Bhabha acceptance at STCF

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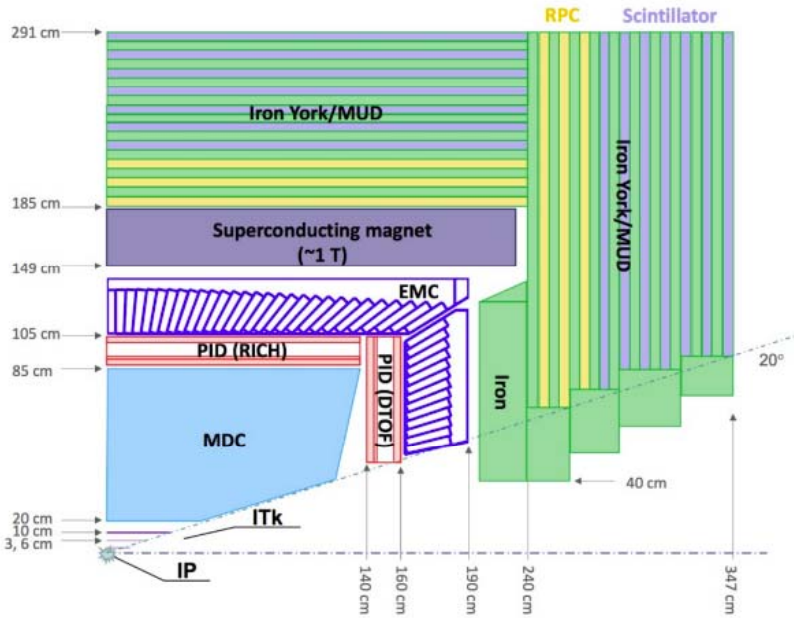
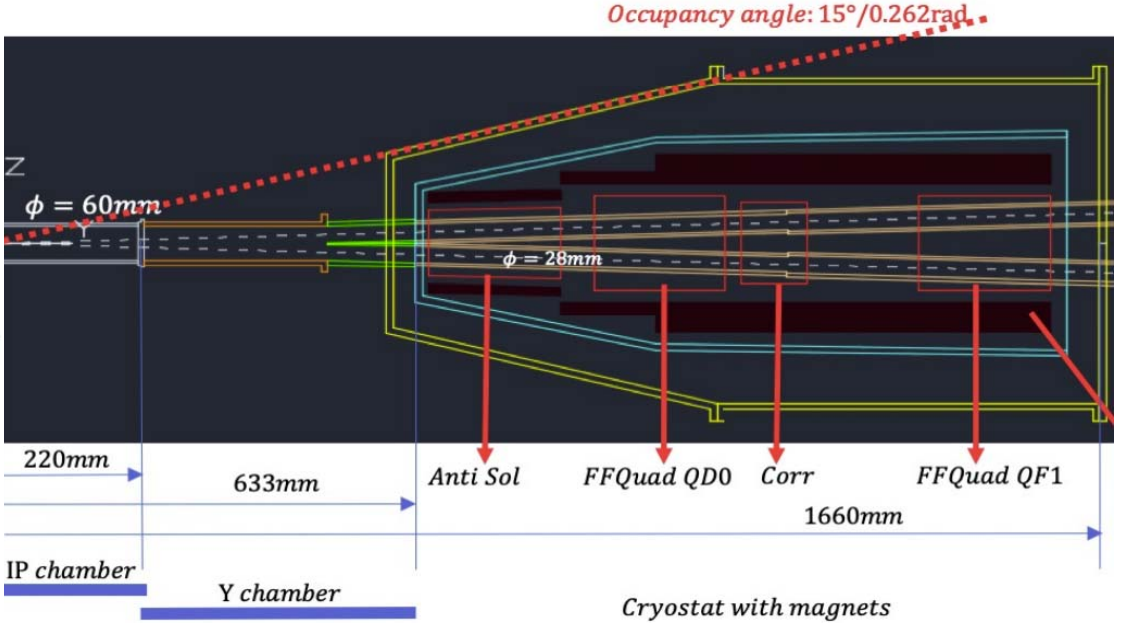
- **BHWIDE** Bhabha simulation
- Radiation gamma measurement
- Event rate in Forward region



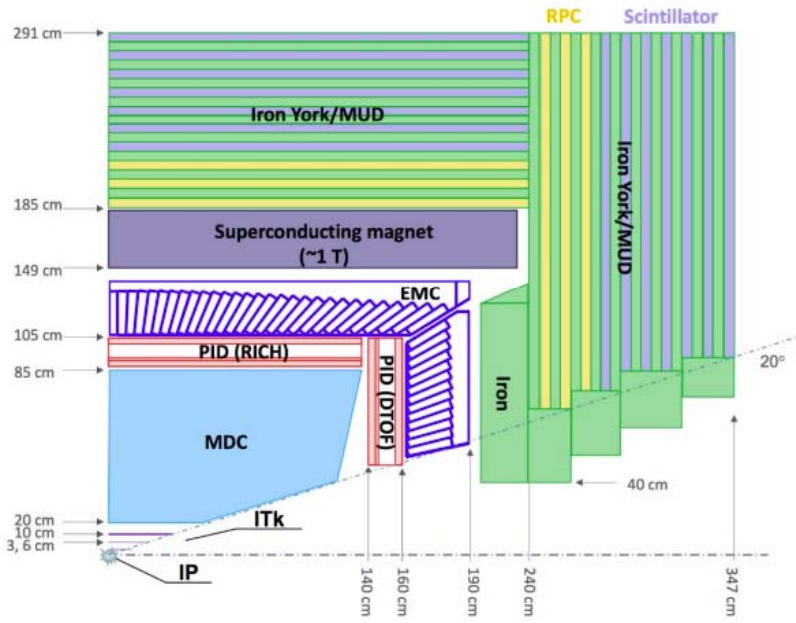


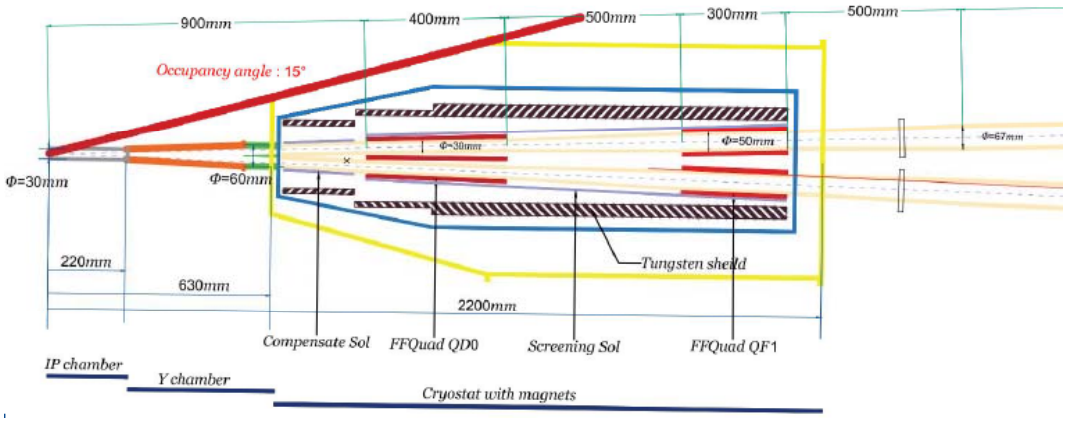
STCF Bhabha acceptance

Small Angle: 60 – 240 mRad (3.4° - 14°)

Large angle: 20° – 160° by EMC

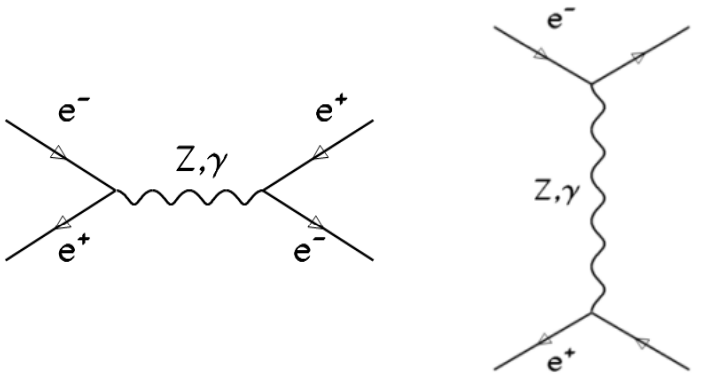
- **BHWIDE** generator in two regions
  1° – 20°, 20° -160°
- Boosted for 60 mRad beam crossing
  √s = 2 – 10 GeV
- **Beam pipe Ø=30 mm**
  FWD at |z| = 500 mm





Luminosity precision required for SM, R

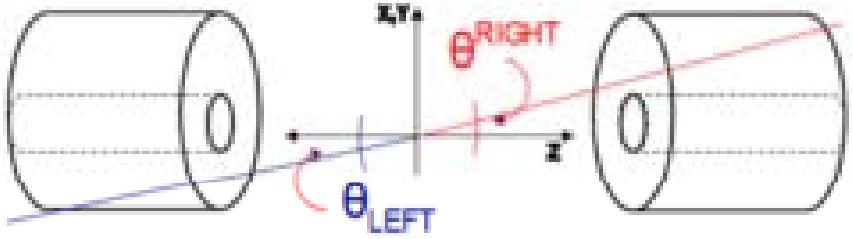
Bhabha $e^+e^- \to e^+e^-(n\gamma)$



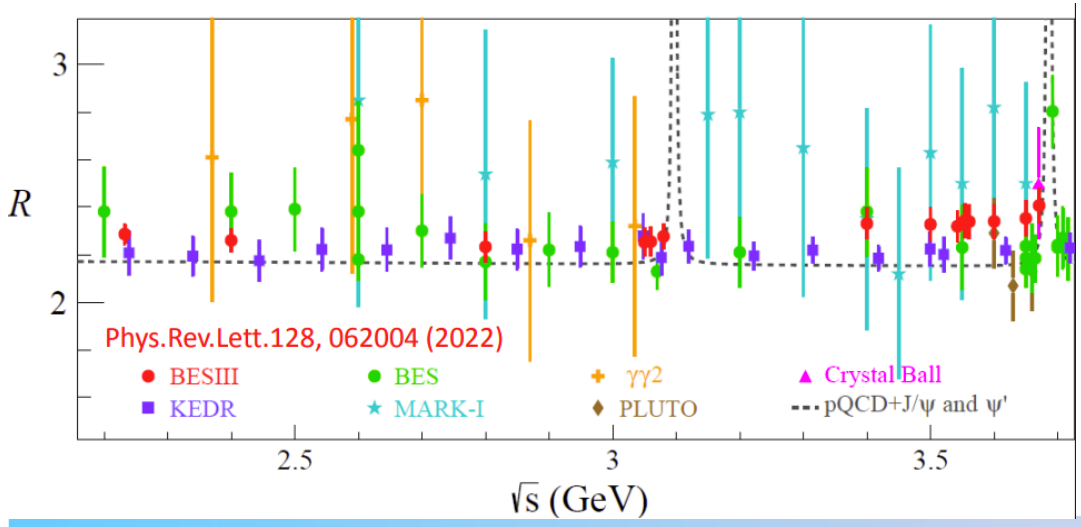
$R(s)$ ratio for SM predictions
$a_\mu = (g_\mu\text{-}2)/2$ and $\Delta\alpha_{had}(M_Z)$

$$a_\mu = \frac{\alpha^2}{3\pi^2}\int_{m_\pi^2}^{\infty} ds\, K(s)\frac{R(s)}{s}$$

$$\Delta\alpha^{(5)}_{had}(M_Z^2) = -\frac{\alpha M_Z^2}{3\pi}\,\mathrm{Re}\int_{m_\pi^2}^{\infty}\frac{R(s)ds}{s(s-M_Z^2-i\epsilon)}$$



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



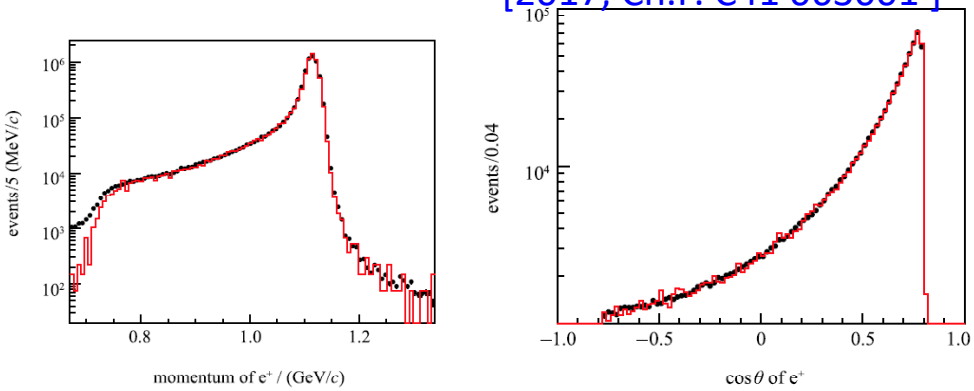
BESII in 2–5 GeV, precision 6%
BESIII 2022 3%

Bhabha experimental results $e^+e^- \to e^+e^-(\gamma)$

BESIII Luminosity $(\gamma)e^+e^-$, $(\gamma)\gamma\gamma$
Systematic error **~0.7%**

√s = 2.23 - 4.59 GeV

[2017, Ch.P. C41 063001]



TASSO Bhabha
Systematic error **~3%**

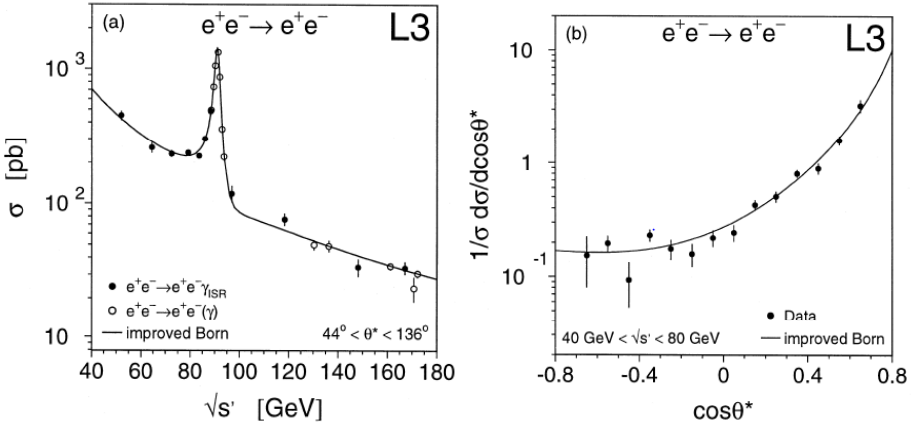
√s = 12 - 47 GeV

Table 1. Data samples used for the analysis $e^+e^- \to e^+e^-$

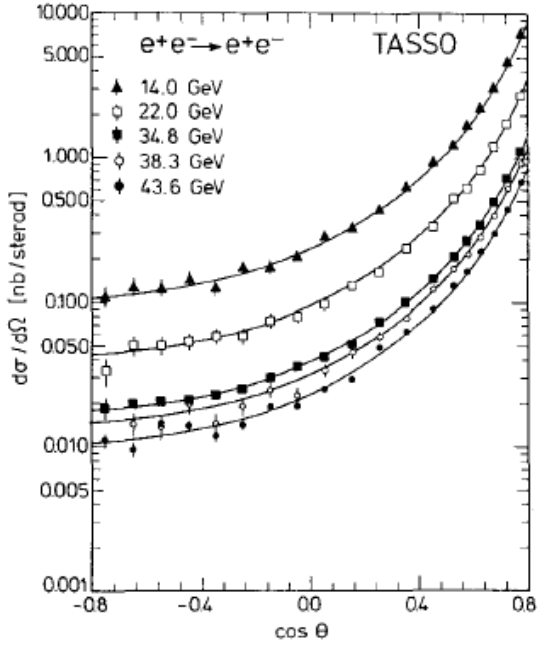
$\langle\sqrt{s}\rangle$ (GeV)	$\int \mathcal{L}\,dt$ (pb^{-1})	N_{Bhabha}
14.0	1.7	10730
22.0	2.7	7106
34.8	174.5	166348
38.3	8.9	6035
43.6	37.1	22951

L3 radiative Bhabha with **ISR**
Systematic error at **~1% level**

√s= 50 ~ 170 GeV, 232 pb^{-1}, 2856 event



[1998, PLB 439, 183]



[1988, ZPC 37, 171]

CM frame BHWIDE cross-sections

BHWIDE demo.f parameters

```
For the bosons we have (everything in GeV):
 mass of the   Z   =   91.1880    total width of the Z =  2.4972819
 mass of the   W   =   80.3352    <==> sin**2(theta-w) =  0.2238667
 mass of the Higgs =  125.2000

Some coupling strengths:
                 1/alfa =    137.036
the QED correction factor =      1.0017421
             alfa-strong =      0.119
the QCD correction factor =      1.0398948
```

```
Xsection_tot =    34034450.347498 [pb]
error        =       90962.430061 [pb]
```

```
*****************************************************************
* BBBBBBB   BBB   BBB  BBB       BBB  BBB  BBBBBBB    BBBBBBB *
* BBB  BBB  BBB   BBB  BBB       BBB  BBB  BBB  BBB   BBB     *
* BBB  BBB  BBB   BBB  BBB       BBB  BBB  BBB   BBB  BBB     *
* BBBBBBB   BBBBBBBBB  BBB       BBB  BBB  BBB   BBB  BBBBBB  *
* BBBBBBB   BBBBBBBBB  BBB   B   BBB  BBB  BBB   BBB  BBBBBB  *
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* BBBBBBB   BBB   BBB  BBBBB    BBBB  BBB  BBBBBBB    BBBBBBB *
*****************************************************************
*     MC Event Generator for Wide-Angle Bhabha Scattering       *
*                   BHWIDE version 1.06                         *
*****************************************************************
********************* December 2024 *****************************
*****************************************************************
*              Last modification: 04.12.2024                    *
*****************************************************************
*                          AUTHORS:                             *
*          S. Jadach              (Deceased)                    *
*          W. Placzek             (wieslaw.placzek@uj.edu.pl)   *
*          B.F.L. Ward            (bfl_ward@baylor.edu)         *
*****************************************************************
*                          PAPERS:                              *
* [1] S. Jadach, W. Placzek, B.F.L. Ward,                       *
*     Phys. Lett. B390 (1997) 298; hep-ph/9608412.              *
*****************************************************************
```

CM frame cross section σ; scattered e± > 0.1 GeV; back-to-back 0 - π					
√s GeV	2	4	6	8	10
1 – 20 deg	851000 nb	214200 nb	95300 nb	53700 nb	34400 nb
20 – 160 deg	1800 nb	455 nb	204 nb	115 nb	73.9 nb

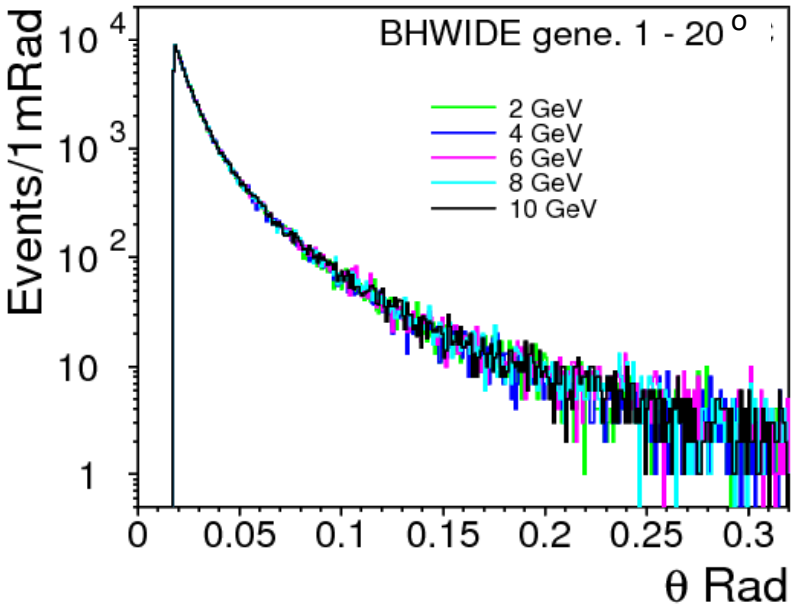
Bhabha √s dependency

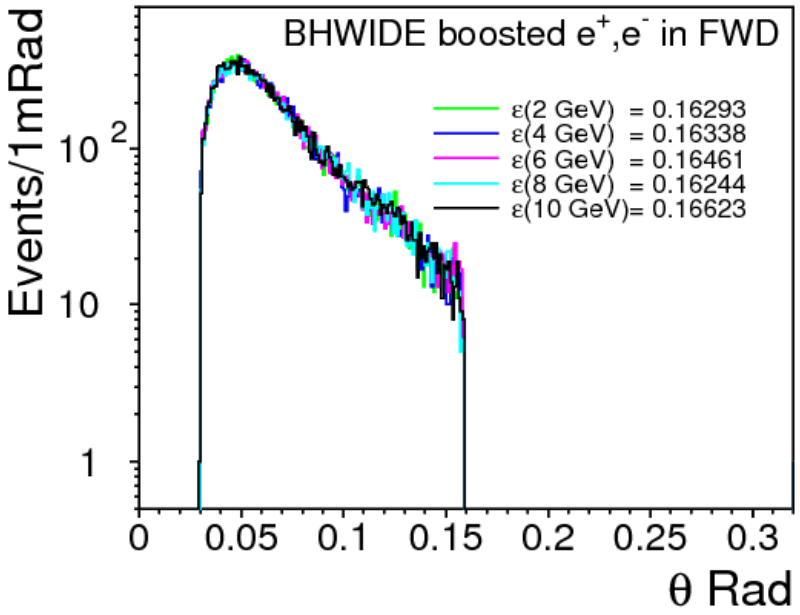
BHWIDE center-of-mass

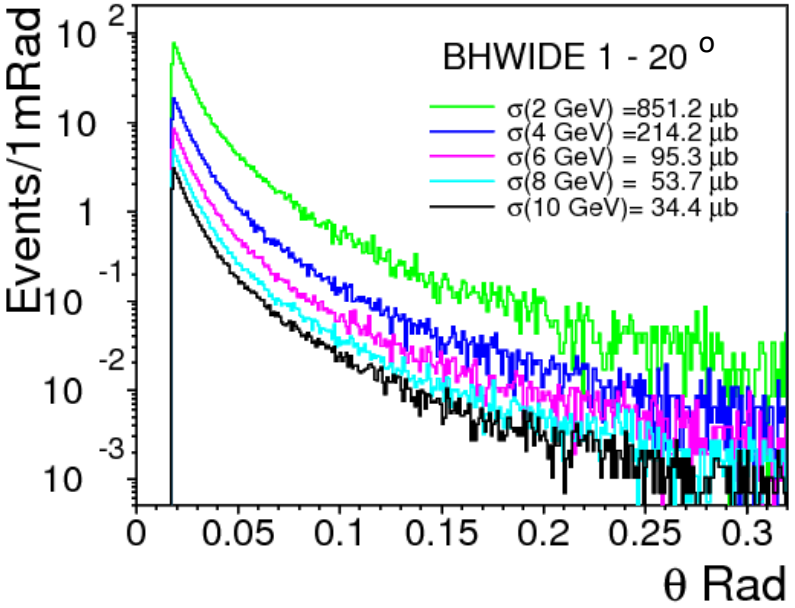
√s = 2 - 10 GeV, θ range 1 – 20°

- **θ distribution**: same, well overlap
- Cross section higher at low
- 60 mRad beam-crossing boost
- Events both e^+, e^- in FWD @ |z| = 500mm off beampipe Ø = 30 mm; r < 80mm

acceptance: ε ~ 16.3 %



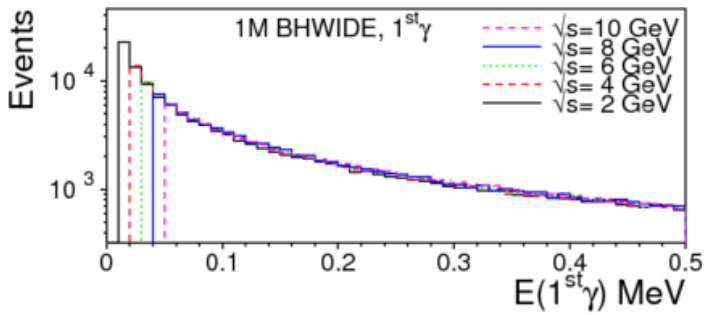


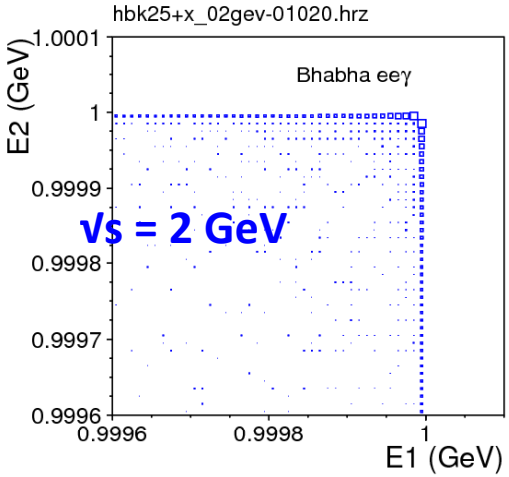


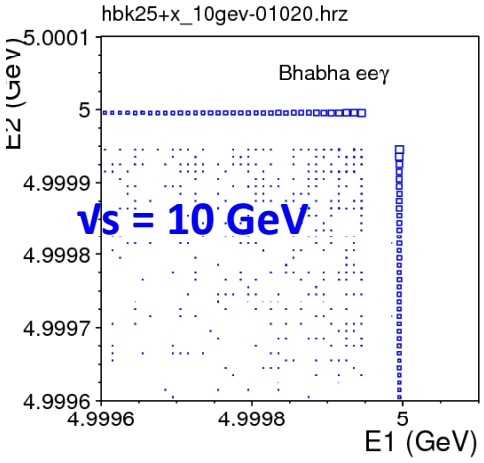
BHWIDE radiative Bhabha $e^+e^-(n\gamma)$

Compare E(γ) in 1M events, √s = 2 – 10 GeV

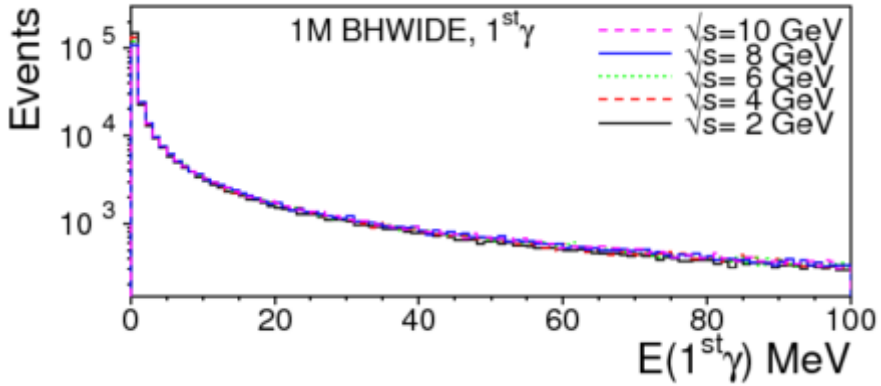
E (γ) cut = 1 x 10^{-5} x E_{beam}

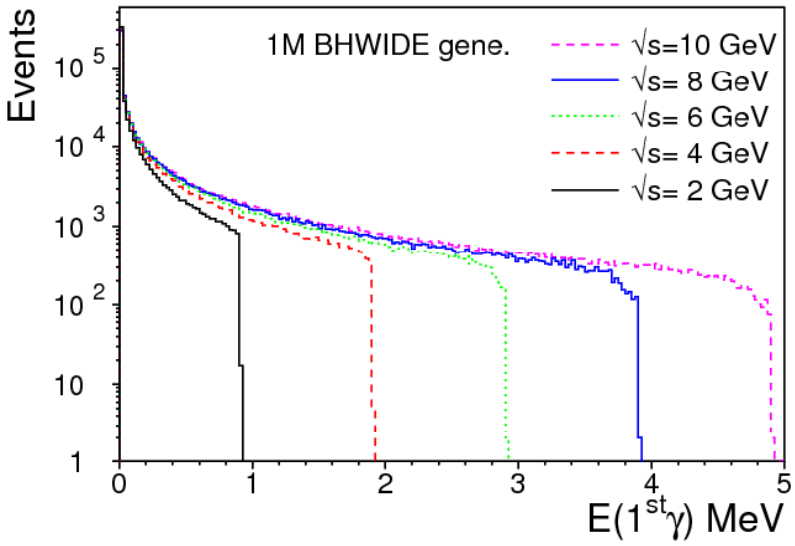






1st γ distribution, (1M @ 2 – 10 GeV)
low E, indep. of √s, extend to E_{beam}



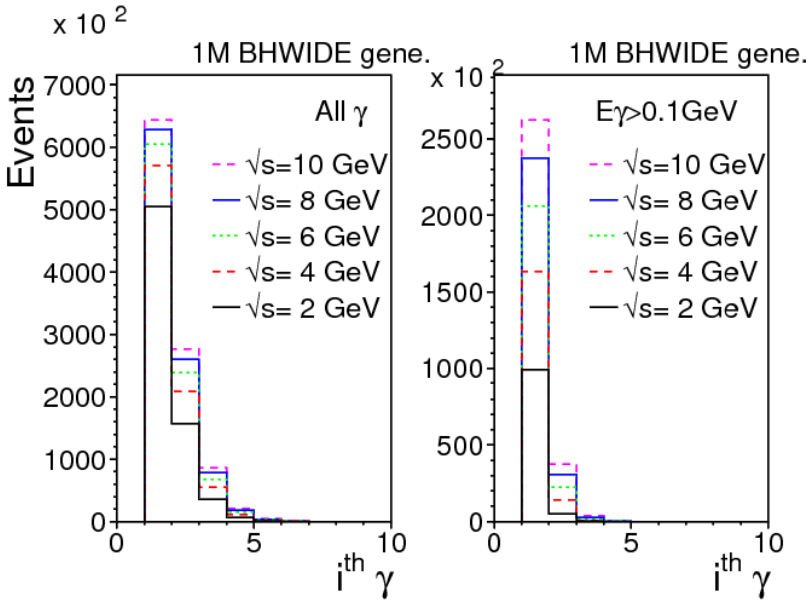


BHWIDE radiative Bhabha $e^+e^-(n\gamma)$

Yennie-Frautschi-Suura (YFS) exponentiation method

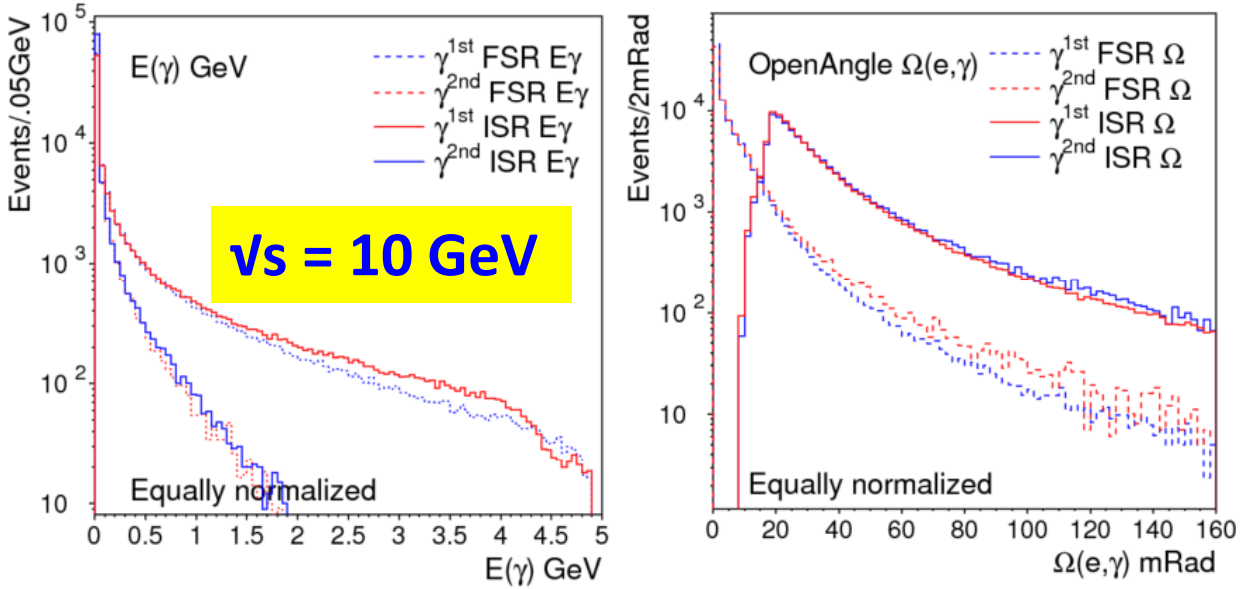
➔ **nγ in Poisson distribution**

➔ **nγ generated at vertex, no correlation with electrons**



Photons ordered by Eγ

ISR/FSR by OpenAngle Ω(e,γ) closer to inci/scat $e^{\pm}$



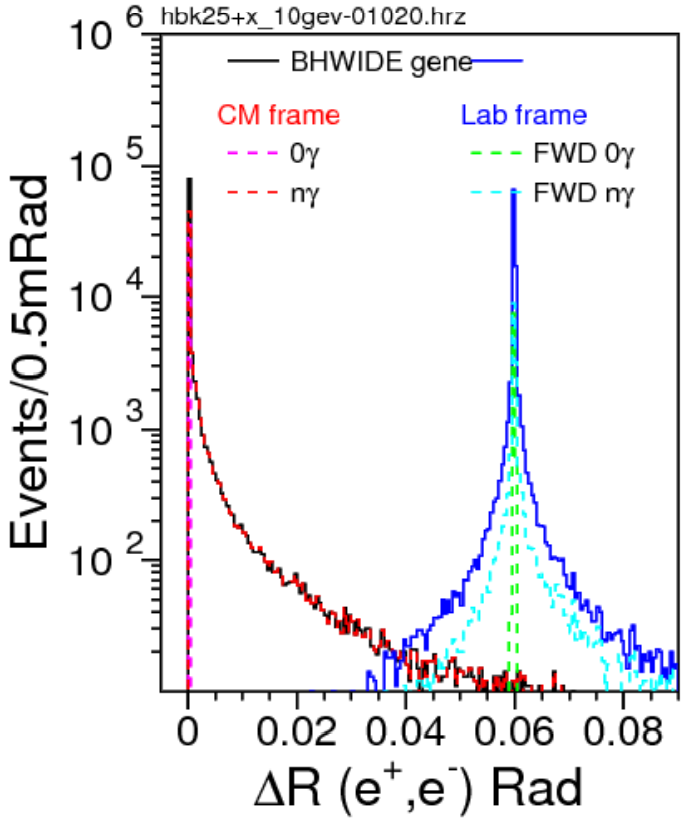
BHWIDE e^+,e^- back-to-back

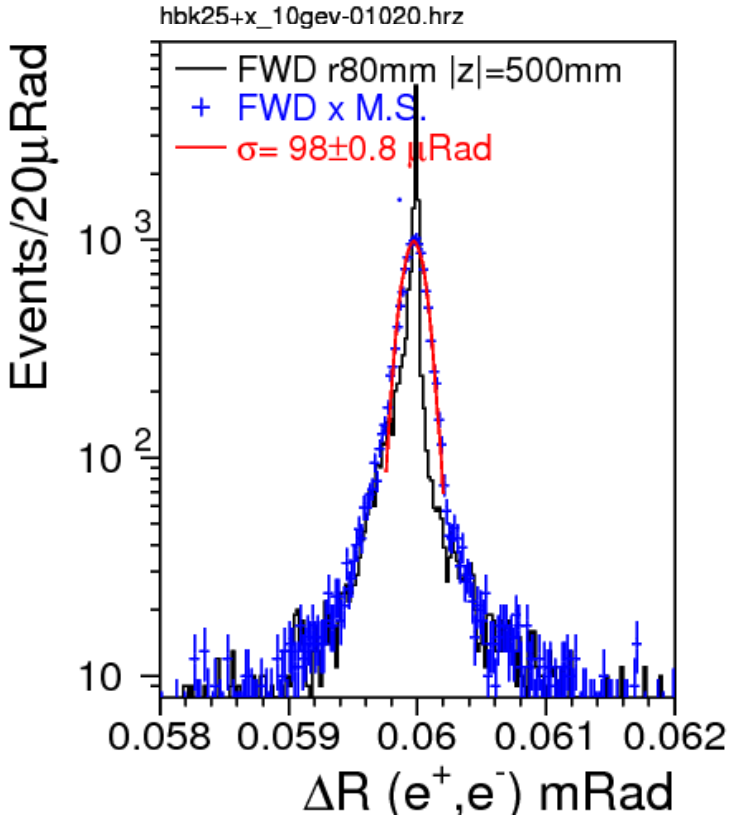
e^+e^- back-to-back angle – π

Delta/tails for 0γ/nγ events

Assuming Multiple-Scattering 100 µRad

Width distinguishable to Bhabha





Bhabha FWD acceptance

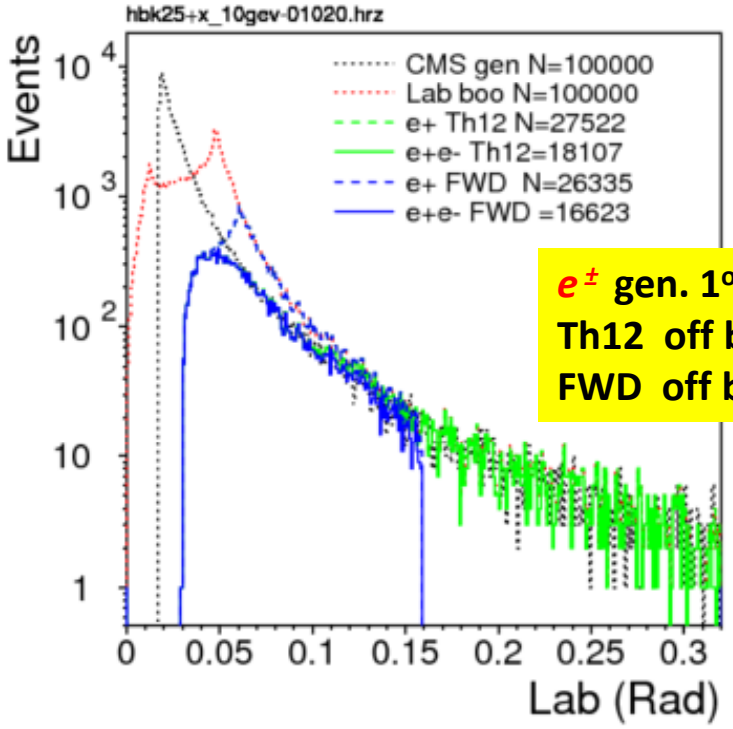
BHWIDE √s = 10 GeV

boosted for 60 mRad e^+e^- beam crossing

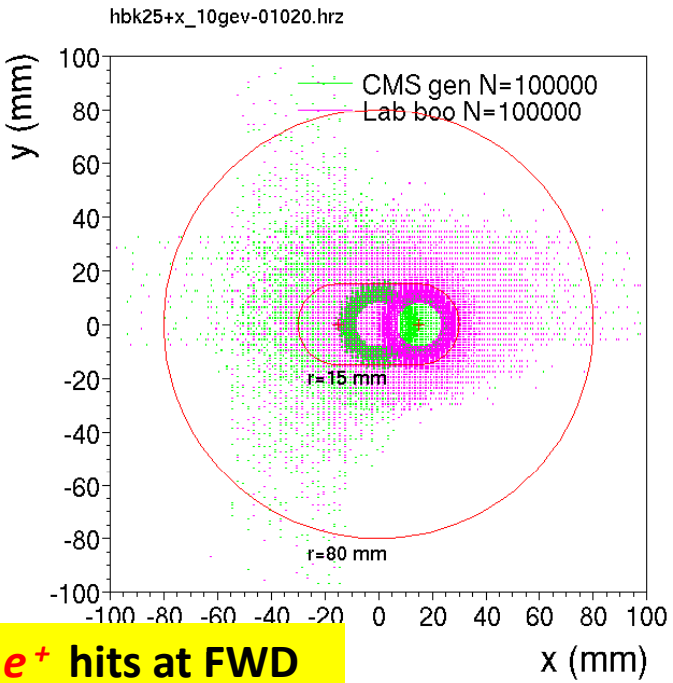
FWD acceptance at |z| = 500 mm

both e^+e^- > beampipe, radius < 80mm

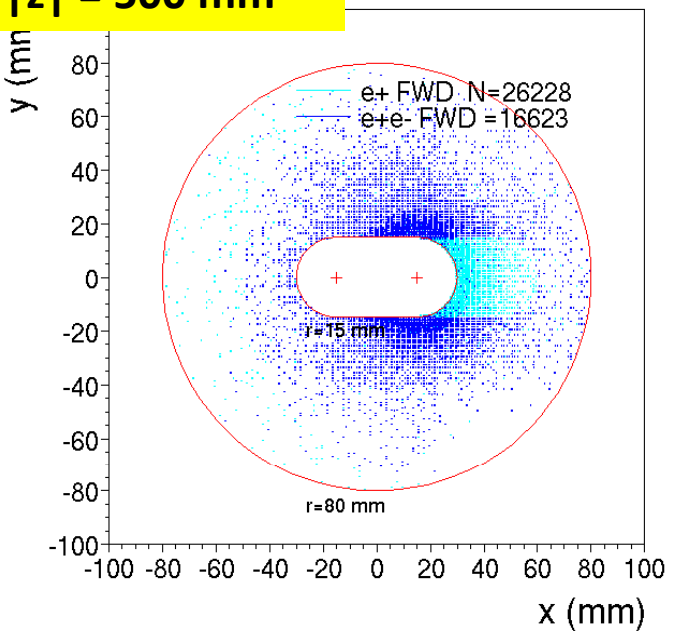
ε = 16.7 %



$e^\pm$ gen. 1° – 20°
Th12 off b.p. < 20°
FWD off b.p. r < 80mm

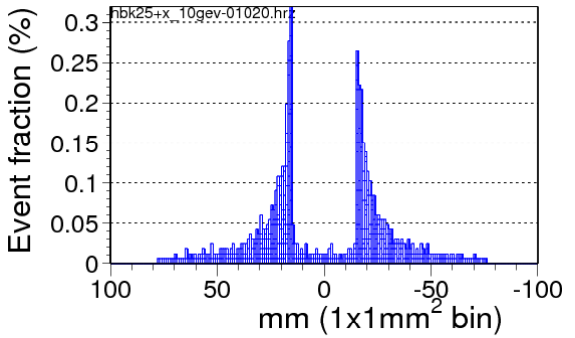


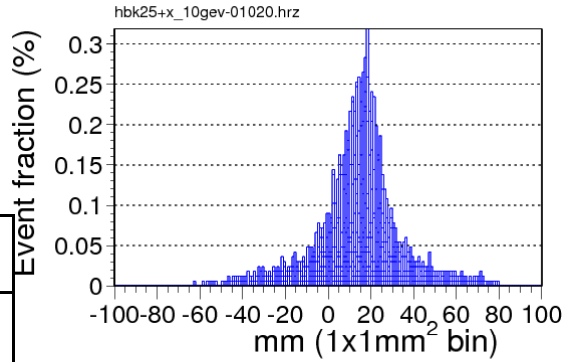
e^+ hits at FWD
|z| = 500 mm

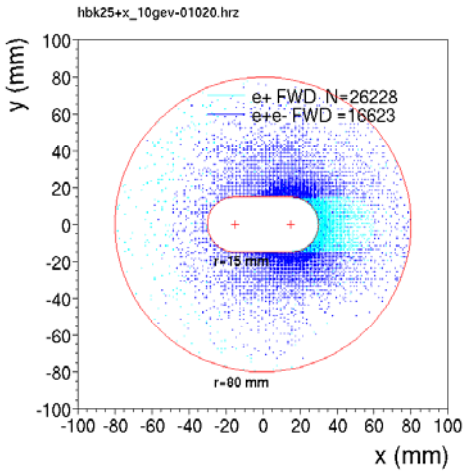


Bhabha on FWD, electron hit rate

Bhabha on FWD normalized to 1







BHWIDE √s = 10 GeV

Gen. 1-20°, **σ=34.4k nb**; Acceptance in FWD, **ε=16.6%**

- **FWD event rate max ~0.3 % in 1x1 mm²**
  (full acceptance normalized to 1)
  $\sigma \times \varepsilon \times$ **0.3%** = $34400 \times 0.166 \times 0.003 = 17.1$ nb
- **Bhabha event rate at FWD** (1 barn = 10^{-28} m²)
  L/IP = 5×10^{34} /cm² sec
  Event rate = $(17.1 \times 10^{-9-24}$ cm²) $(5 \times 10^{34}$ /cm² sec)
  at the hottest 1x1 mm² **= 857 /sec**

CMS cross section σ; scattered $e^{\pm}$ > 0.1 GeV; back-to-back 0-π					
√s GeV	2	4	6	8	10
1 – 20°	851k nb	214k nb	95k nb	54k nb	34.4k nb
both $e^{\pm}$ in FWD (off-pipe ϕ30mm, r<80mm)					
FWD ε	0.163	0.163	0.165	0.162	0.166
1x1 mm² hottest cell, electron hit rate					
Ev. /sec	**21.2k**	**5.33k**	**2.37k**	**1.34k**	**0.86k**

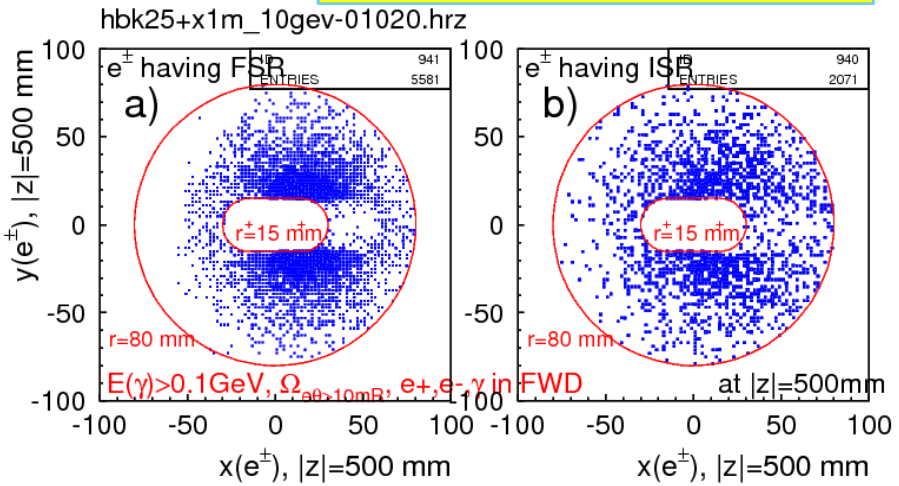
Per 100 ns event pile-up rate at 2 GeV: 21.2k/10^7= 0.0021

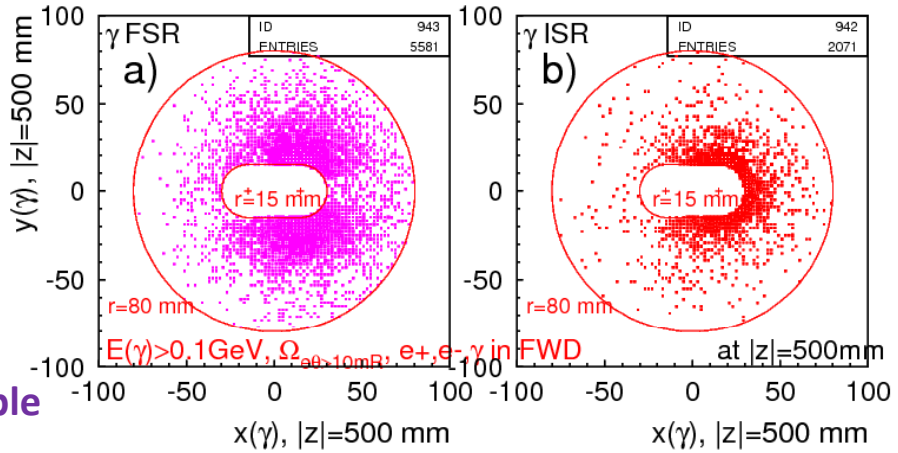
Rad-Bhabha distributions $e^+e^- \rightarrow e^+e^-(n\gamma)$

BHWIDE $\sqrt{s}$ = 10 GeV $e^+e^- \rightarrow e^+e^-(n\gamma)$

- **Detect rad-Bhabha, scattered e^+, e^-, γ^{1st}**
- **FWD acceptance:**
  off-pipe ϕ30mm, $x_c = \pm 15$mm
  external r<80mm
- **γ^{1st} selection:**
  $E\gamma > 0.1$ GeV,
  opening angle $\Omega(e^{\pm}, \gamma^{1st}) > 10$ mRad
- **event rate in Bhabha**
  to both e^+, e^- detected in FWD
  each z-side, **$e^{\pm}$ with γ^{1st} measured**

- $e^{\pm}$ with near γ^{1st} (FSR) near beam-pipe
- $e^{\pm}$ with far γ^{1st} (ISR) Loose scattered





BHWIDE scattered $e^{\pm}$ > 0.1 GeV; $\Omega(e^+e^-)$: 0-π $\sigma(1\text{-}20^o)$= **34.4k nb**, e^+e^- in FWD rate= 16.5%		
Detected in each z-side both e^+e^- in FWD		**each z-side, $e^{\pm}, \gamma^{1s}$ in FWD** E_γ> 0.1GeV $\Omega(e^{\pm}, \gamma^{1st})$>10mR
$e^{\pm}$,0γ	56.1 %	
$e^{\pm}$,nγ	43.9 %	**ISR 0.63 %** **FSR 1.7 %**

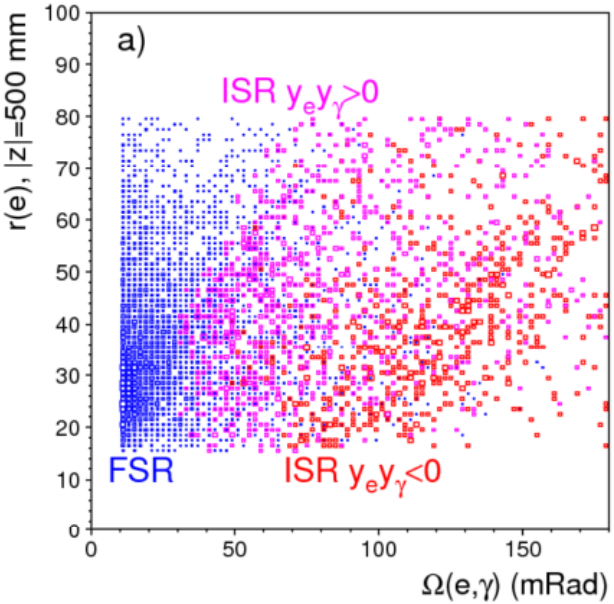
measurable

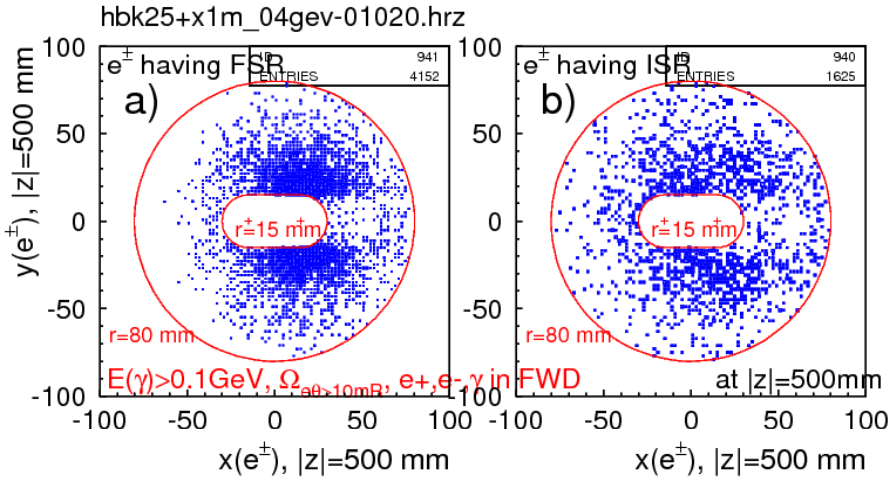
Rad-Bhabha distributions $e^+e^- \rightarrow e^+e^-(n\gamma)$

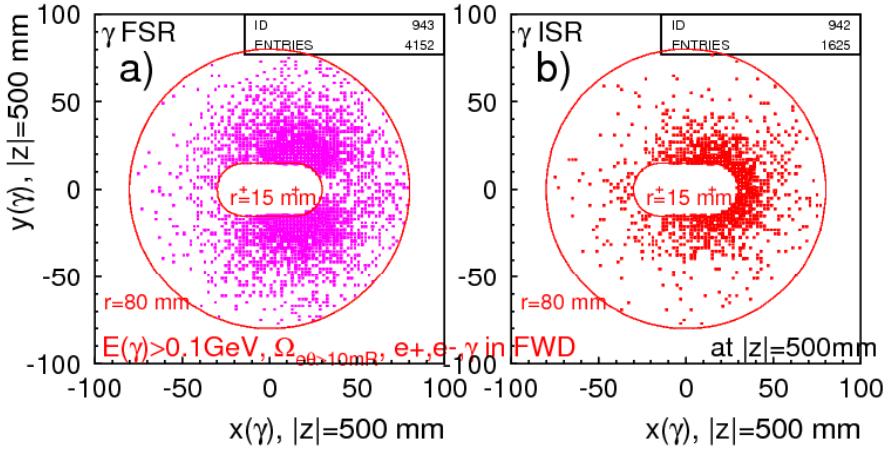
BHWIDE $\sqrt{s}$ = 4 GeV $e^+e^- \rightarrow e^+e^-(n\gamma)$

- **Detect rad-Bhabha, scattered e^+, e^-, γ^{1st}**
- **Distinguish ISR/FSR $r(e^\pm)$ vs $\Omega(e^\pm, \gamma^{1st})$**

- $e^\pm$ with near γ^{1st} (FSR) near beam-pipe
- $e^\pm$ with far γ^{1st} (ISR) Loose scattered







BHWIDE scattered $e^\pm$ > 0.1 GeV; $\Omega(e^+e^-)$: 0-π $\sigma(1\text{-}20^o)$= **34.4k nb, e^+e^-** in FWD rate= 16.5%		
Detected in each z-side both e^+e^- in FWD		**each z-side, $e^\pm, \gamma^{1s}$ in FWD** E_γ> 0.1GeV $\Omega(e^\pm, \gamma^{1st})$>10mR
$e^\pm$,0γ	61.6 %	
$e^\pm$,nγ	38.4 %	**ISR 0.50 %** **FSR 1.26 %**

measural

Perspective for measuring Bhabha @ STCF

BHWIDE $\sqrt{s}$ = 2 – 10 GeV

scattered $e^{\pm}$ > 0.1 GeV; $\Omega(e^+e^-)$: 0-π

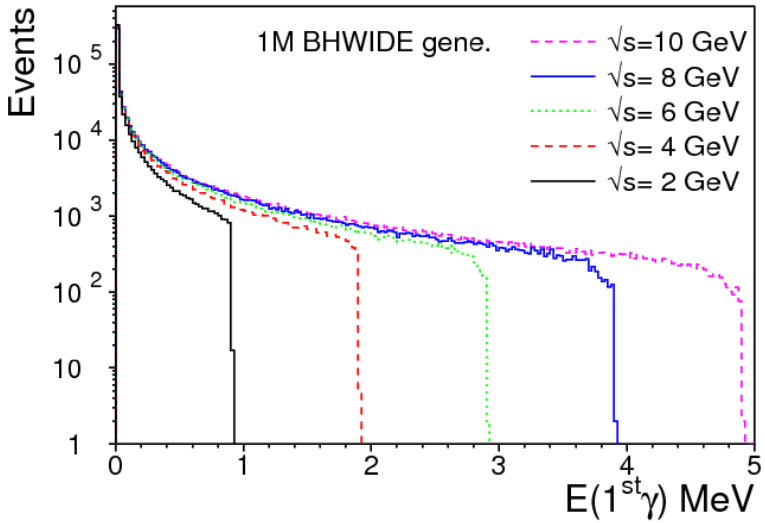
CMS generted for σ(1-20°)

Acceptance e^+e^- in FWD **= 16.5%**

Both e^+e^- fall in FWD

event ratio with

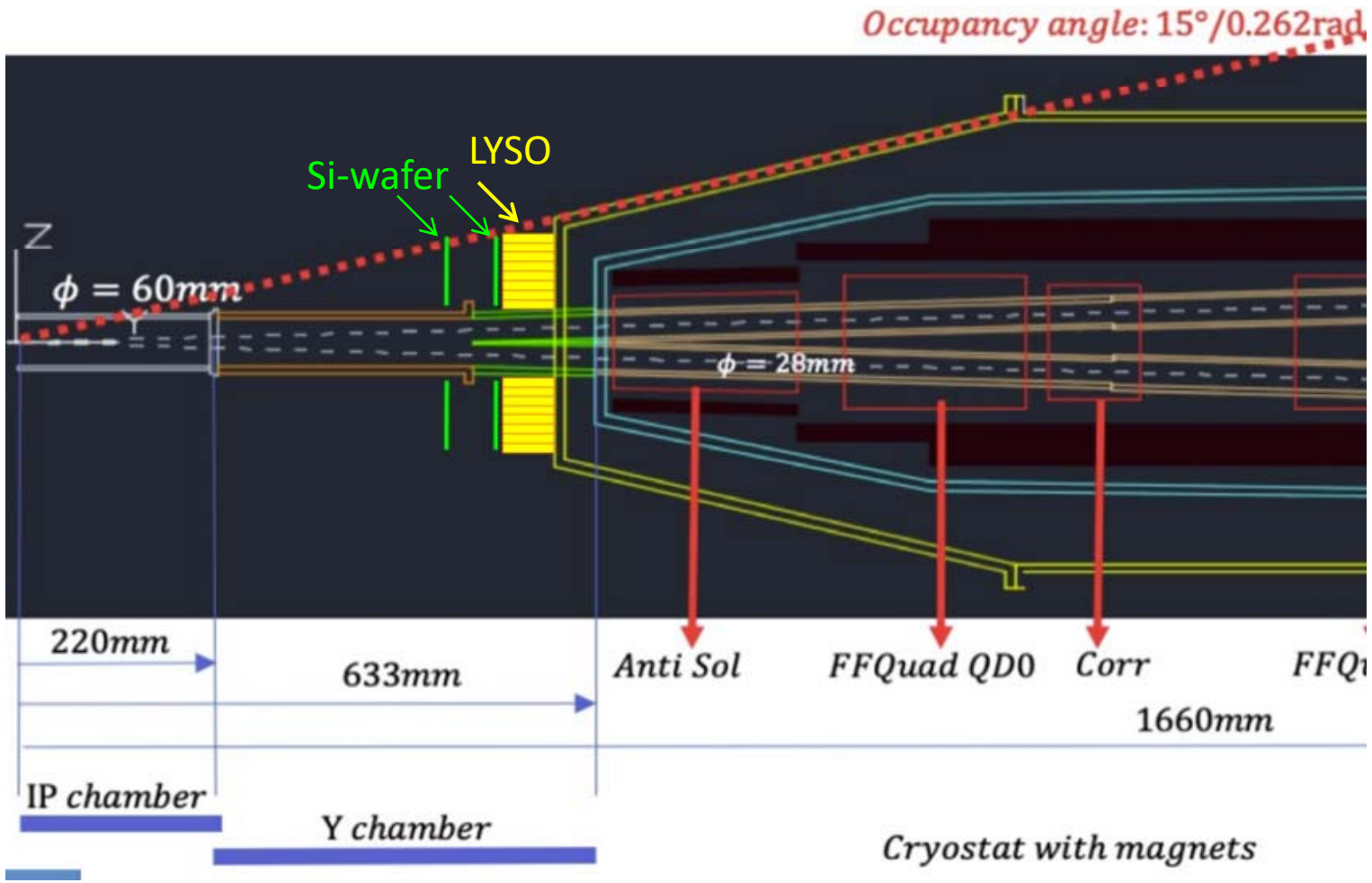
- **0/nγ** generated
- **γ^{1st}** Eγ>0.1 GeV, $\Omega(e^{\pm},\gamma^{1st})$>10 mR



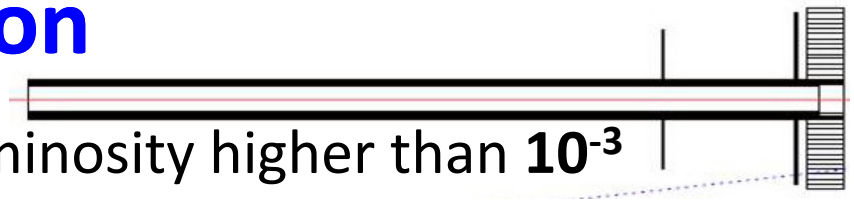
Detected in each z-side	√s =	10 GeV	8 GeV	6 GeV	4 GeV	2 GeV
both e^+e^- in FWD	$e^{\pm}$,0γ	56.1 %	57.1 %	59.1 %	61.6 %	66.0 %
	$e^{\pm}$,nγ	43.9 %	42.9 %	40.9 %	38.4 %	34.0 %
$e^{\pm},\gamma^{1s}$ in FWD E_γ> 0.1GeV, $\Omega(e^{\pm},\gamma^{1st})$>10mR	$e^{\pm},\gamma^{1s}$	ISR 0.63 % FSR 1.69 %	ISR 0.64 % FSR 1.62 %	ISR 0.58 % FSR 1.47 %	ISR 0.50 % FSR 1.26 %	ISR 0.40 % FSR 0.94 %

ForWard Det, FWD of Si+LYSO @ STCF

- **Forward detector** for Bhabha Lumi; two-photon $e^{\pm}$-tagging
- **Si-wafer**: $e^{\pm}$ impact θ,ϕ; **LYSO 10 X_0**: to id. $e^{\pm}(E_{beam})$

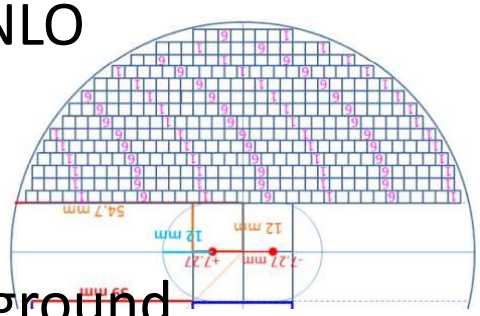


ForWard Det specification



- Measure **Radiative Bhabha**, for Luminosity higher than 10^{-3}

  $e^{\pm}(\theta,\phi)$ to 10 uRad, **e/γ** radiative photon to QED NLO

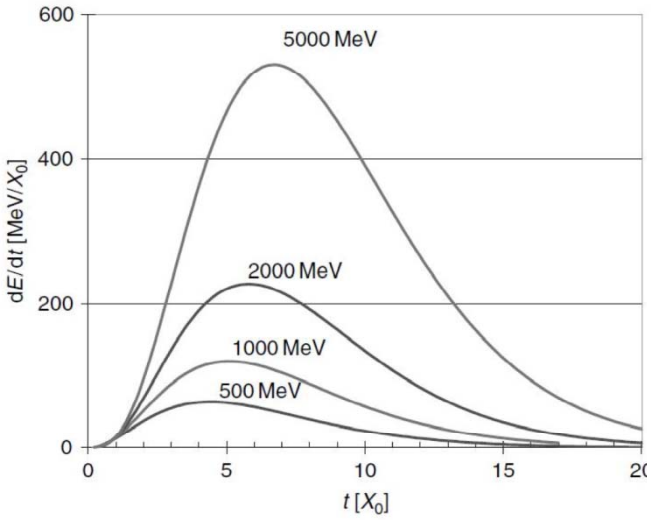


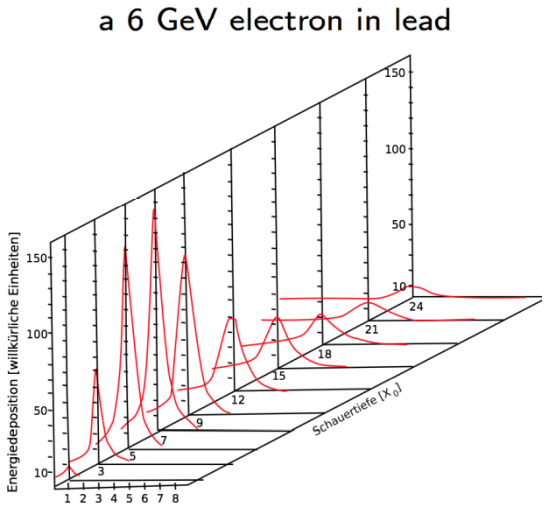
- **Si-wafer**: 2D strip, 100 μm pitch;

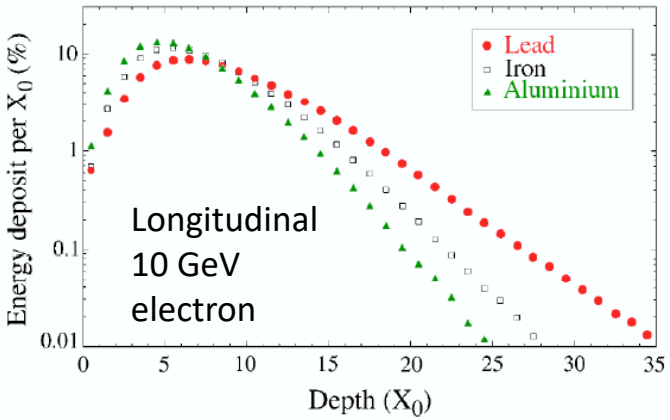
  LYSO 10 X_0: for shower max to 10 GeV

  Be, Al 0.3 X_0 beam pipe: prevent Preshower background

Space limit for LYSO up to 10 X_0 ?





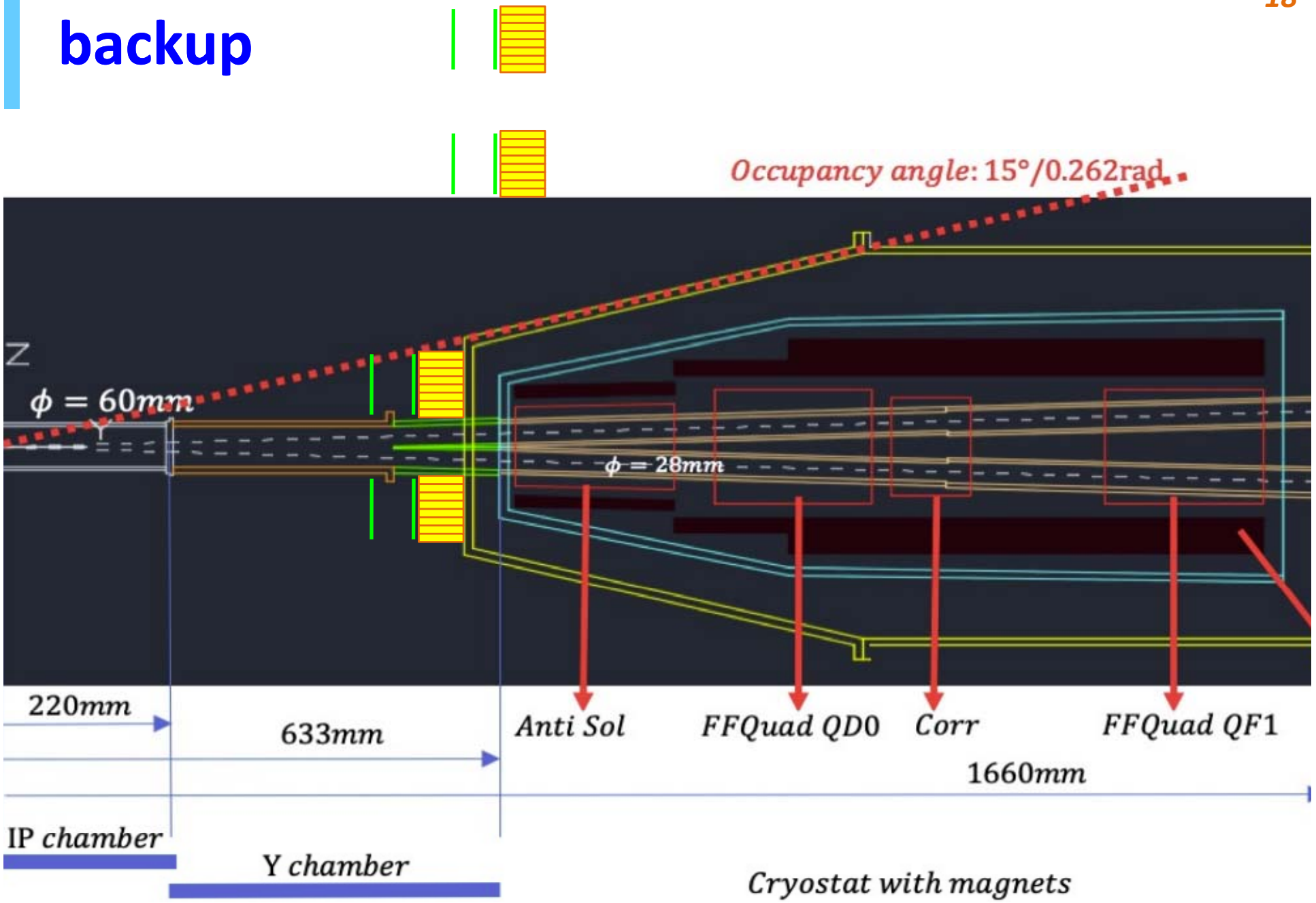


Longo 1975

Discussion

- **Radiative Bhabha**, evaluated with **BHWIDE** for **STCF**
- **LumiCal** at **|z| = 500 mm** for acceptance
  off-pipe **ϕ30 mm**, $x_c = \pm 15$ mm
  external **r < 80 mm** to z_{lab} axis
- **Hot spot** 1x1 mm^2 near beam-pipe,
  for **√s= 2** GeV electron hit **21 kHz**
  100 ns interval pileup rate **0.002** events
- **Bhabha radiative photon measurements**
  most energetic **γ^{1st}** Eγ>0.1 GeV, $\Omega(e^{\pm},\gamma^{1st})$>10 mRad
  for **√s= 2 to 10** GeV detect in FWD: e^{+},e^{-},γ^{1st}: **FSR 1.7% to 0.9%**
  ISR 0.6% to 0.4%
- **LumiCal** detect **e/γ : $e^{\pm}(\theta,\phi)$** to 10 uRad**,**
  Si-wafer: 2D strip, 100 μm pitch;
  LYSO 2x2mm^2 bars to 20mm (front $2X_0$)
  LYSO up to 10 X_0: for shower max to 10 GeV

backup


Occupancy angle: 15°/0.262rad
Z
ϕ = 60mm
ϕ = 28mm
220mm
633mm
1660mm
Anti Sol
FFQuad QD0
Corr
FFQuad QF1
IP chamber
Y chamber
Cryostat with magnets