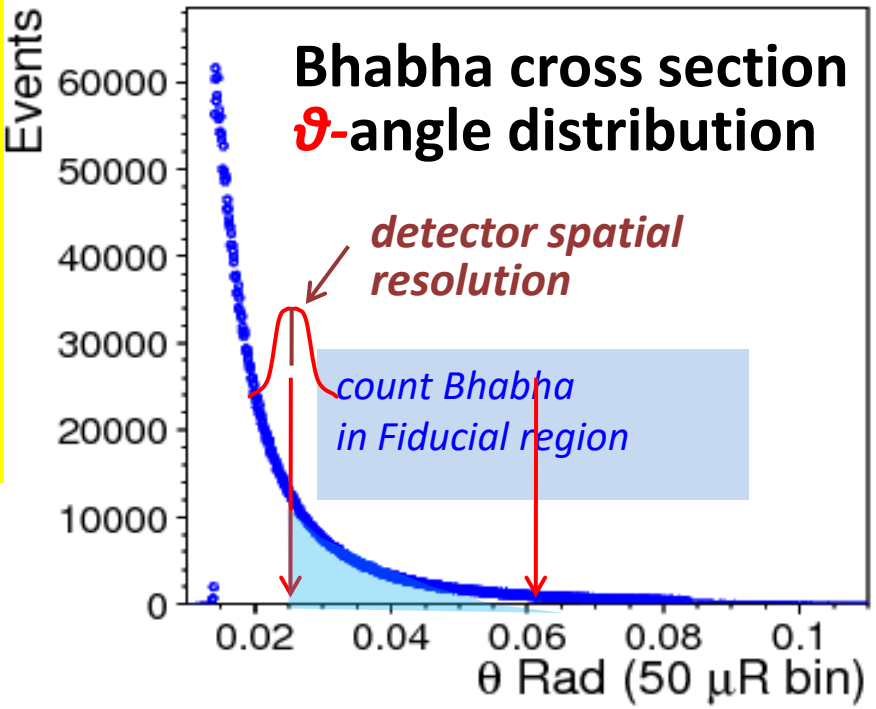
Require $\delta L/L = 10^{-3}$

at **z = ±1 m,** θ_{min} = 20 mRad

→ $\delta\vartheta$ = ***10 µRad*** or ***dr = 10 µm***

Error due to offset on Z

→ ***0.5 mm*** *on Z* or $dr = \delta z \times \vartheta$ = ***10 µm***

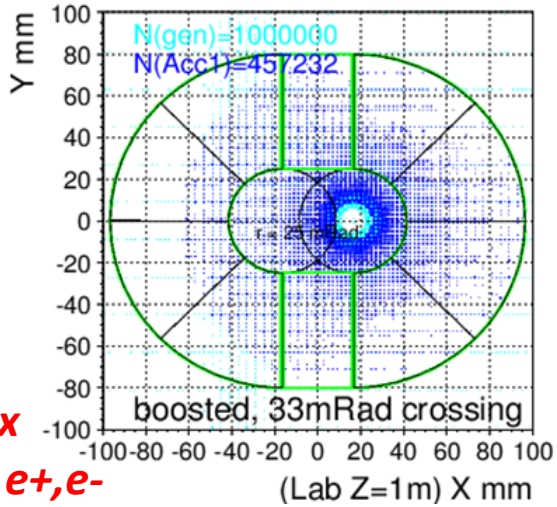


Luminosity systematics
due to
events counted in/miss fiducial region

➔ *spatial resolution* = ***offset/error on the mean of*** θ_{min}

BHLUMI + beam-crossing

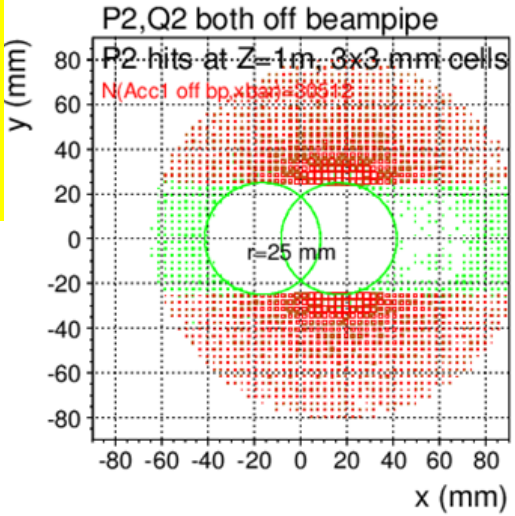
1. **BHLUMI** QED 0.06% precision (PLB 450, 262)
   CMS m_Z = 92. 3 GeV, **fiducial region:** Th1<θ<Th2, s'> 0.5s
2. **CEPC boost** : e^+e^- beam crossing, **33 mRad**
3. **X-section** : count events in fiducial region,
   w.r.t. QED calculation

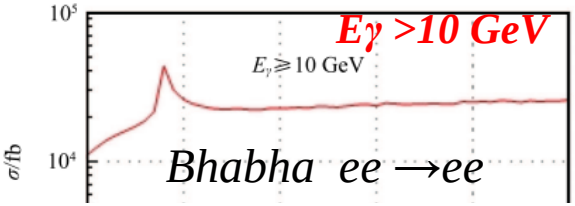


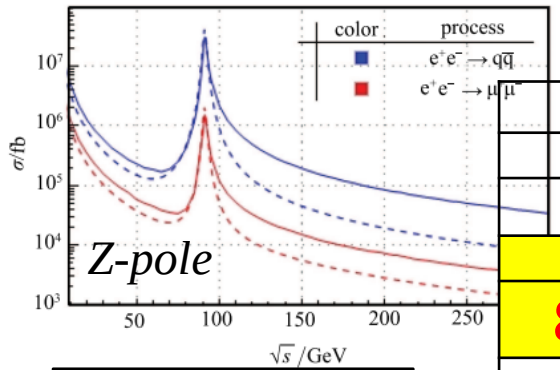
Boost to +x
scattered e+,e- symm. to outgoing pipe

X-sec. Lab frame acceptance @ z= 1m
r > 25 mm, |y|> 25 mm

c.f. σ(Z→qq) = ***41 nb***



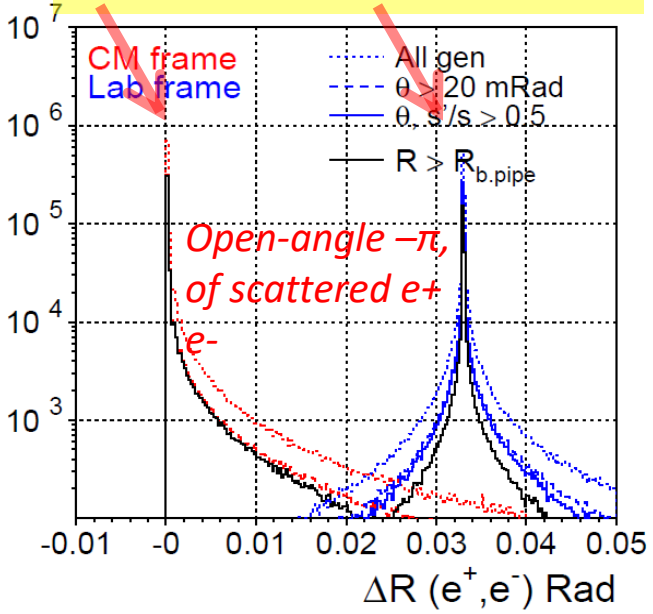




Chinese Phys. C 40 033001

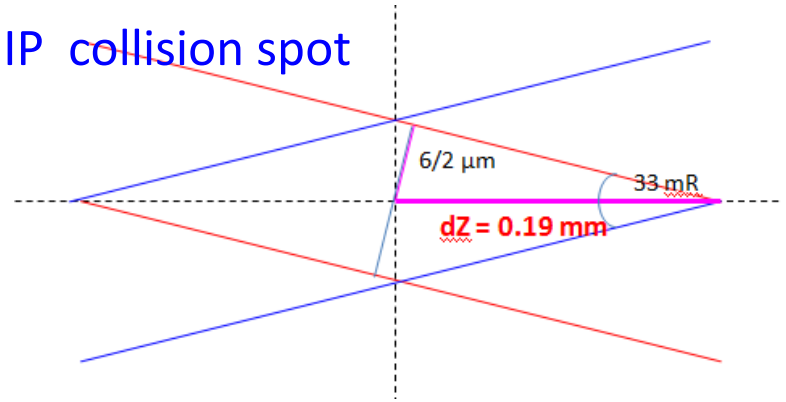
LAB both e^+, e^- detected	
θ>15 mRad	θ>15mR & |y|>15mm
257.8	245.9
θ>25 mRad	θ>25mR & |y|>25mm
85.4 nb	**78.0 nb**
θ>30 mRad	θ>30mR & |y|>30mm
54.9	49.1

Multi. Scatt., rad. Bhabha, → wider back-back



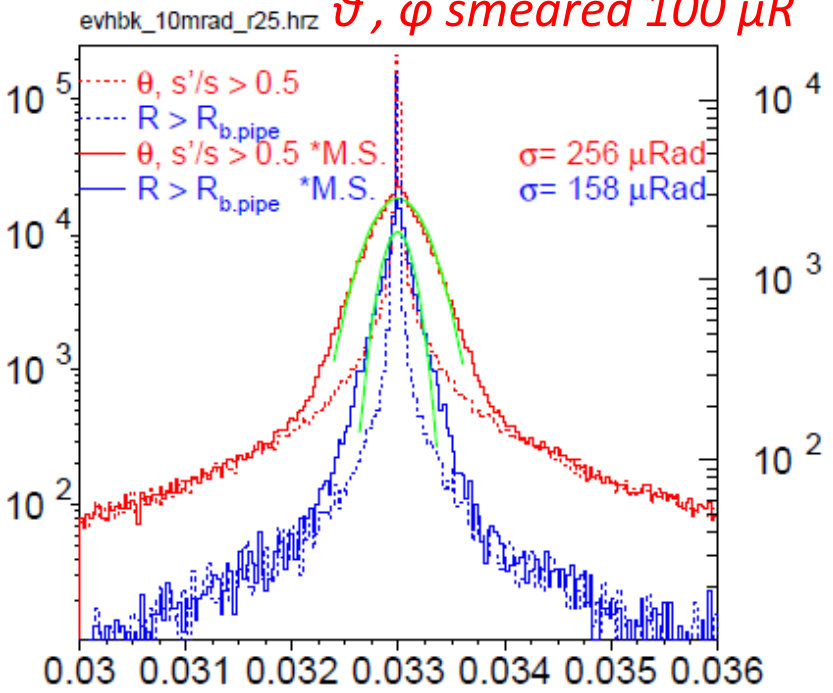
Tracking of IP position

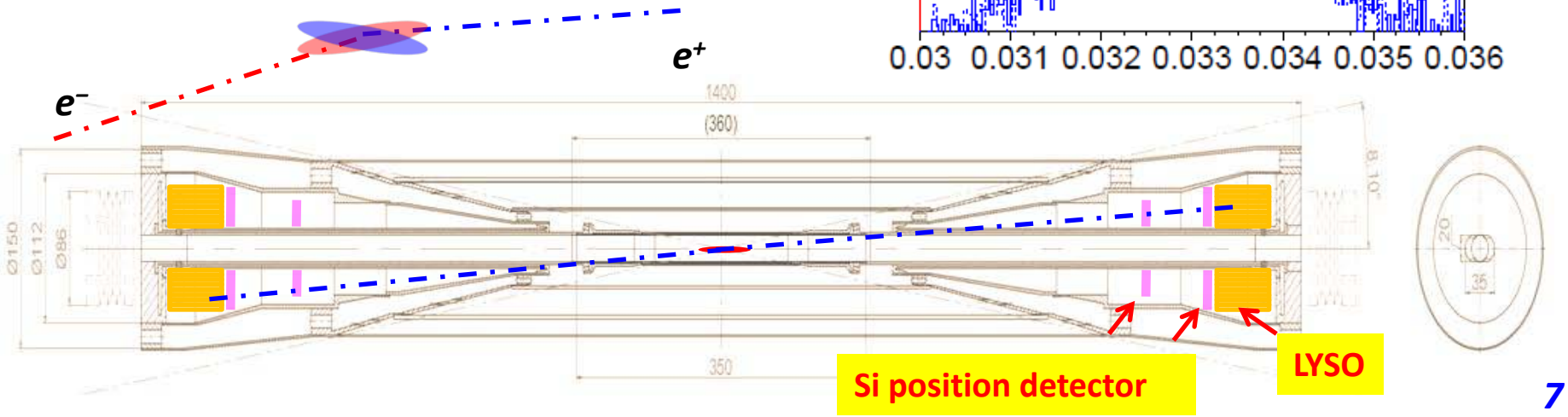
- **Deviation to electron θ by IP spread**
  beam bunch $\sigma_x = 6\ \mu m$ $\sigma_z = 9\ mm$
  crossing @ 33 mRad
- **Beam crossing spot: $\sigma_z = 0.38$ mm**



e^+, e^- back-back angle

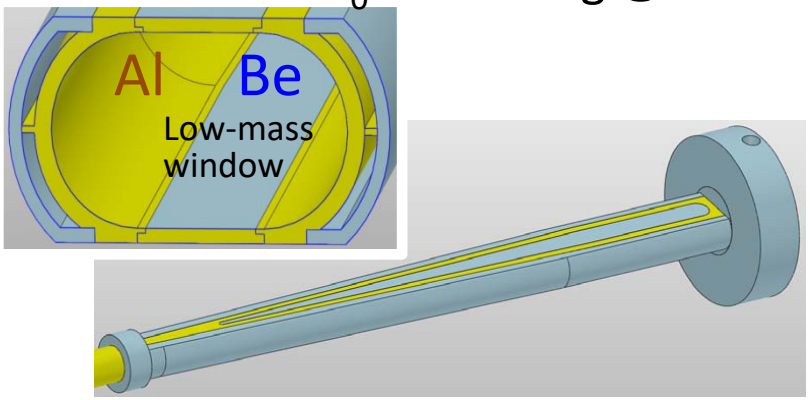
compare scattered e^+, e^- ϑ, φ smeared 100 μR





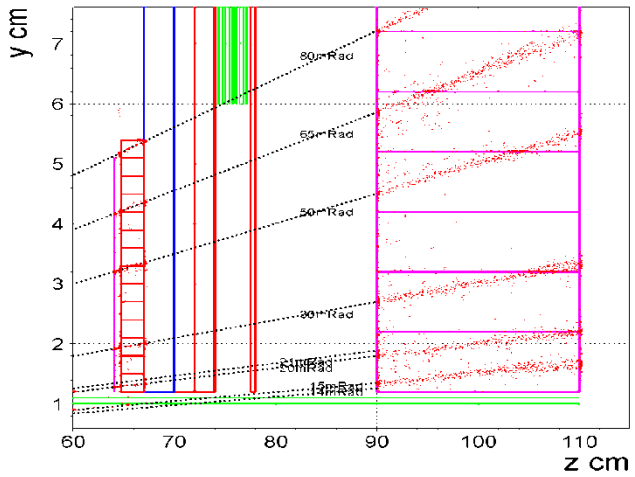
Reduce mult. scatt. & preshower

1 mm Be thin pipe window
33mm = 0.09X_0 traversing @ 30mR



- Mult. Scatt. traversing 1 mm Be pipe symmetric, Gaussian

RMS = 60 µRad @ 30 mRad

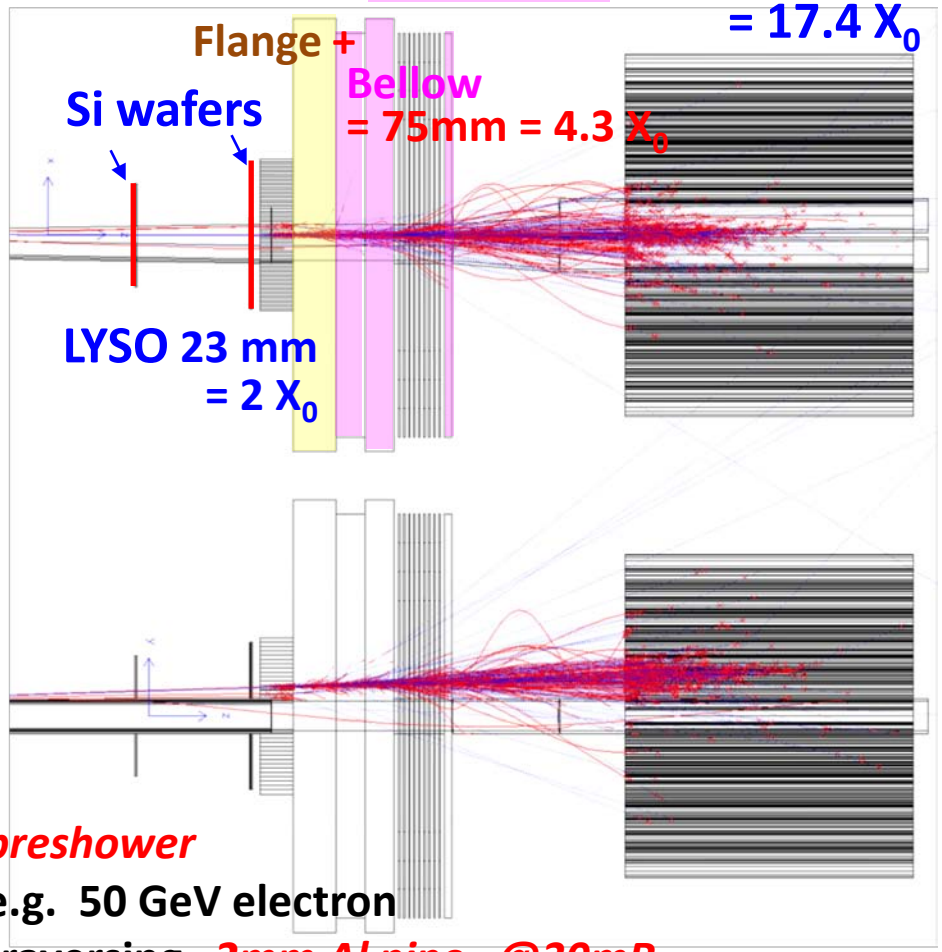


Fe $1X_0$=17.6mm

Flange
30mm
Steal

20mm
+20mm
+10 blades
+5mm

LYSO
200 mm
= 17.4 X_0



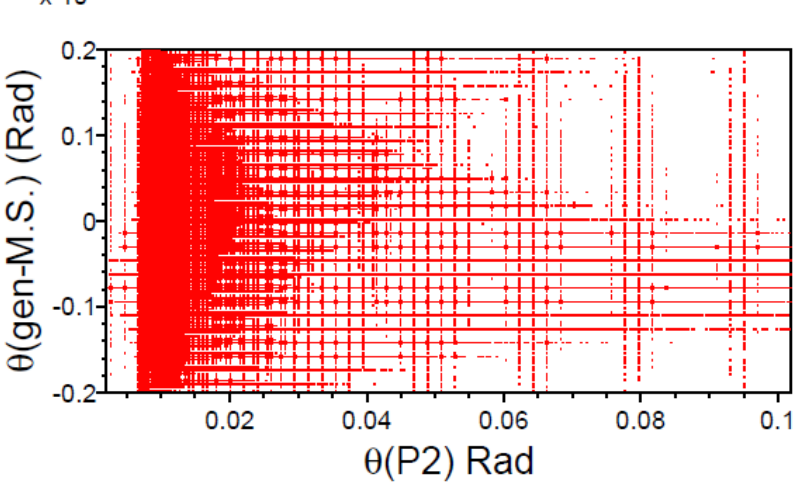
preshower

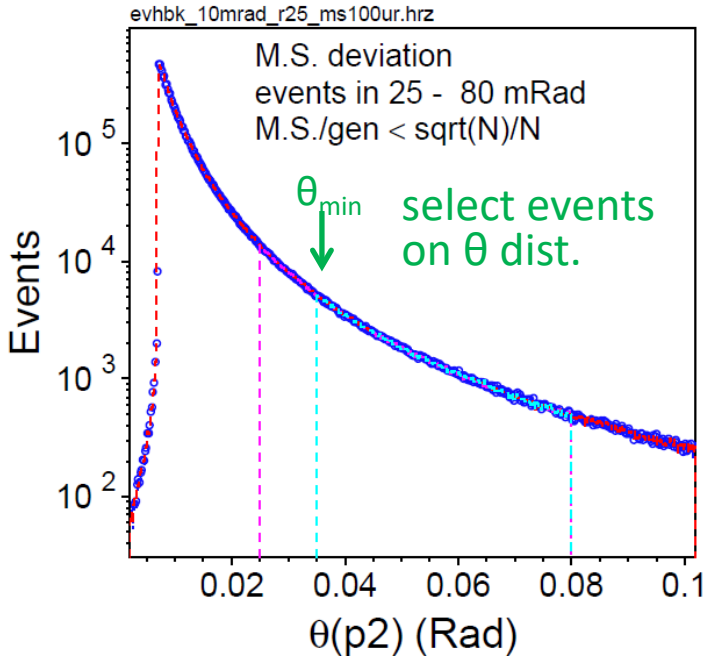
e.g. 50 GeV electron traversing *2mm Al pipe @30mR*

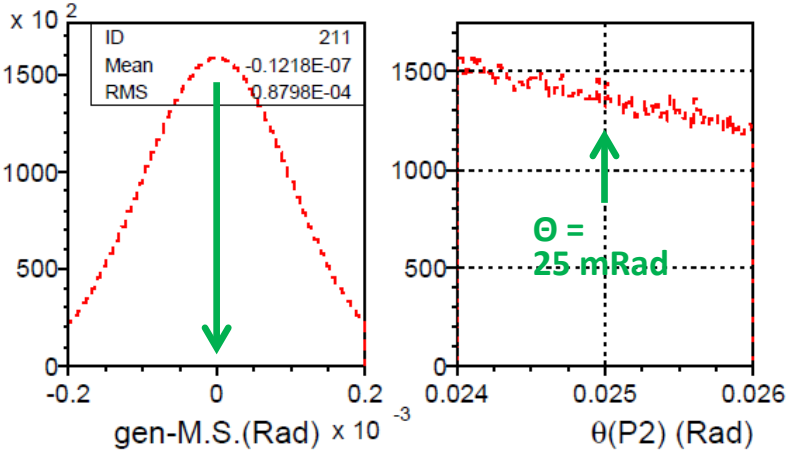
= 67mm thick @30mR = 0.75 X_0

10^{-4} systematics, multiple scattering

1. **BHLUMI** smear θ', ϕ' of scattered e^+, e^-
   Multi. Scatt. 100 µRad θ'= θxGauss(100µR), ϕ'= ϕxGauss(100µR)
2. **δN/N systematics**:
   δN = count event deviation due to M.S.
   M.S is Gaussian, Symmetric
   at **θ_{min}= 25 mRad, slope of Bbhabha**
   in neiboring 100 µRad bins to 25mR
   δN(@25mR)/N(25-80 mR) <10^{-4}







10^{-4} is determined by survey of the mean position

Electron/gamma, Physics application

50 GeV electron @ θ = 32 mRad, ϕ=90°

- 1mm Be beam pipe
- 2X0 LYSO + 4.3X0 Flange,Bellow + 17X0 LYSO

Shower deposition

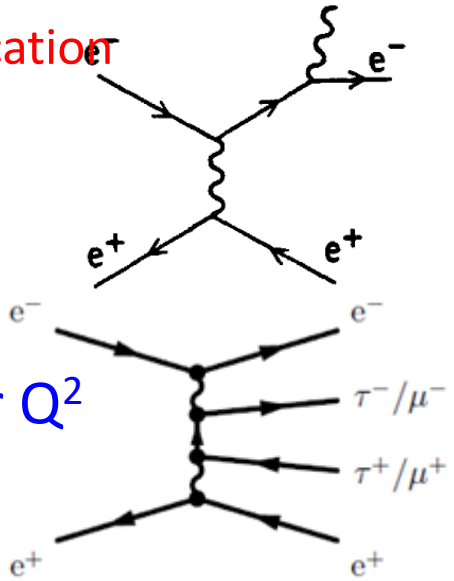
- in front LYSO: 1.0 %
- in back LYSO: 61 %

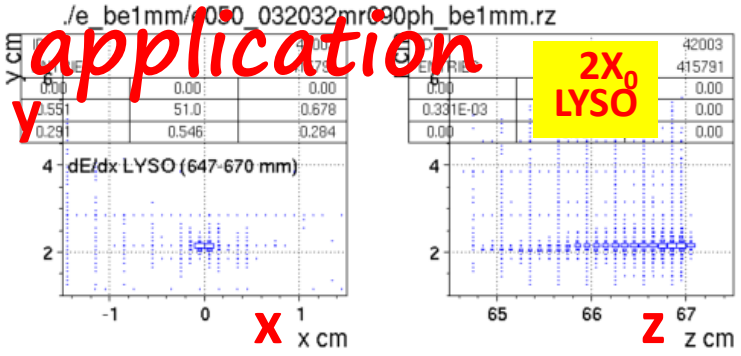
Pre-shower design before flange

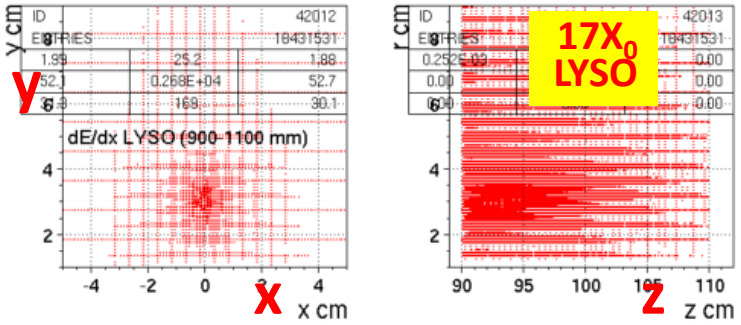
- **two Si wafers:** electron tracking
  5 μm resolution
- 2X0 **LYSO:** e/γ identification

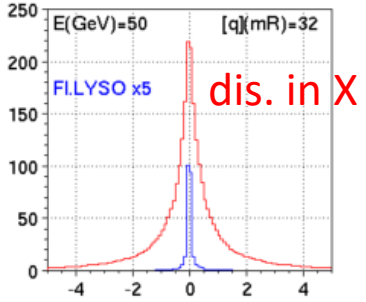
Physics purpose

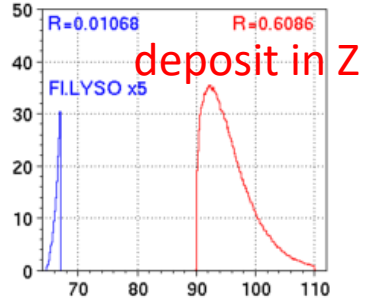
- Radiative Bhabha, e+γ versus QED
- two-photon, electron tagging for Q^2

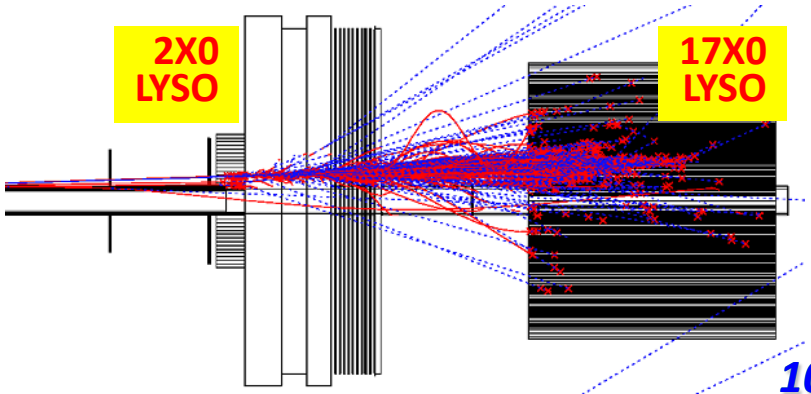












LumiCal summary

Investigated for luminosity to 10^{-4} systematics

- LumiCal construction survey to < 1 μm
- monitoring on beam, IP, detector z deviations
- challenge for $\delta N/N < 10^{-4}$ counting Bhabha in fiducial θ_{min}

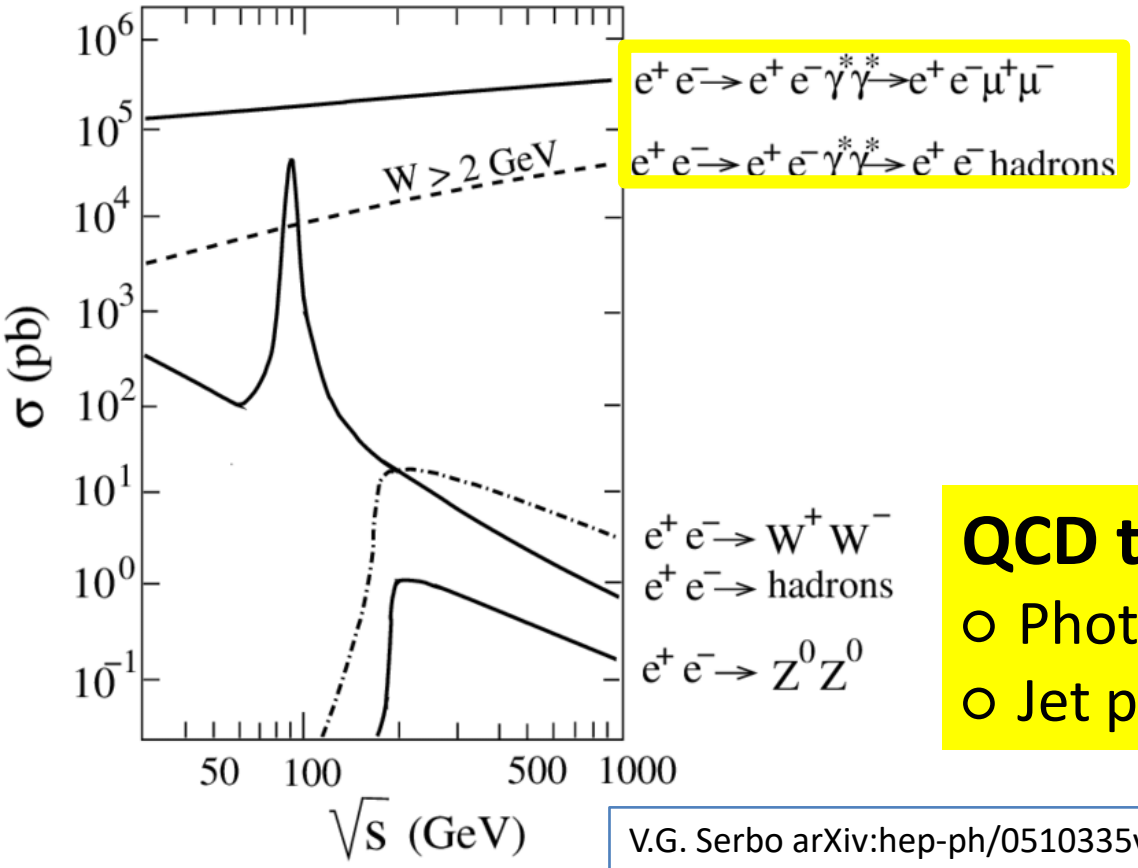
two-photon physics at e^+e^- collider

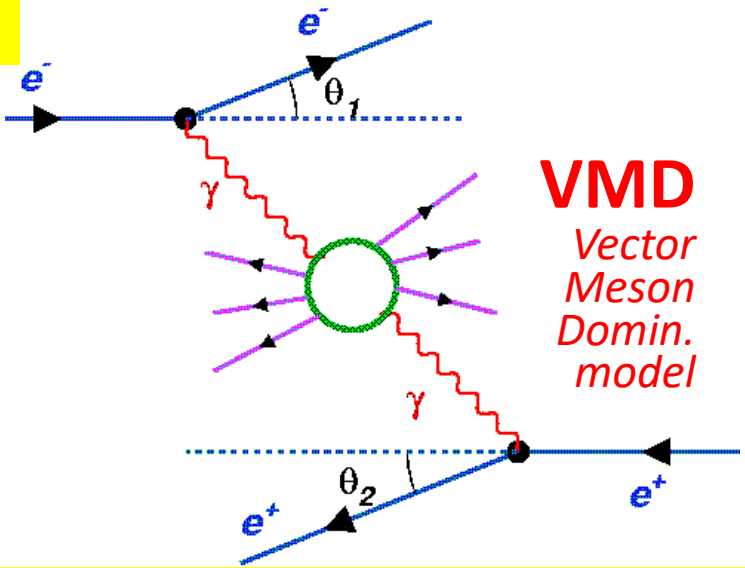
two-photon topics:

electron-tagging by forward detector

- Resonances : π^0, η, η', f_2, a_2, η ,η_c, χ_c
- Lepton pairs: $\gamma\gamma \rightarrow \mu\mu, \tau\tau$
- Vector boson pairs $\gamma\gamma \rightarrow \pi\pi, \rho\rho, KK, pp$

Cross section very large
detection
limited by low $W_{\gamma\gamma}$





VMD

Vector Meson Domin. model

QCD topics:

- Photon structure $F_2(x,Q^2)$
- Jet production $\gamma\gamma \rightarrow$ hadrons

V.G. Serbo arXiv:hep-ph/0510335v2

two-photon $\gamma\gamma \to \ell^+\ell^-$

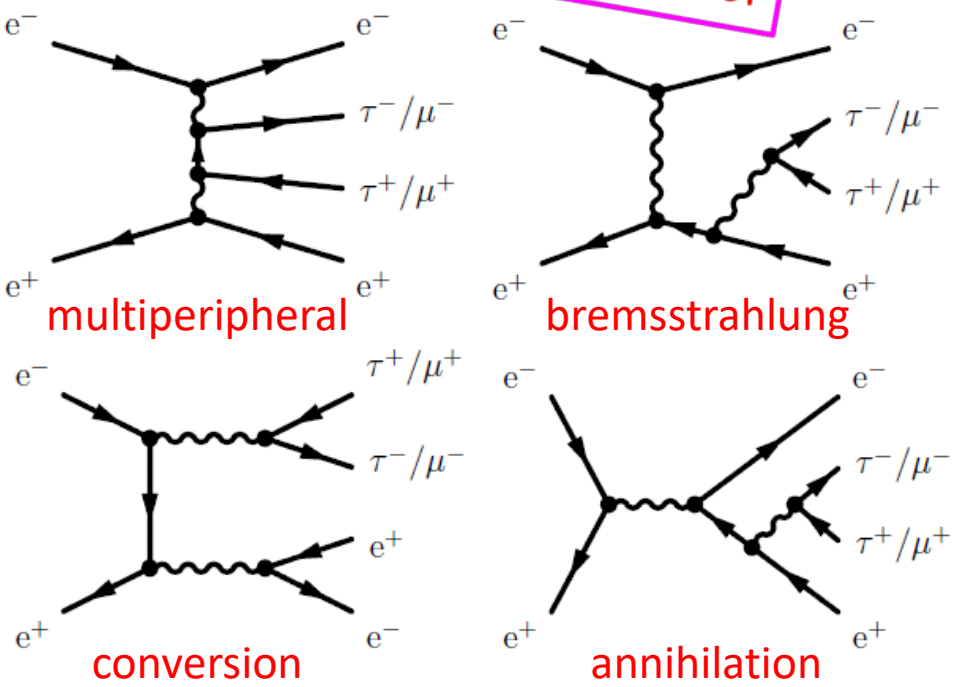
Classical $\gamma\gamma$ channel

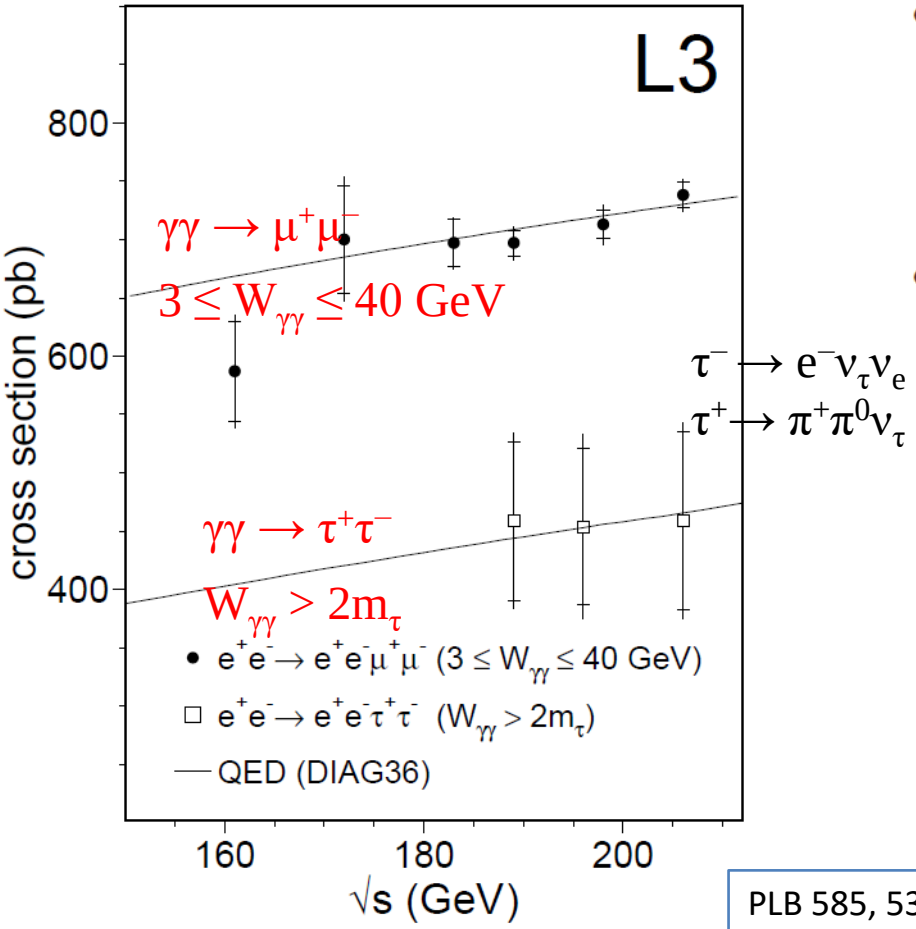
QED process, well calculated

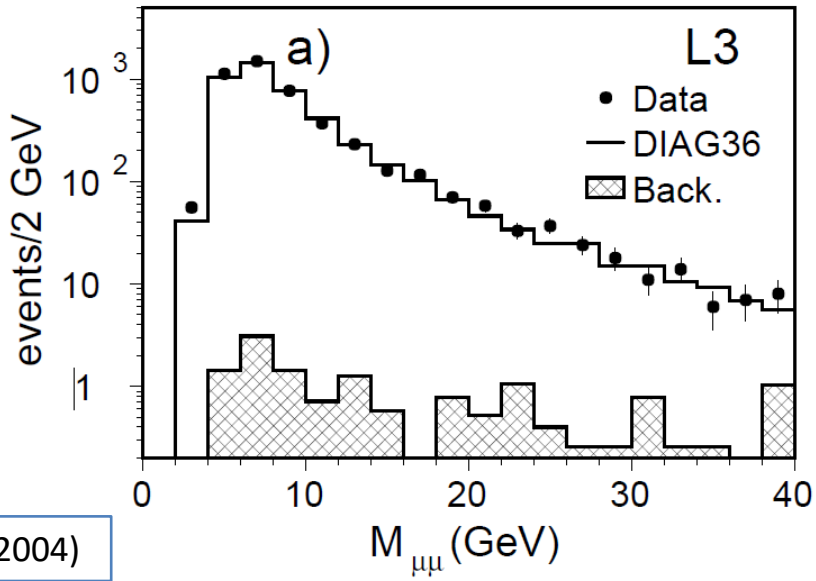
$e^+e^- \longrightarrow e^+e^-\ell^+\ell^-$, DIAG36

L3 measurement (2003)

Un-tagged events







PLB 585, 53 (2004)

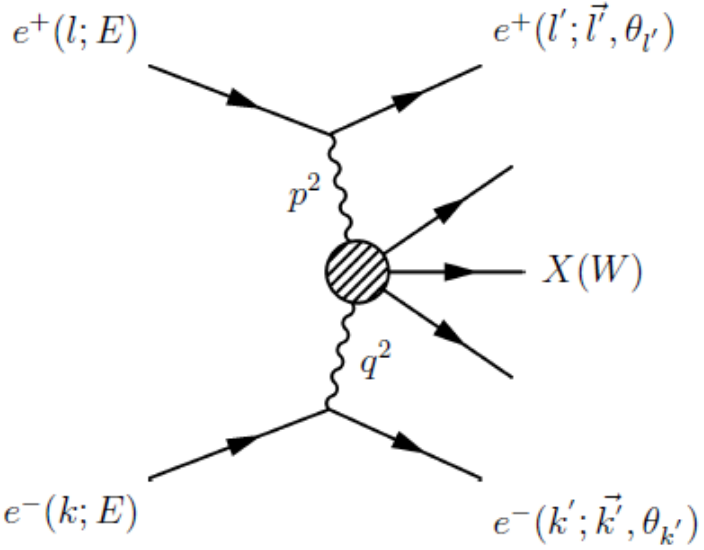
two-photon Resonances

Vector Meson Dominance (VMD)

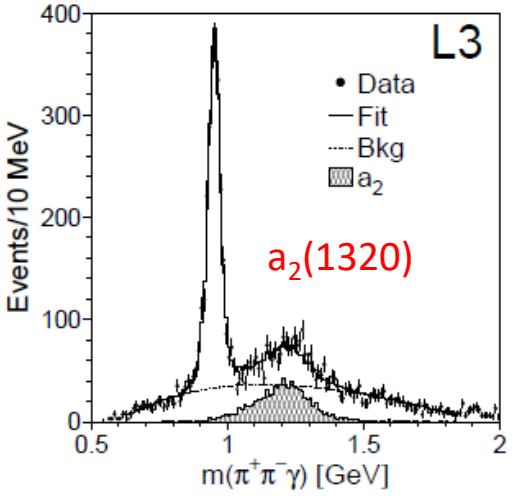
γγ resonance: *C*-even, J≠1

spin-parity analysis

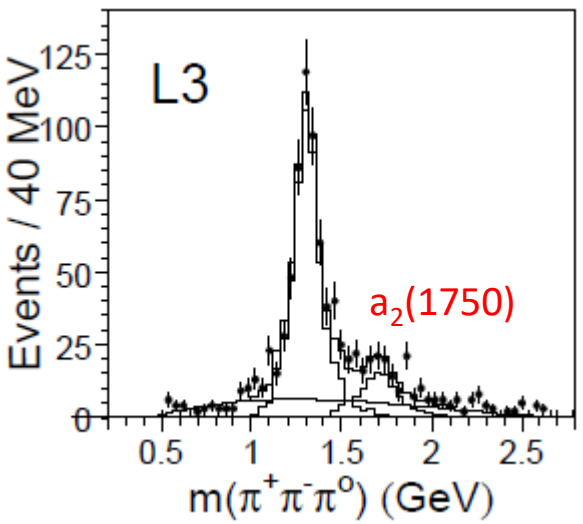
$$\sigma(\gamma\gamma \to \mathrm{R}) = 8\pi(2\mathrm{J}+1)\frac{\Gamma_{\gamma\gamma}(\mathrm{R})\Gamma(\mathrm{R})}{(W_{\gamma\gamma}^2 - m_R^2)^2 + m_R^2\Gamma^2(\mathrm{R})}$$



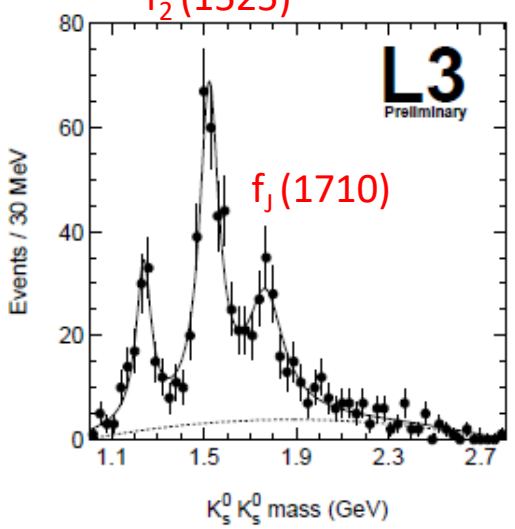
η′(958)



a_2(1320)



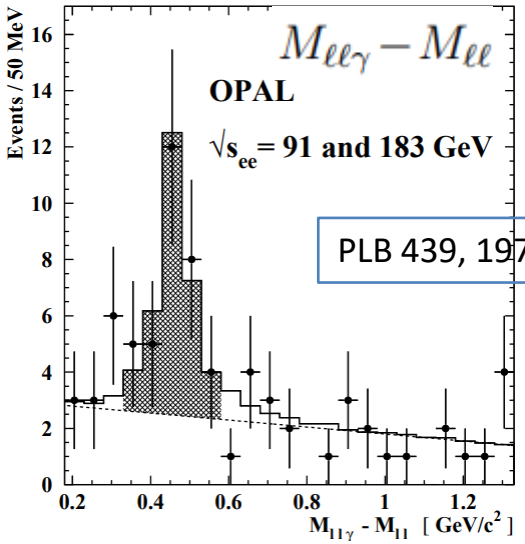
f_2'(1525)



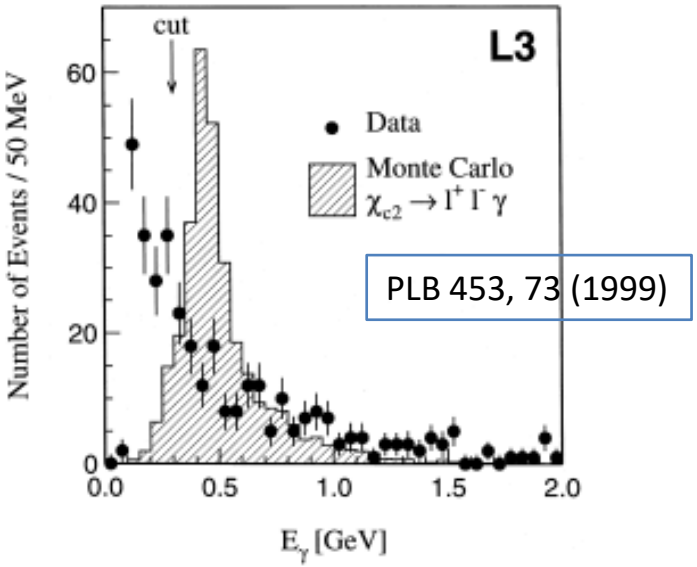
$\gamma\gamma$ Charm resonances η_c, χ_{c2}

$\chi_{c2}(3555)$

$\chi_{c2} \to J/\psi\ \gamma \to \ell^+\ \ell^-\ \gamma$



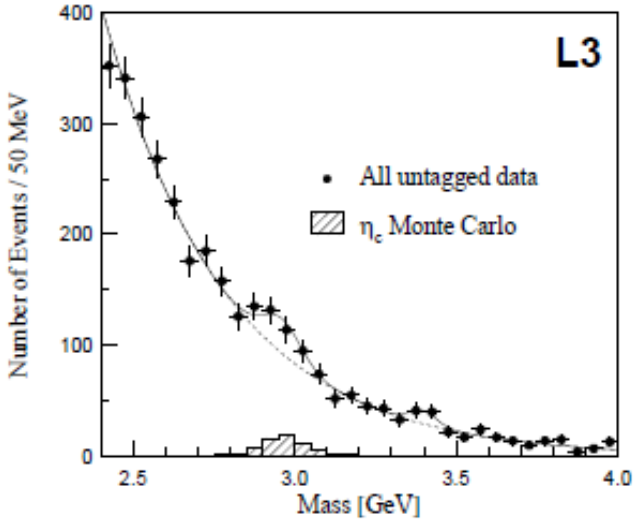
PLB 439, 197 (1998)



PLB 453, 73 (1999)

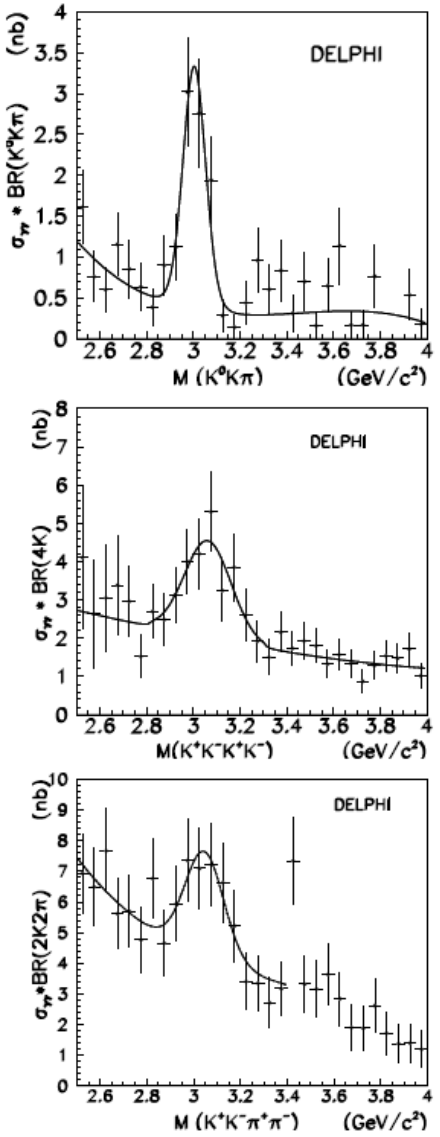
$\eta_c(2980)$ L3

Decay mode
$\eta_c \to \pi^+\pi^-\pi^+\pi^-$
$\eta_c \to K^+K^-\pi^+\pi^-$
$\eta_c \to K^0_S K^\pm \pi^\mp$
$\eta_c \to \pi^+\pi^-\eta(\gamma\gamma)$
$\eta_c \to K^+K^-\pi^0$
$\eta_c \to \rho^+\rho^-$
$\eta_c \to \pi^+\pi^-\eta(\pi^+\pi^-\pi^0)$
$\eta_c \to \pi^+\pi^-\eta'(\pi^+\pi^-\eta)$
$\eta_c \to \pi^+\pi^-\eta'(\rho\gamma)$



PLB 31 461 155 (1999)

$\eta_c(2980)$ DELPHI



EPJC 31 481 (2003)

photon structure, single-tag $F_2^\gamma(x,Q^2)$

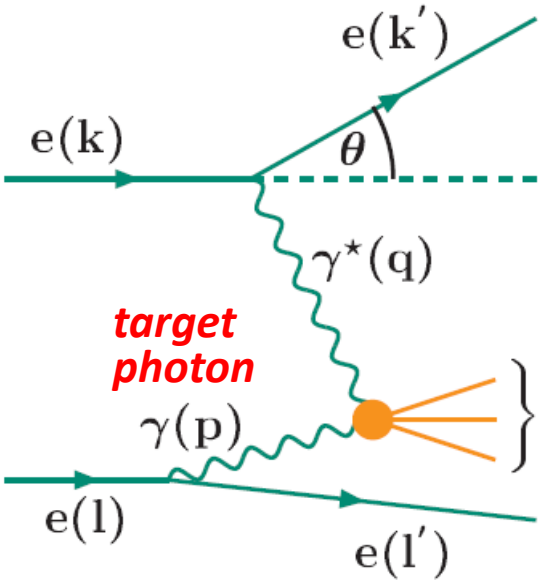
Deep inelastic eγ scattering $e^+e^- \to (e^+e^-\gamma\gamma) \to e^+e^- X$

$$\frac{d\sigma(e\gamma \to eX)}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4} \cdot \left[\{1+(1-y)^2\}F_2^\gamma(x,Q^2) - y^2 F_L^\gamma(x,Q^2)\right]$$

$$Q_i^2 = 4E_b E_i' \sin^2(\theta_i/2),$$

$$y_{ei} = 1 - \frac{E_i'}{E_b}\cos^2(\theta_i/2),$$

$$x_i = \frac{Q_i^2}{Q_1^2 + W^2 + Q_2^2},$$

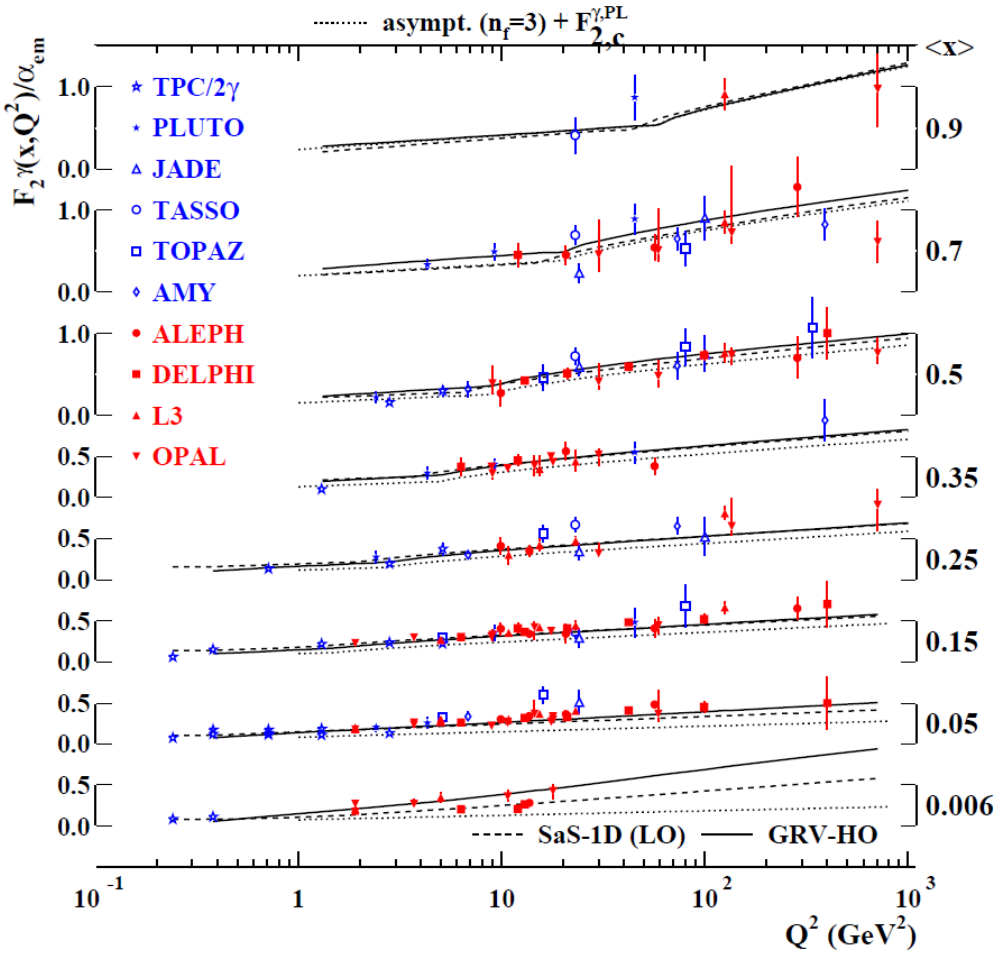


probe

tag

$Q^2 = -q^2 > 0$

anti-tag



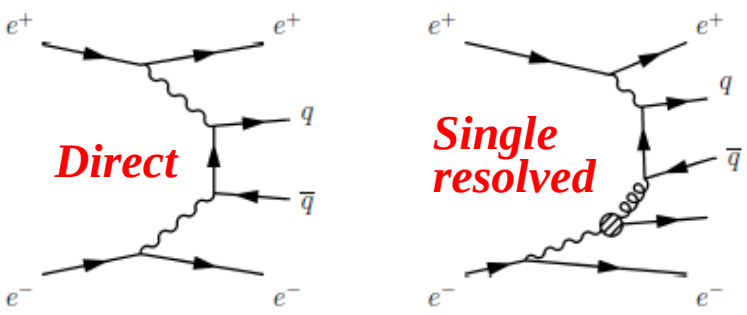
$\gamma\gamma$ open-Charm $D^{*\pm}$

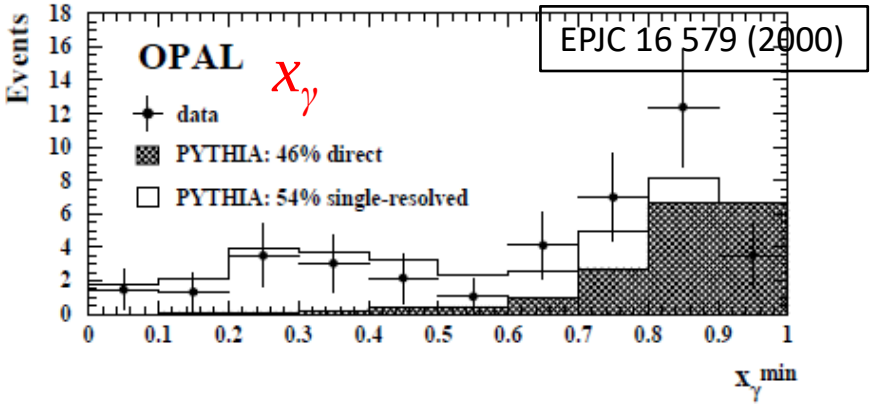
$$e^+e^- \to e^+e^- D^{*\pm} X$$

$$D^{*+} \to D^0 \pi_s^+$$

$$x_\gamma^{\pm} = \frac{\Sigma_{\text{jets}}(E \pm p_z)}{\Sigma_{\text{hadrons}}(E \pm p_z)}$$

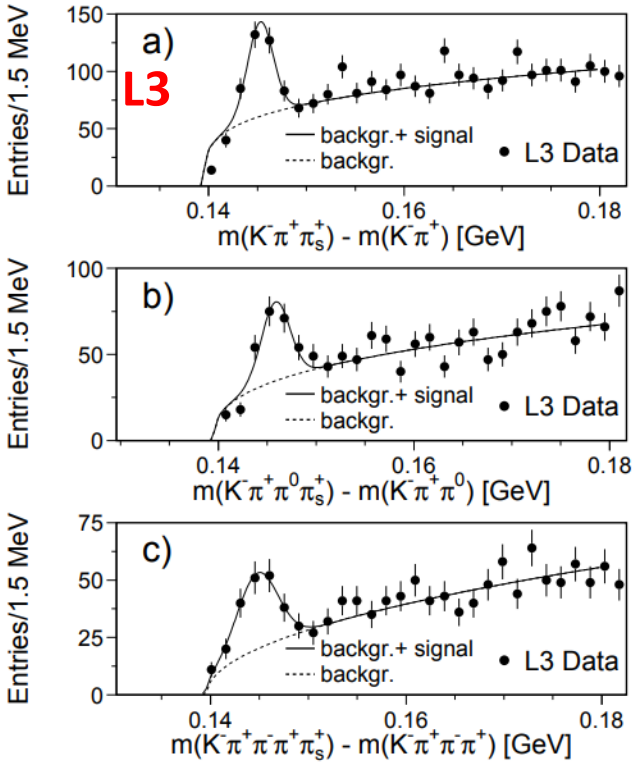
$x_\gamma \sim 1$ for **Direct** proc.



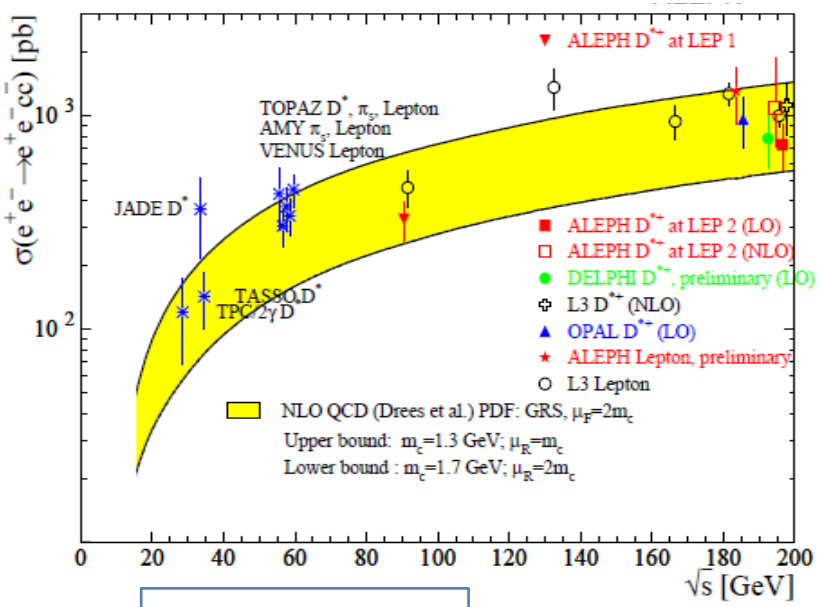


EPJC 16 579 (2000)

$$\Delta M = M(D^0 \pi_s^+) - M(D^0)$$



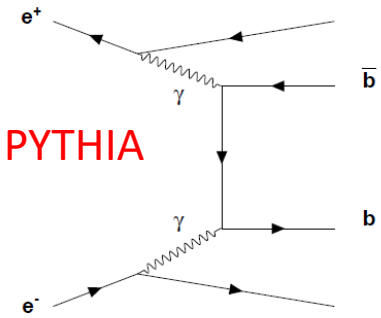
PLB 535:59 (2002)



EPJC 28 (2003) 437

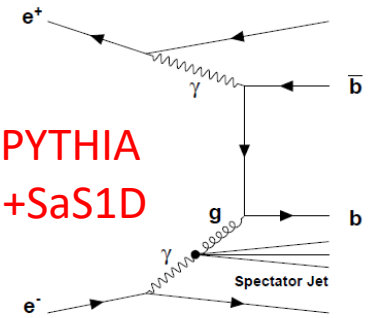
$\gamma\gamma$ open-beauty production

$$e^+e^- \to e^+e^- b\bar{b}X$$



PYTHIA

Direct



PYTHIA +SaS1D

Single Resolved

ALEPH

- o two-photon hadronic
- o b-tagging by long-lifetime

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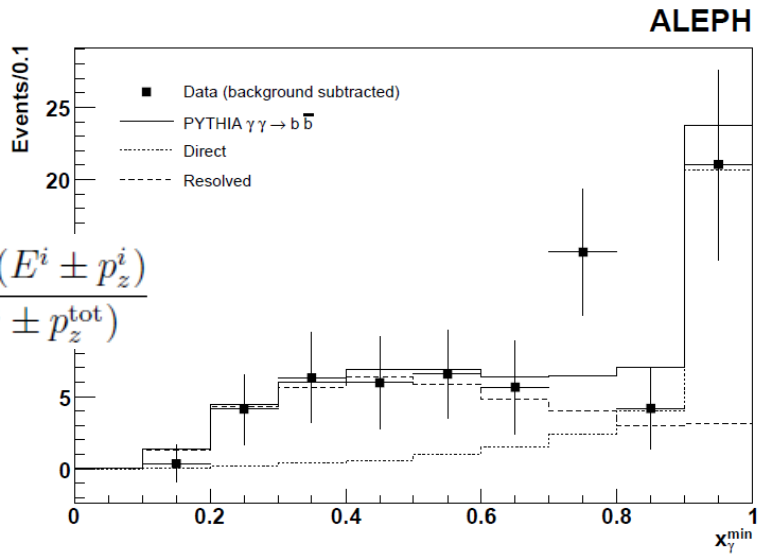
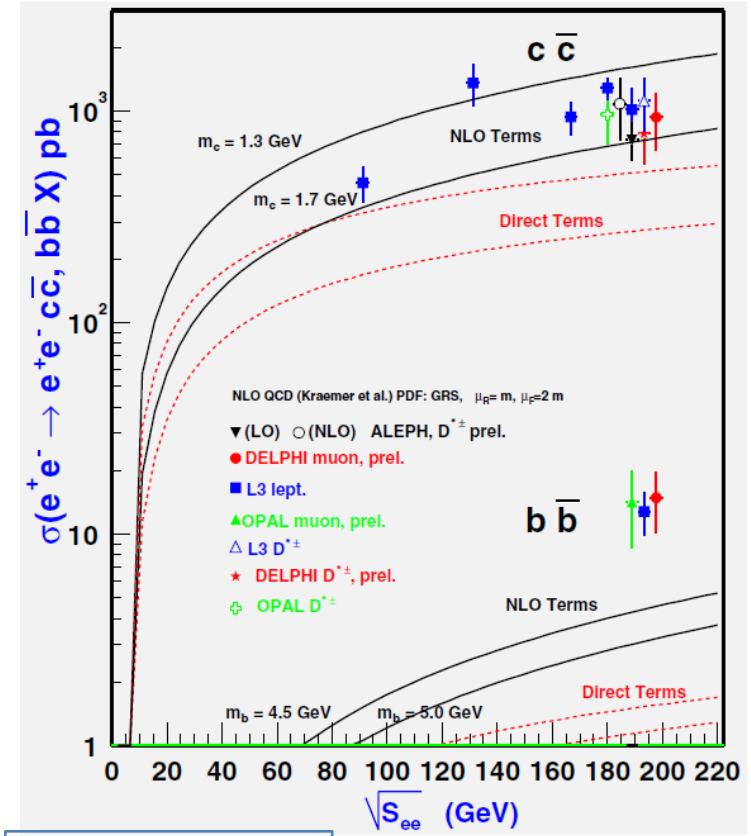
$$\sigma(e^+e^- \to e^+e^- b\bar{b}\,X) = (5.4 \pm 0.8_{\,\mathrm{stat}} \pm 0.8_{\,\mathrm{syst}})\,\mathrm{pb}$$

$$x_\gamma^{\pm} = \frac{\sum_{i=1,2}(E^i \pm p_z^i)}{(E^{\mathrm{tot}} \pm p_z^{\mathrm{tot}})}$$



DELPHI, L3

- o anti-tagged hadronic
- o b-jet semi-leptonic: e, mu



PLB 619 71 (2005)

DELPHI 2003 CONF-A325 , EPJC 33 s482 (2004)

Summary on two-photon

- two-photon final states
  detected by central tracker, Ecal, with small $E_{\gamma\gamma} < \sqrt{s}$
- scattered electrons
  tagged by LumiCal
- Requires two-photon trigger:
  multiple low energy tracks + Ecal clusters

➔ ***CEPC statistics will clarify two-photon c, b production***

➔ ***higher two-photon Q^2 to photon structure***