$K_L \Rightarrow \pi^0 \nu\bar{\nu}$ at a Φ factory?

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Some bare facts:

A Φ-factory is naturally suited for a search of $K_L \to \pi^0 \nu\nu$ events since:

- Kaons are tagged
- Kaons 4-momentum is known (reconstruction of decay kinematics allowed)
- Beam free of neutral baryons backg.

Some bare facts:

Production rate: 10^6 K_S-K_L pairs / pb^{-1}

1 year @ 10^{35} $cm^{-2}s^{-1}$: 10^{12} K_L produced

observed decays: 30 $*$ ε_{tot} / year (SM)

must be $\varepsilon_{tot} \gtrsim$ 10%

The machine

2 options under study:

"conventional"

E_{beams} = 510 MeV

Short beams ($\sigma_z \sim$ 2 mm)

Improved optics

↓

4 π detector

"large crossing angle"

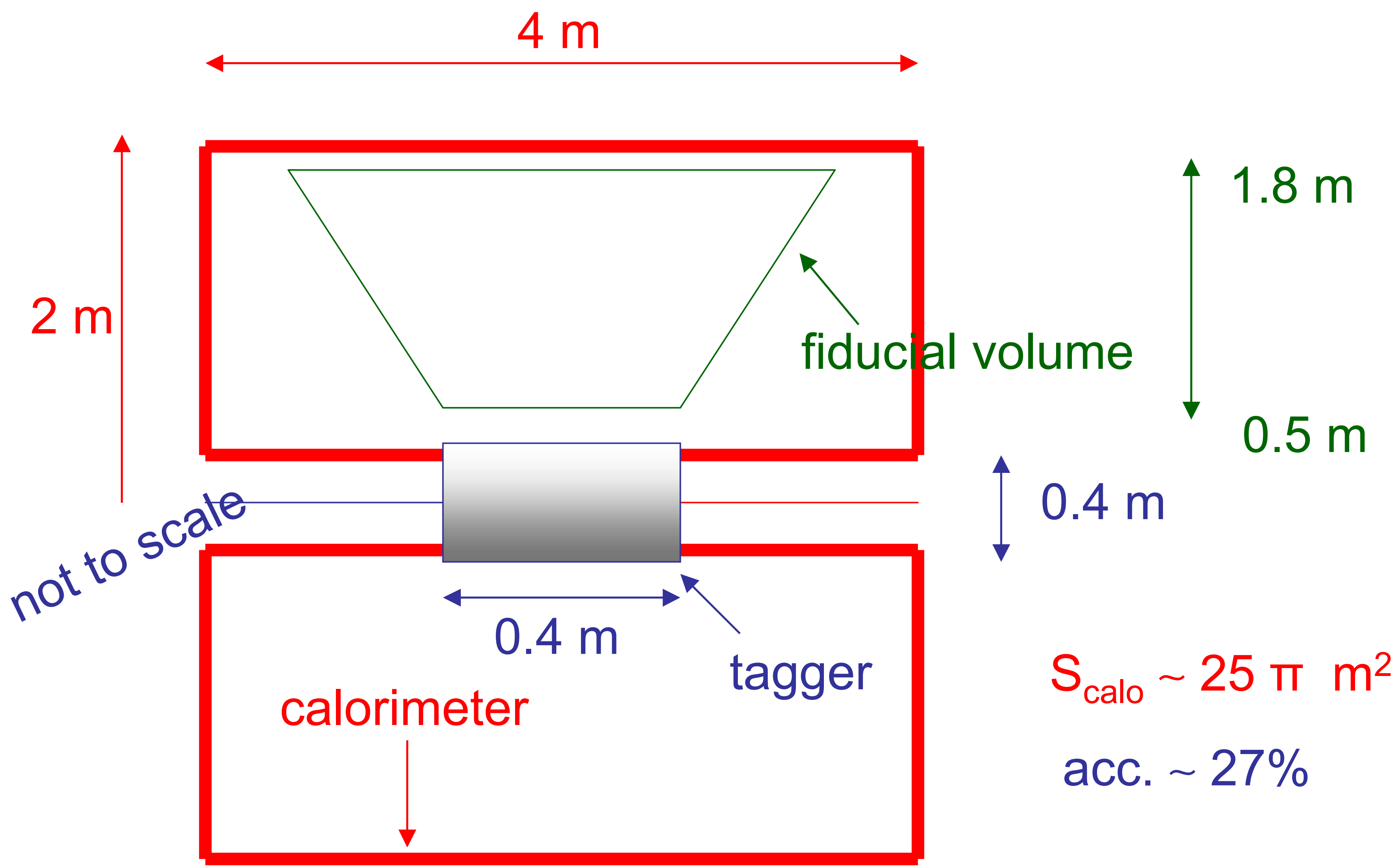
$E_{beams} \sim$ 1 GeV

Gain from natural increase of luminosity with energy

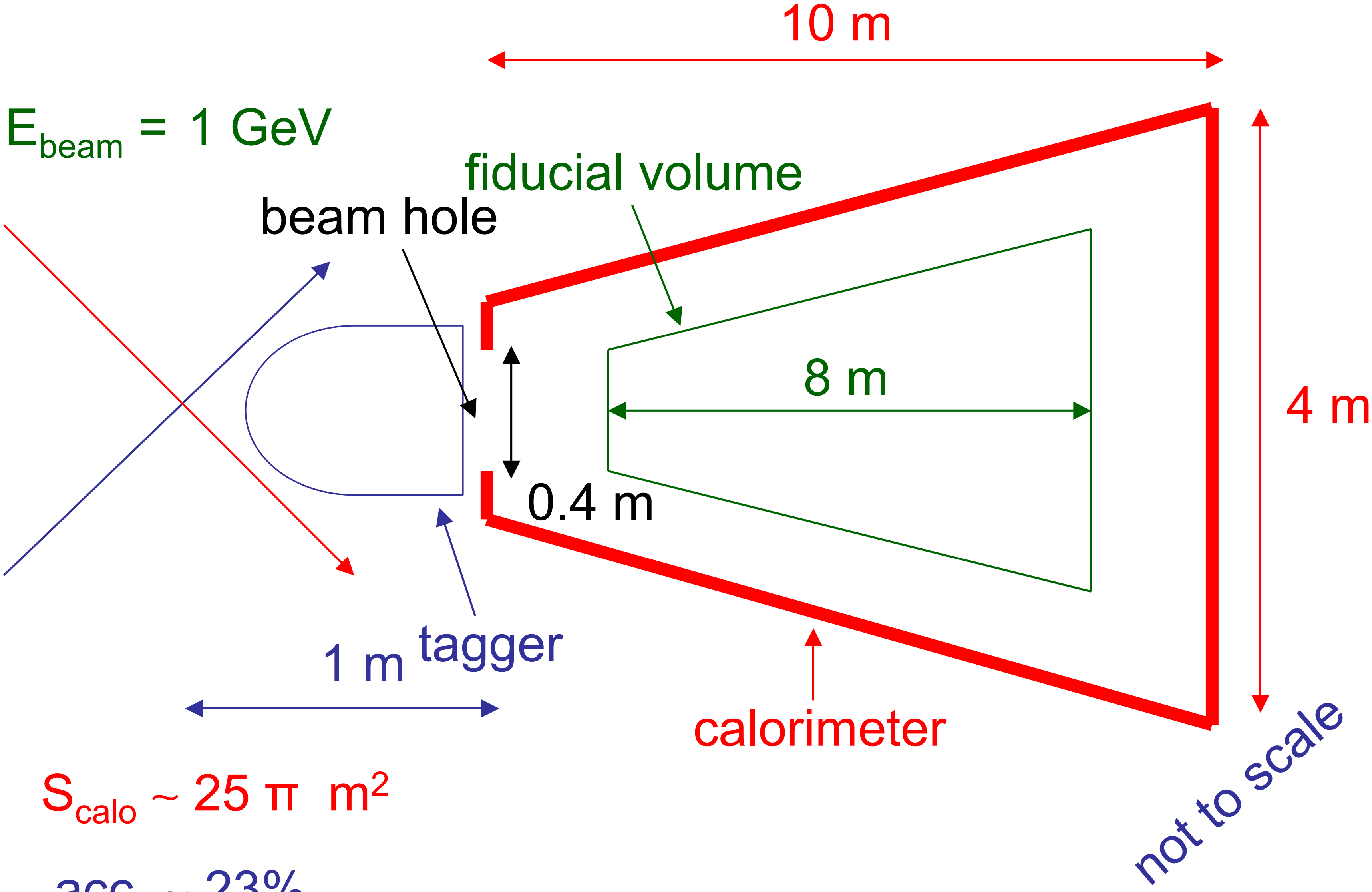
↓

forward detector

Detector concepts: "conventional"



Detector concepts: "forward"



$S_{calo} \sim 25\,\pi\ m^2$

acc. ~ 23%

Detector concepts: common

Choice of components driven ***mainly*** by the exceptionally high need for background rejection : (~ 10^8 $K_L \rightarrow 2\pi^0$ decays)

Calorimeter:

Totally hermetic

Highly efficient to γ (20 MeV – E_{max})

Excellent timing performance for decay point/time determination with the ***KLOE*** method (bunch x-ing every ~ 3 ns)

Tagger:

Compact

High rate capabilities because (also) of machine background close to i.p.

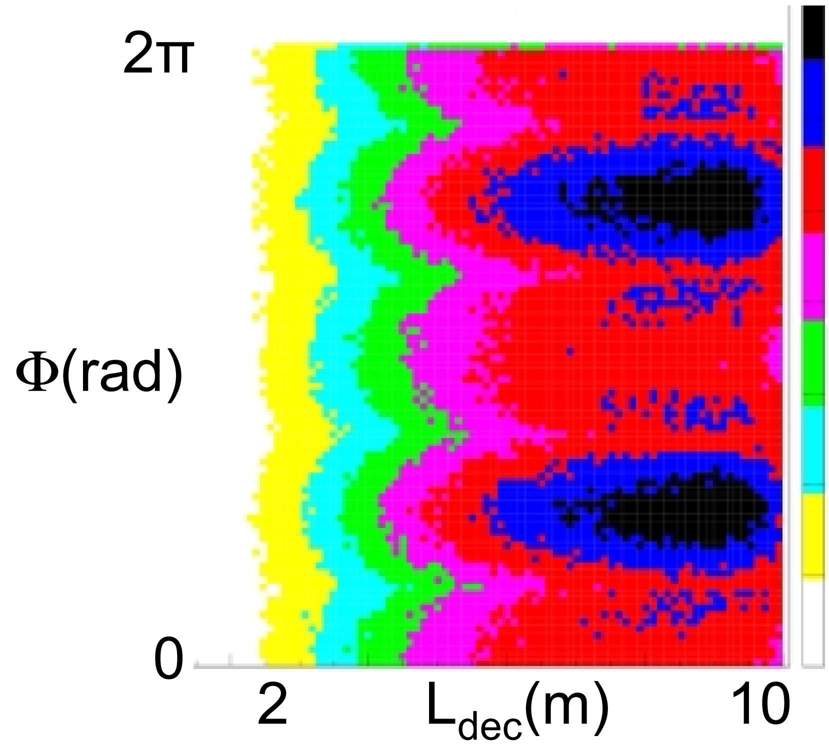
Photons acceptance

"forward "

naturally hermetic

critical point: beam hole

$P_{2\gamma lost} \sim 10^{-7}$ ($2\pi^0$ decays)



"conventional"

critical point: i.r. + tagger

$P_{2\gamma lost} \sim k\, f(x^0)^2_{tagg}$

($2\pi^0$ decays)

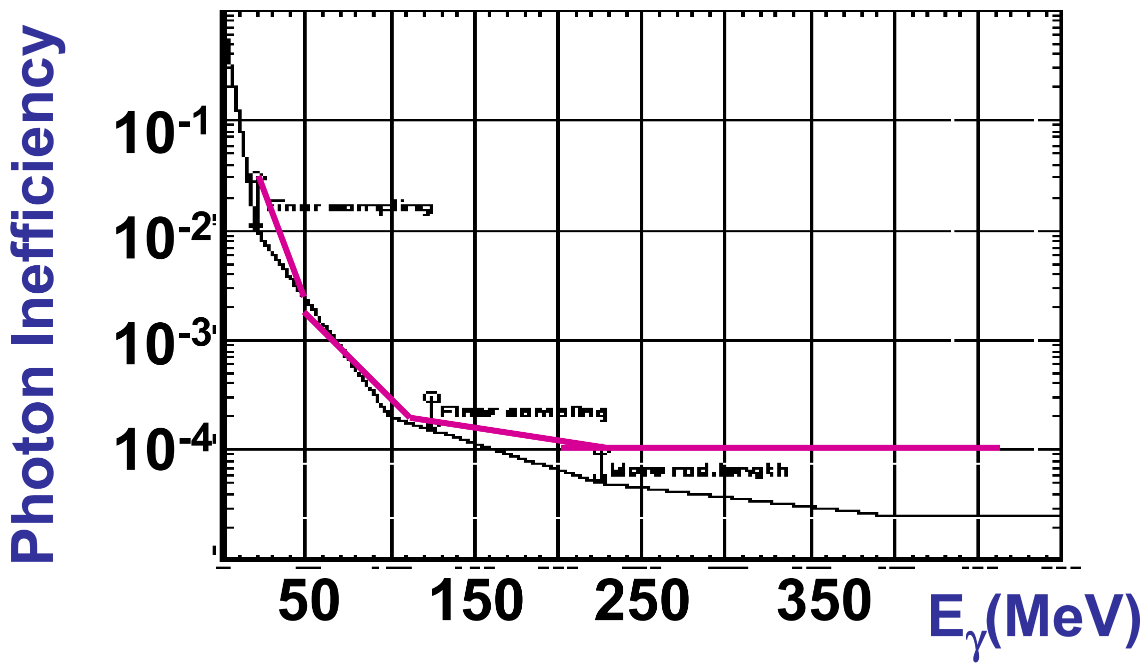
R_{min}(cm)	*k*	acc.(%)
50	$1 \cdot 10^{-4}$	27
80	$3 \cdot 10^{-5}$	18
100	$2 \cdot 10^{-5}$	14

(R_{max} = 180 cm)

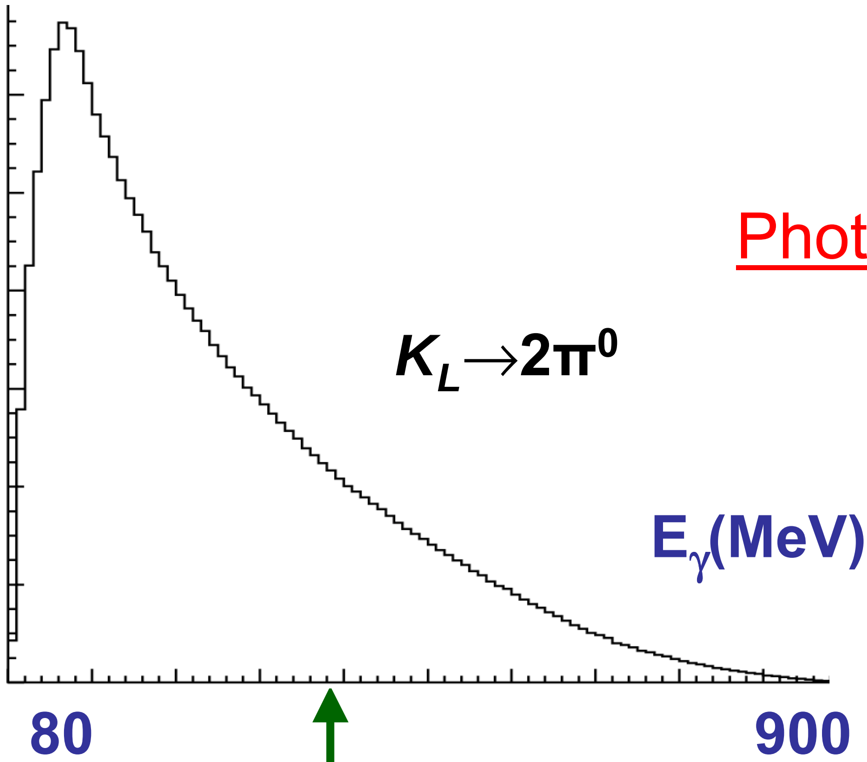
Photon detection efficiency

Enormous amount of work done by KOPIO, KAMI and KEK-E8171 mainly on ***lead-scintillator*** calorimeters

I use numbers close to those on KOPIO proposal for my calculations (albeit slightly more pessimistic)



Photon detection efficiency

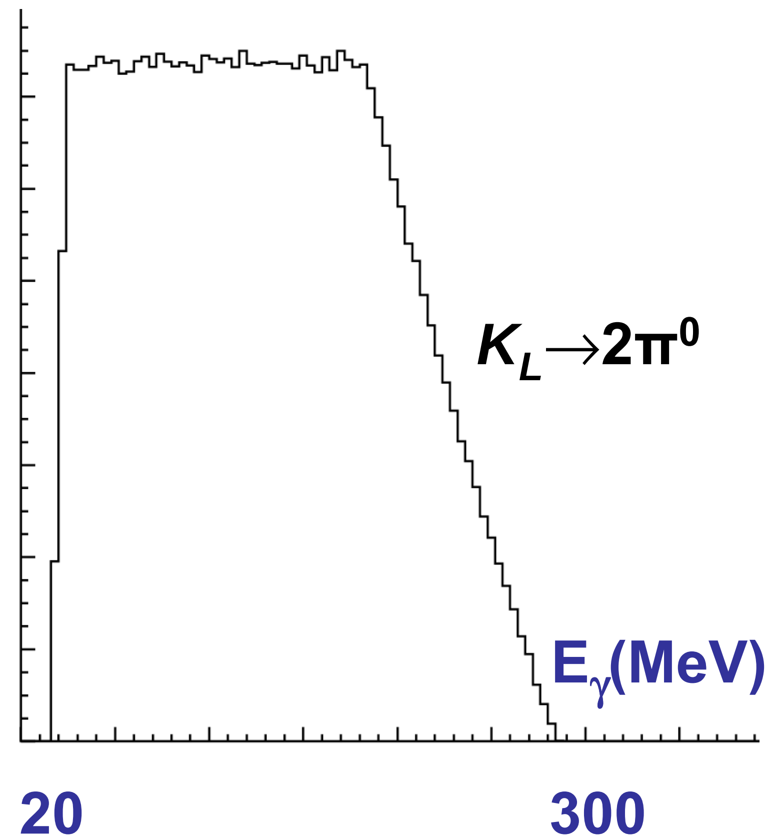


forward 1 GeV

$P_{2\gamma lost} \sim 10^{-5}$

conventional

$P_{2\gamma lost} \sim 10^{-5}$



Cfr. ***KOPIO 10^{-7}*** !

Conventional

Lost photons are mostly low energy ones: total energy could help

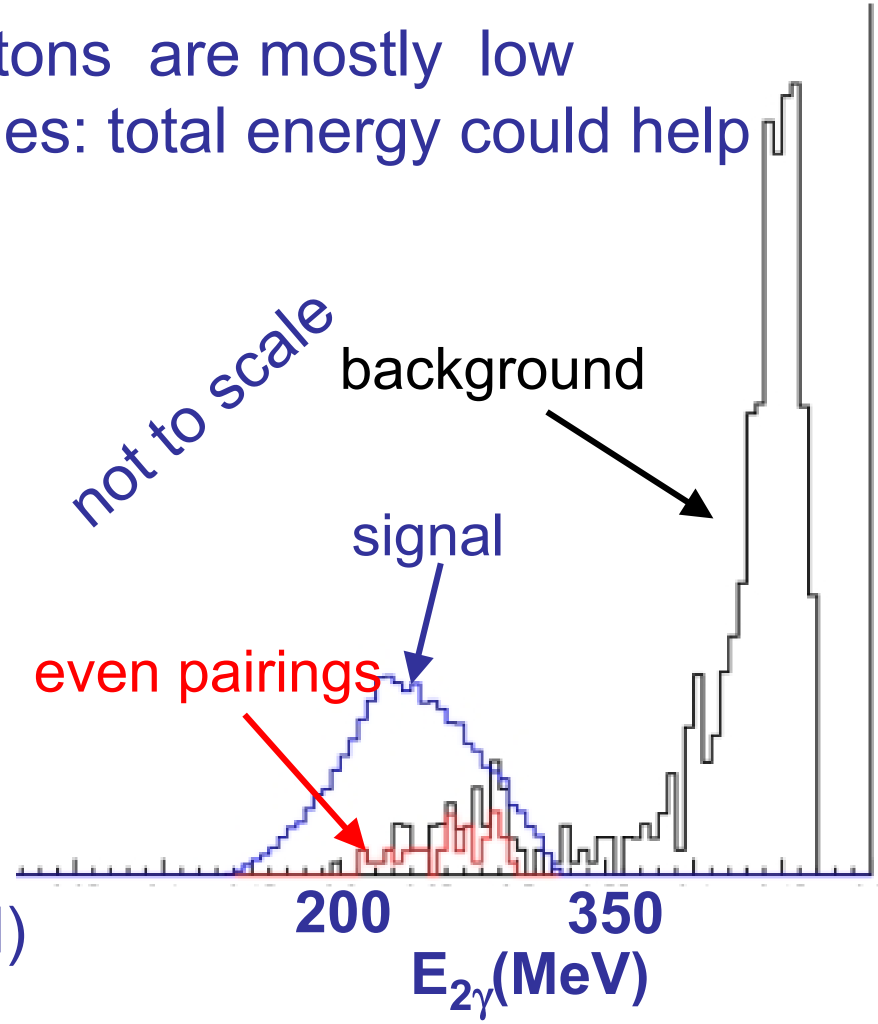
Even pairings, however, are the less separated wrt E_{tot}

Requiring:

$E_{tot} < 210$ MeV
$M_{\gamma\gamma} = M_{\pi}$

Gives $\varepsilon_{tot} \sim 6\%$ at best

(Resolution effects *NOT* included)



Photon detection efficiency still the key issue

Interaction region

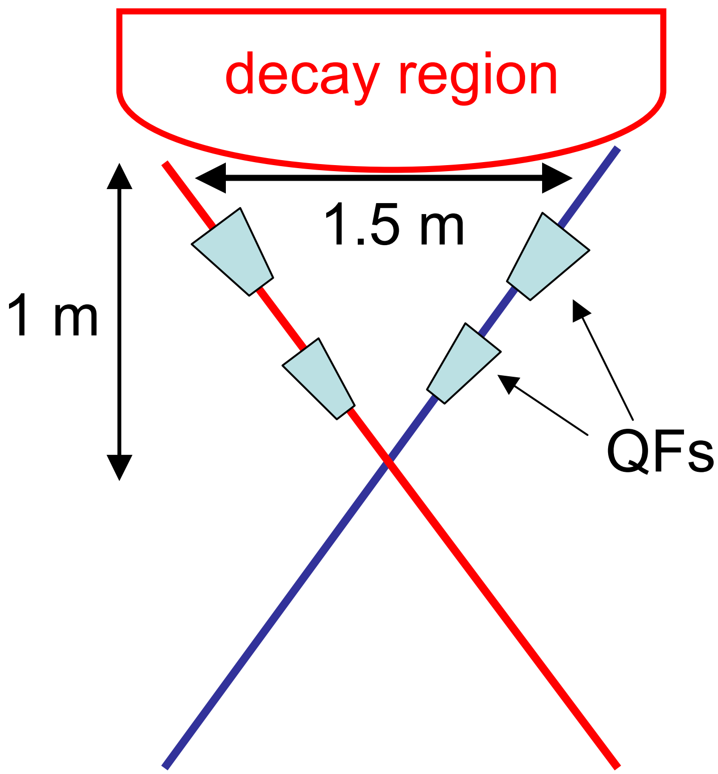
Interaction region design very different in the two cases. Common concepts are however used

- Beam pipe(s) of small transverse dimension (~ 1 cm)
- Low-β quadrupoles very close to i.r. (~ 20 cm)
- Compact elements to be used (R_{quad} ~ 2 cm)

The tagger: forward

Due to “forward” geometry the tagging device has to be accommodated in a region filled with machine elements

Clever design + use of *compact components* needed



No ***magnetic*** measurement of K_s momentum allowed not to interfere with beams

A time of flight system must be envisaged for K_S daughter to allow t_0 determination

The tagger: conventional

op. angle (degrees)	K_S acc. (%)
45	60
60	80
80	90

The need for low-β quads close to the I.P. + hermetic calorimetry reduces acceptance to ***K_S***

Amount of material to be minimised to keep backwards γ losses under control. Nothing conceivable less than 2-3 % X_0. ⇒ $P_{2\gamma lost} \sim 10^{-8}$

Experience with KLOE/DAΦNE ⇒ rates O(10 kHz) on inner DC wires (R = 35 cm)

Better be prepared to O(100 kHz) @ D2 !

(although on paper should be better)

Event rates and trigger

Besides machine background, ***physics*** event rates are big:

- Φ decays ~ 300 kHz
- Large angle Bhabhas O(100 kHz) (depending on acceptance)

A very selective trigger needed

(Farewell, my lovely !)

Conclusions

Physics & Machine

The search for $K_L \rightarrow \pi^0 \nu\nu$ is probably the most exciting goal and solid motivation for the high luminosity option of DAΦNE 2 (*see Gino's talk yesterday)*

It requires however luminosities of order ***10^{35}*** $cm^{-2}s^{-1}$

The *large x-ing angle* option, although fascinating, seems to present some major disadvantage in terms of tagging wrt to the conventional one

Beam related *backgounds* have to be kept under control

Conclusions

Detector

Supplementary investigations needed on *photon detection efficiency*

Tagging and t_0 determination are an issue

New detector concepts are still conceivable: *bigger is better (?)*

…*to be continued*…