Pad PET HPD

Preliminary results

of the first PET HPD

PCR5 prototype tube

CIMA collaboration meeting - CERN - August 2003

PET HPD Specifications

Round prototype "PCR5"

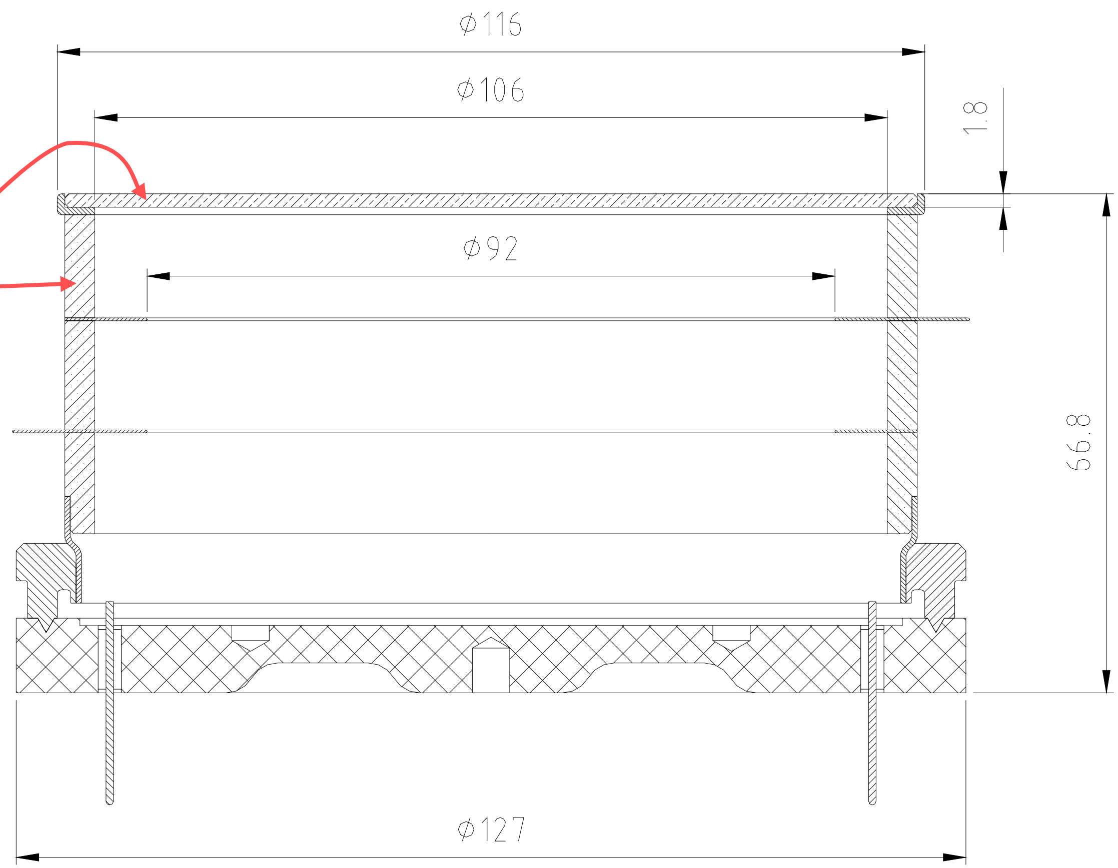
- 127 mm Ø overall
- Proximity focused

- Sapphire window (d=1.8 mm)
- Ceramic body

- Nb skirt
- Nb electrodes

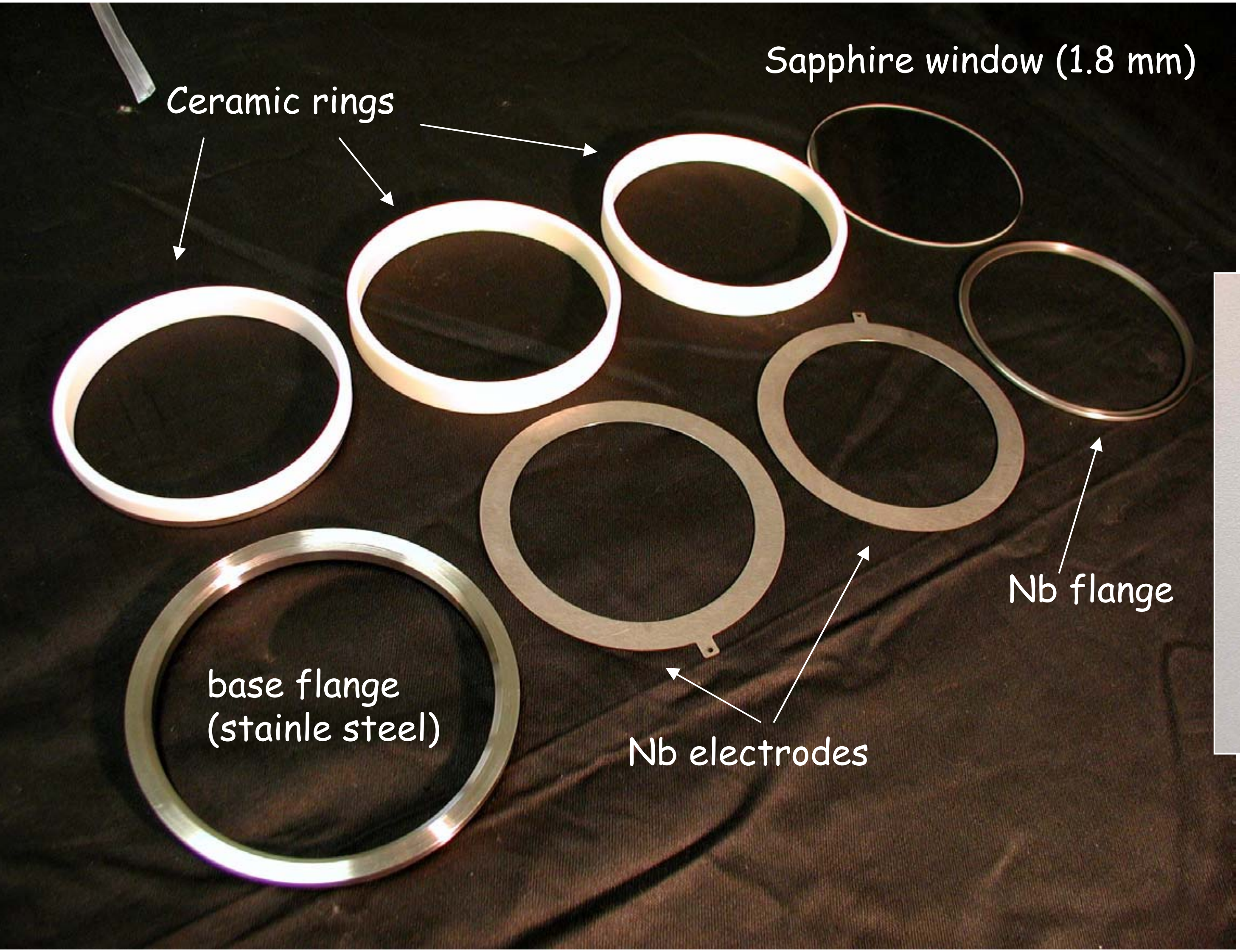
- Bialkali photocathode
- QE(370 nm) ≈ 25%

- $U_C \approx 12$ kV
- Gain ≈ 3000

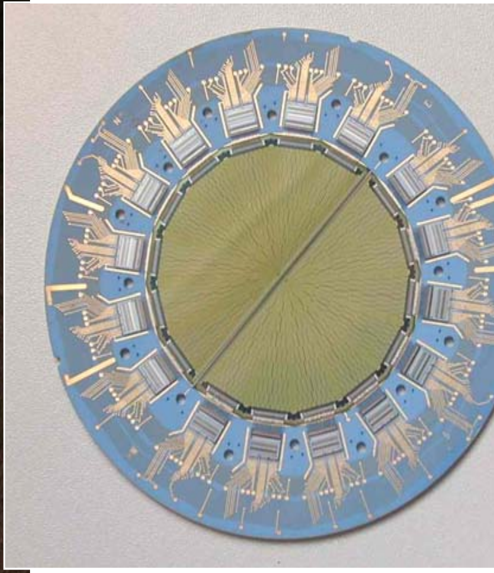


Body construction by ceramic / metal brazing technique (under vacuum). Technology available at CERN.

Components for 1 PCR5 envelope



Si sensor and electronics
Standard = Non-PET !

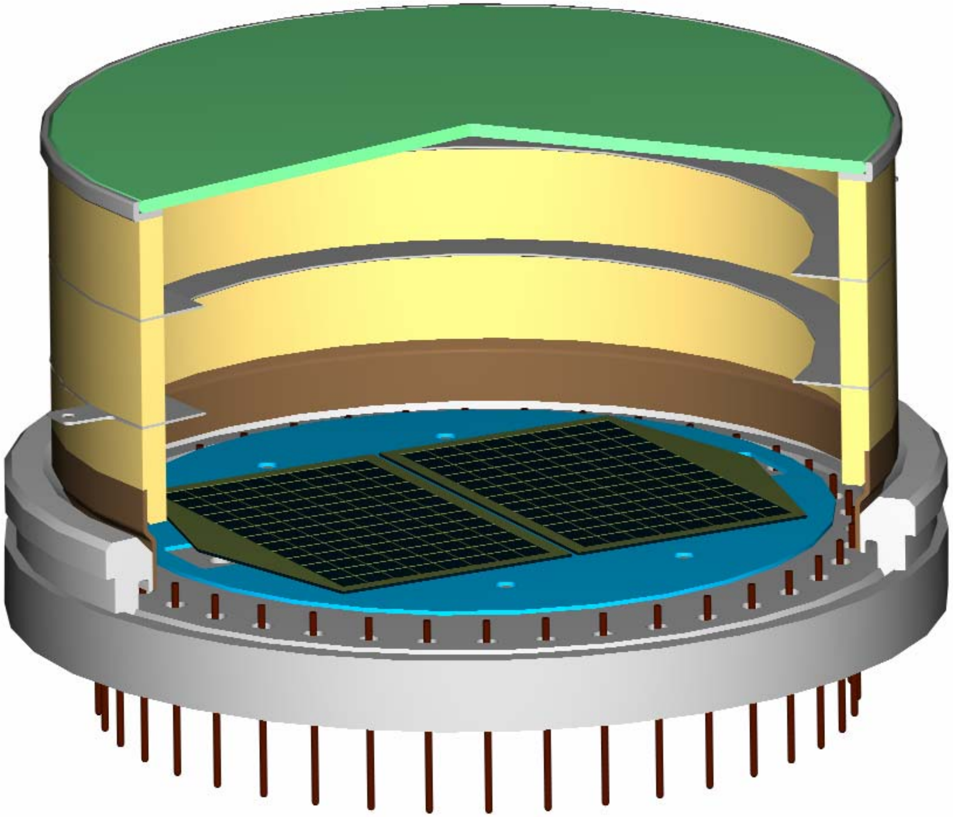


Si Sensor
50 mm Ø

16 VA-prim
chips

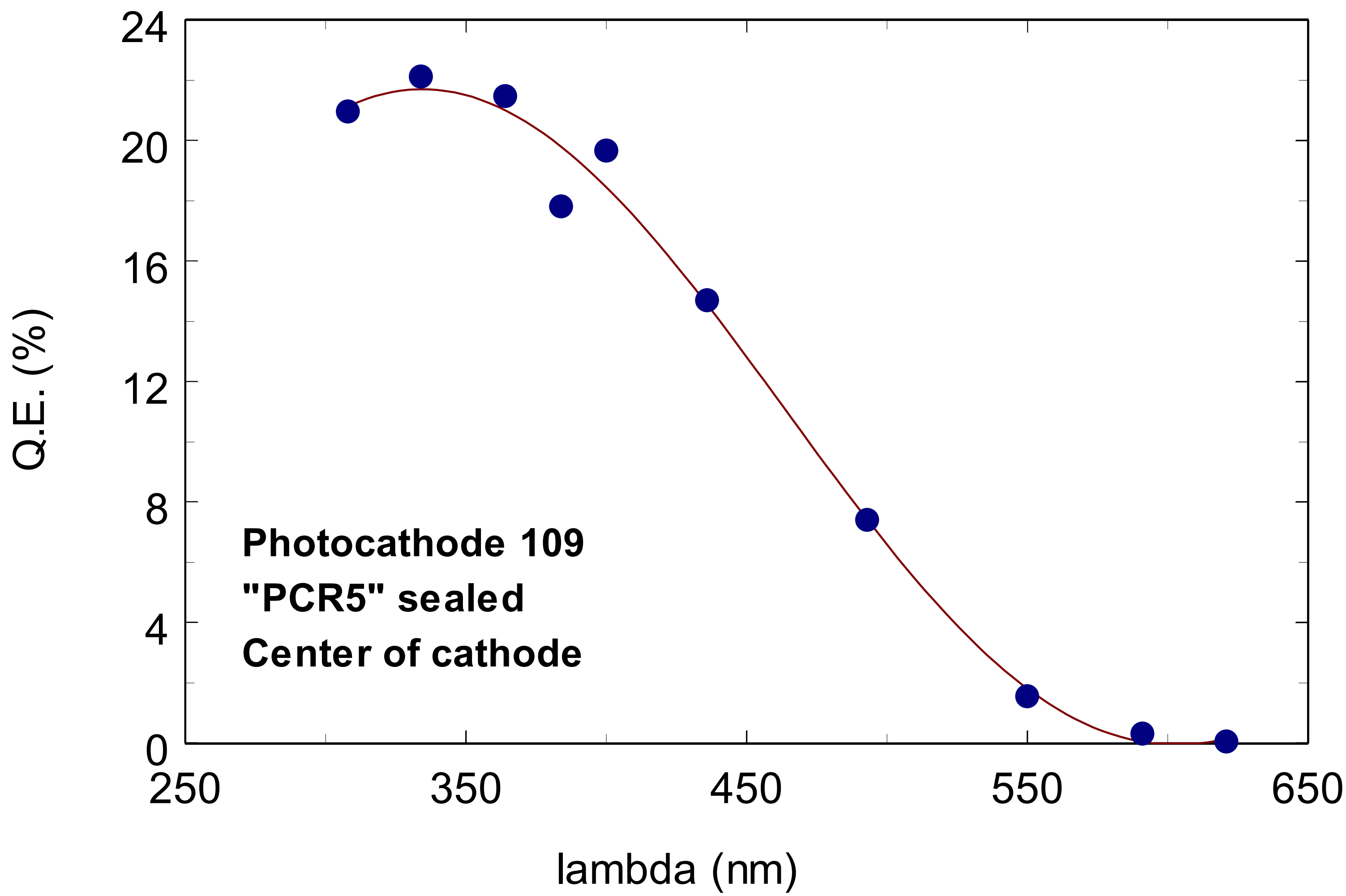
2048 pads
(1x1 mm^2)

PET HPD
round prototype "PCR5"

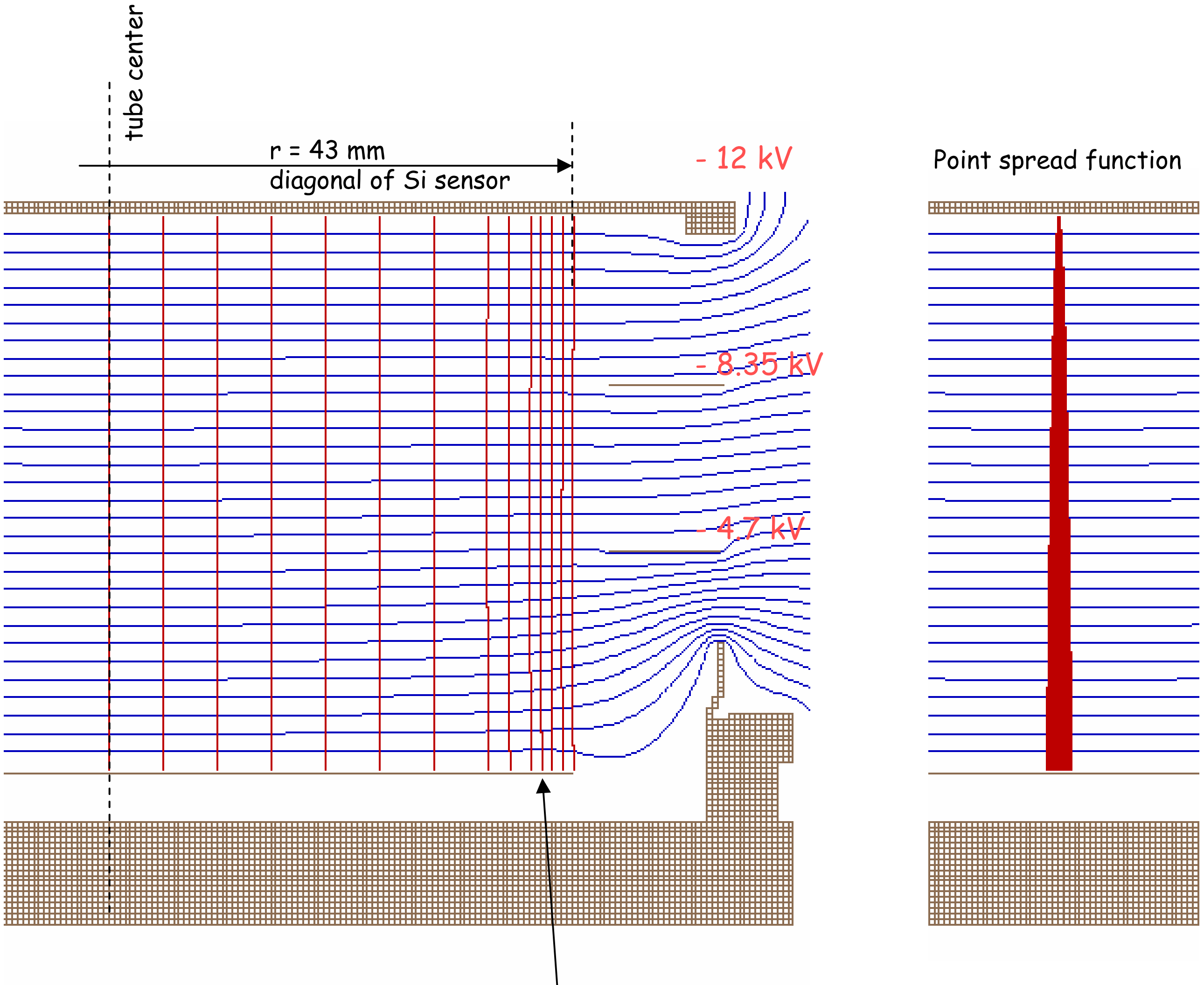


Reasonable but not optimum Q.E.

(explained by some irregularities during processing)



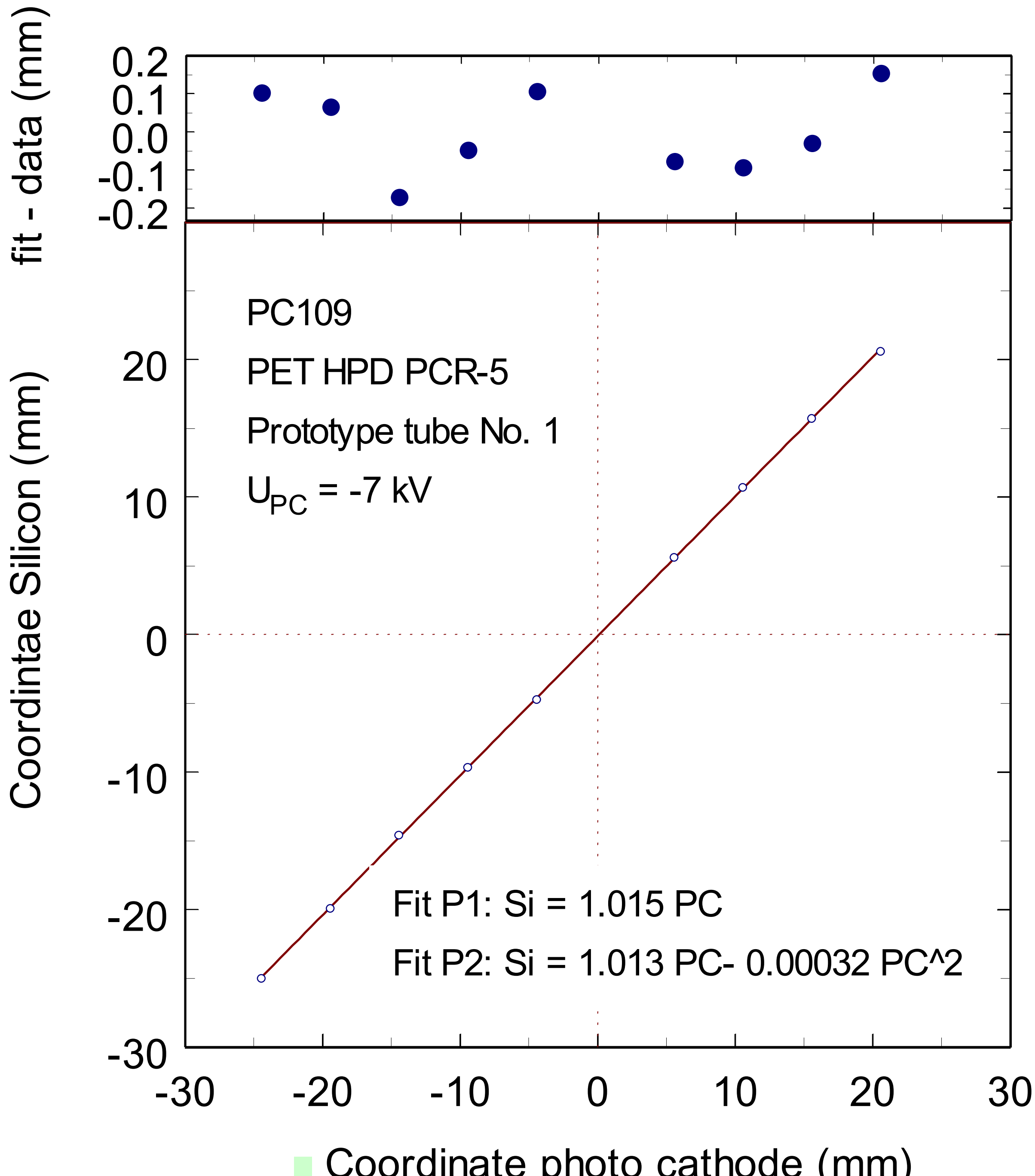
Electrostatic simulations of PCR5 with SIMION 7



deviations < 0.2 mm

PSF ~0.3 mm

➨ expect almost perfect 1:1 correspondence of crystals to Si pads



fit - data (mm)
0.2
0.1
0.0
-0.1
-0.2
PC109
PET HPD PCR-5
Prototype tube No. 1
U_{PC} = -7 kV
Fit P1: Si = 1.015 PC
Fit P2: Si = 1.013 PC- 0.00032 PC^2
Coordintae Silicon (mm)
20
10
0
-10
-20
-30
-30
-20
-10
0
10
20
30
Coordinate photo cathode (mm)

The YAP absorption length problem

z: ratio of light detected by the 2 HPDs

$$z = \frac{1}{2}\left(L + k_g \cdot \lambda_a \cdot \log\left(\frac{Q_R}{Q_L}\right)\right)$$

k_g is a geometrical factor $k_g = \left\langle \frac{z_{eff}}{z} \right\rangle \approx 0.8$

$$\sigma_z = \frac{k_g \cdot \lambda_a}{2}\left[\frac{Q_L + Q_R}{Q_L \cdot Q_R}\right]^{1/2} \qquad Q_L = Qe^{-z/\lambda_a} \qquad Q_R = Qe^{-(L-z)/\lambda_a}$$

$$\sigma_z = \frac{k_g \cdot \lambda_a}{\sqrt{2Q}}\left[e^{z/\lambda_a} + e^{(L-z)/\lambda_a}\right]^{1/2}$$

The z resolution degrades with increasing λ_a - the energy resolution improves !

We had hoped for λ_a = 75 mm.
↓
σ_z = 2.5 - 3 mm
σ_E = 3.5 - 4 %

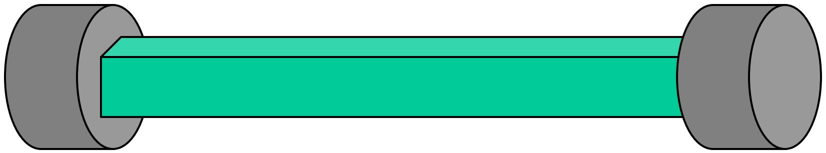
With λ_a = 279 mm we would get
↓
σ_z ~ 5 mm too bad !
σ_E = 2.5 - 3 %

Possible solutions ?

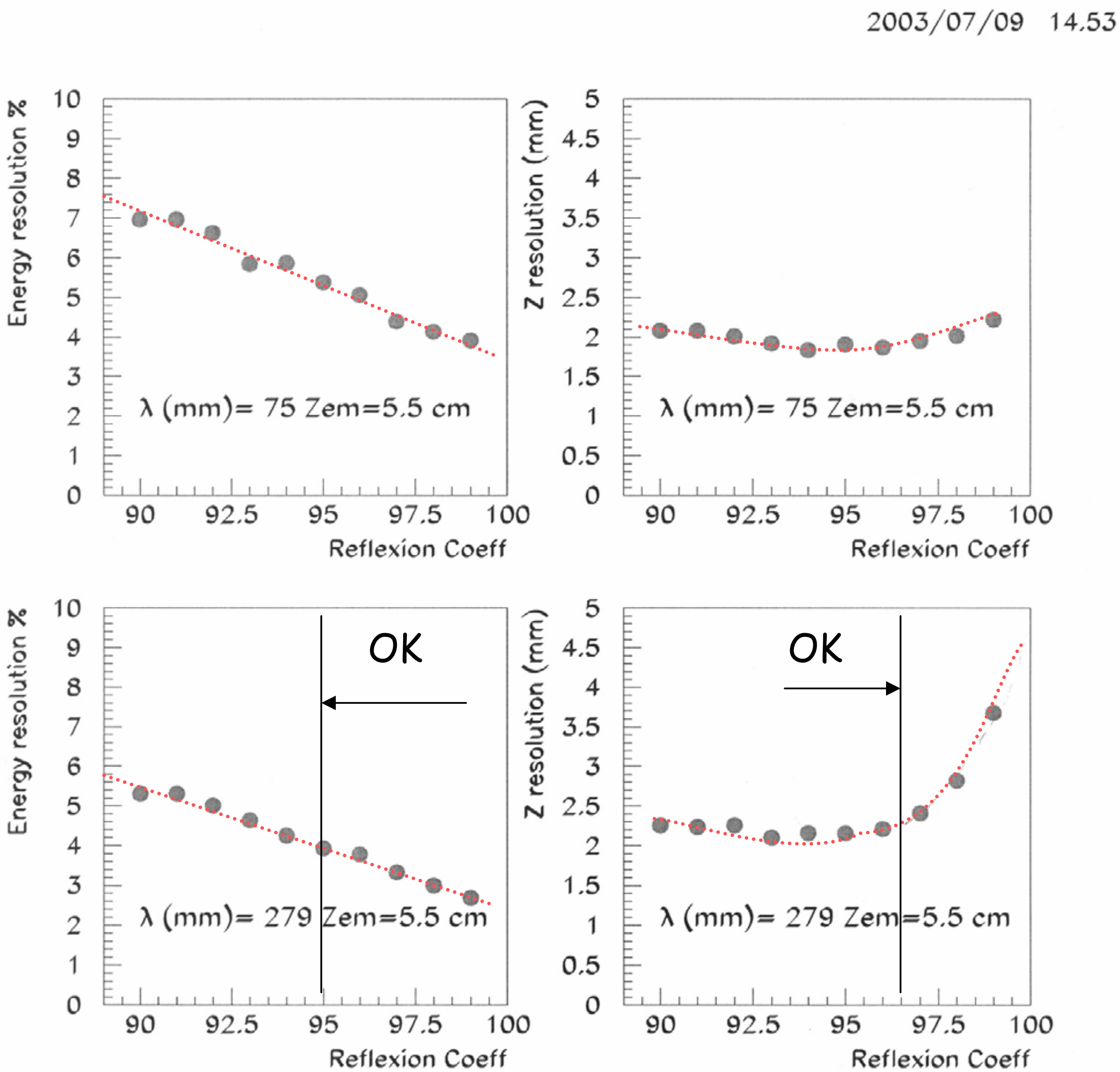
- Can λ_a be tuned by changing the Ce concentration ? DEVELOPMENT ! Does not help for now !
- Can one treat (chemically de-polish) the surface to decrease the reflectivity ?
- Can one coat the surface with a metal and use metallic reflectivity rather than total internal reflection ?

Maria Chamizo and I made some simulation studies for the last option

Assume uniform reflective coating with reflectivity R for all 4 side surfaces



Pad PET HPD


2003/07/09 14.53
Energy resolution %
Z resolution (mm)
λ (mm)= 75 Zem=5.5 cm
λ (mm)= 75 Zem=5.5 cm
Reflexion Coeff
Reflexion Coeff
OK
OK
λ (mm)= 279 Zem=5.5 cm
λ (mm)= 279 Zem=5.5 cm
Energy resolution %
Z resolution (mm)
Reflexion Coeff
Reflexion Coeff

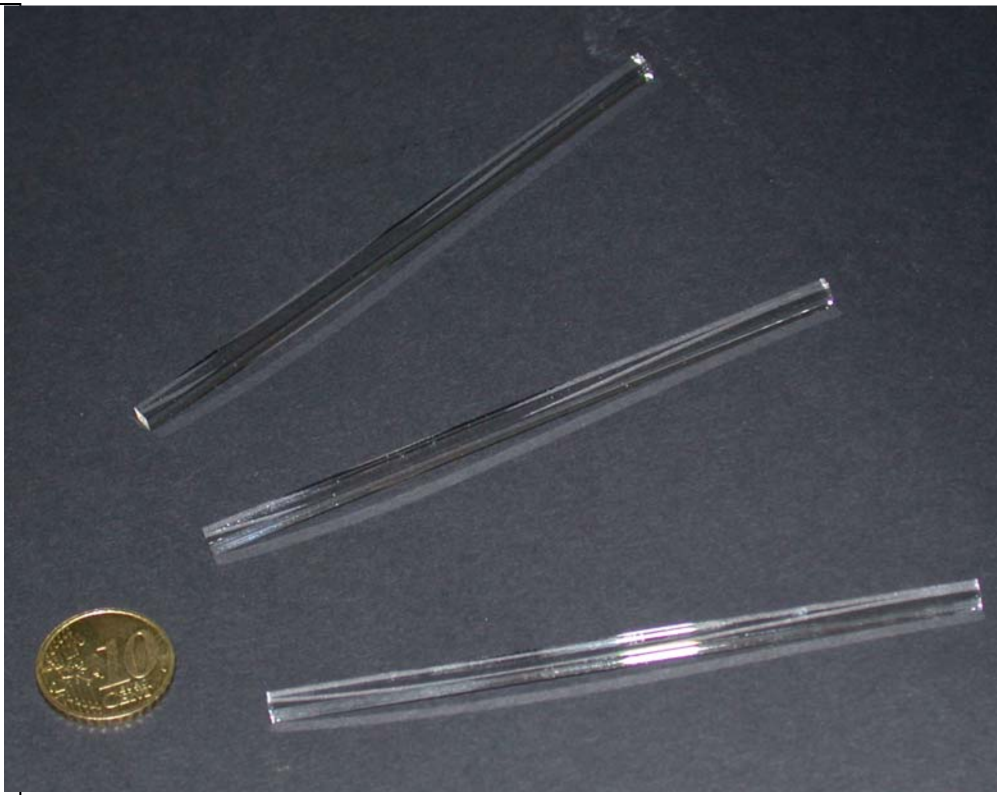
First results from measurements of optical properties of YAP:Ce crystals

- Procurement of YAP:Ce crystals
  - Price enquiry for 3.6x3.6x100 mm^3 crystals started in January 2002
    - CRYTUR Ltd. Czech republic (Mr. Karel Blazek): price quotation very fluctuating (from 90 €/cm^3 to 113-266 €/piece for an order of about 400 crystals; five months of delivery time)
  - Order for 64 crystals (3.2x3.2x100 mm^3) issued in November 2002 by INFN Bari and Rome ISS: 150 €/piece.
    - 32 crystals delivered to Bari on 5th of February 2003: shipped back to CRYTUR…..surfaces were not optically grinded
    - Final delivery to Bari and Rome in the end of May 2003 (almost seven months from the order !!)
  - Price enquiry to Saint-Gobain for 64 crystals: 620 €/piece

Transparency by
Eugenio Nappi, Bari

Mechanical tolerancies

- Specifications in the order
  - Length: 100 ± 0.1 mm
  - Transversal size: 3.2 ± 0.05 mm
  - Optical polishing: better than 10 nm (rms)
  - Surface cloth/felt polished, free of scratches and inclusions by visual inspection
- Quality control
  - Dimensions within specs (max deviation from nominal values is 0.03 mm)
  - Surfaces look optically grinded and of a very good aspect



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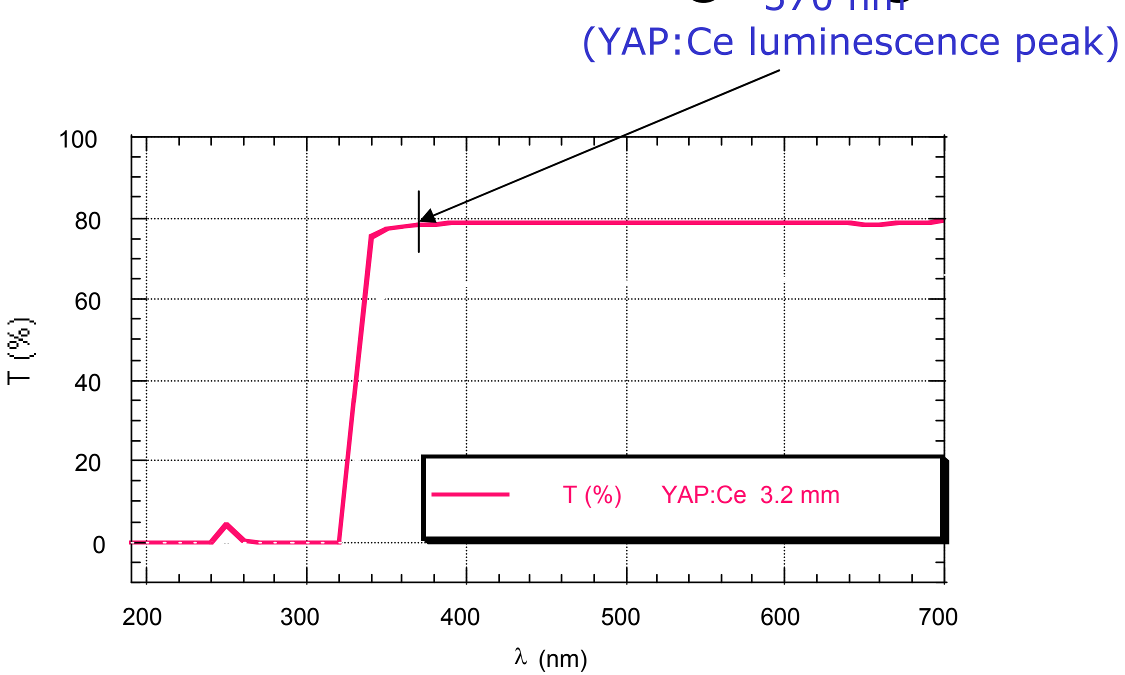
Transmission measurement

- Spectrophotometer measurements with a Perkin-Elmer Lambda-9 in the wavelength range 200-700 nm



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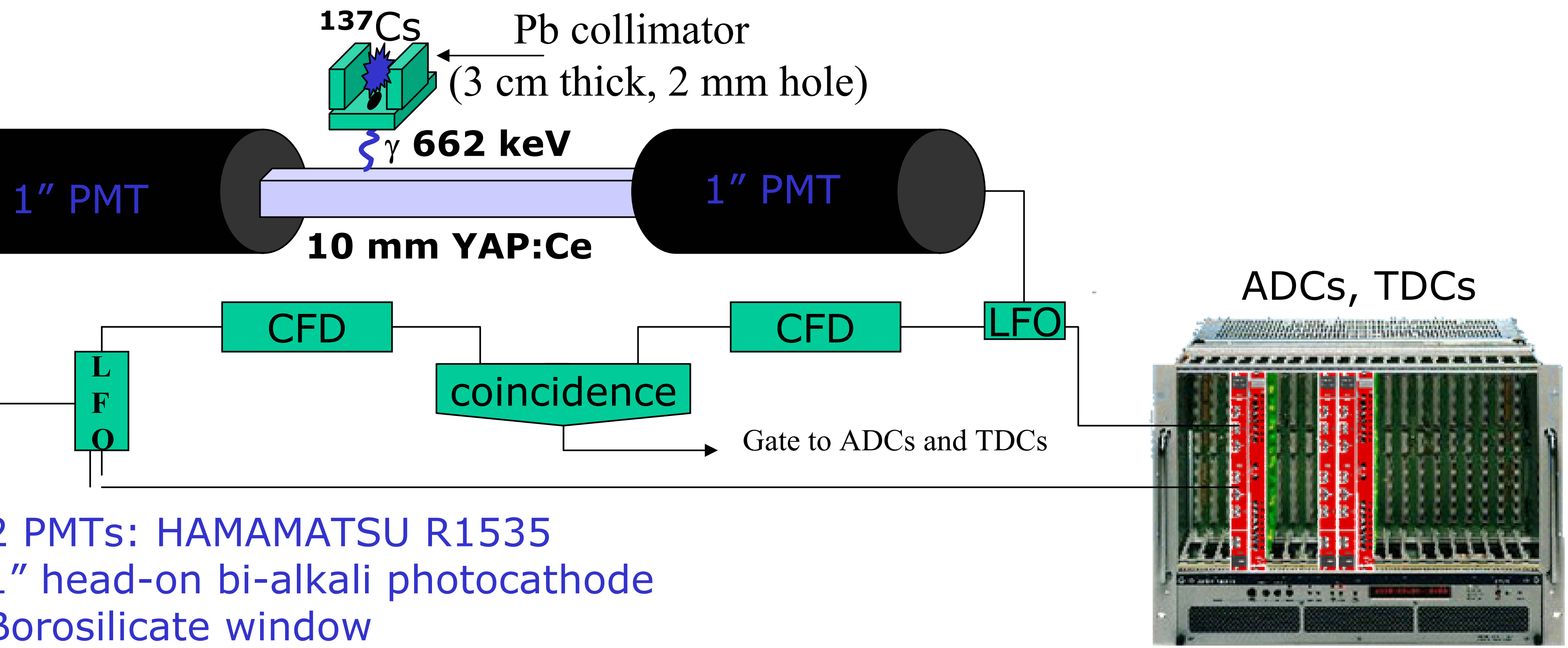
Light absorption length measurement



2 PMTs: HAMAMATSU R1535
1″ head-on bi-alkali photocathode
Borosilicate window
Δλ range: 300-600 nm (peaked at 420 nm)

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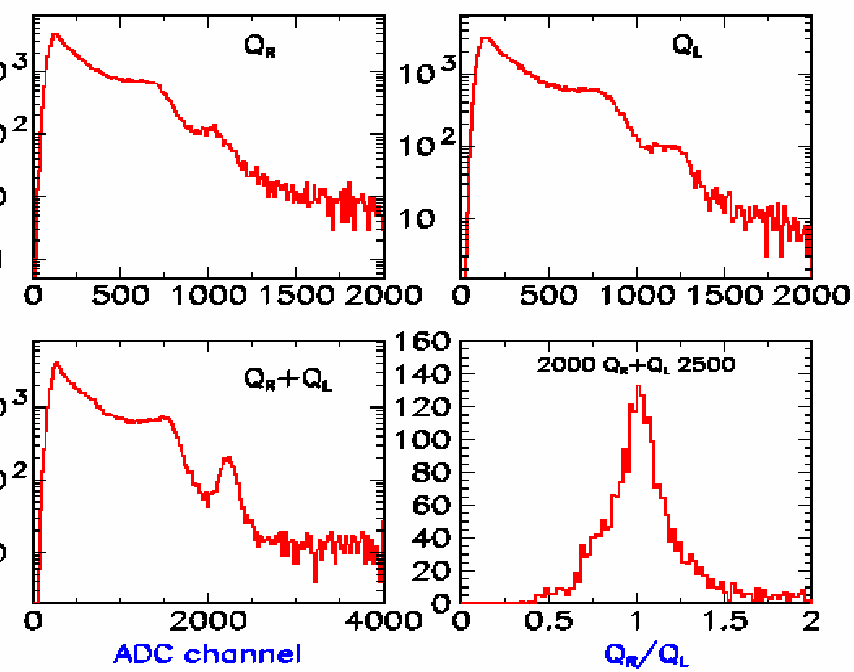
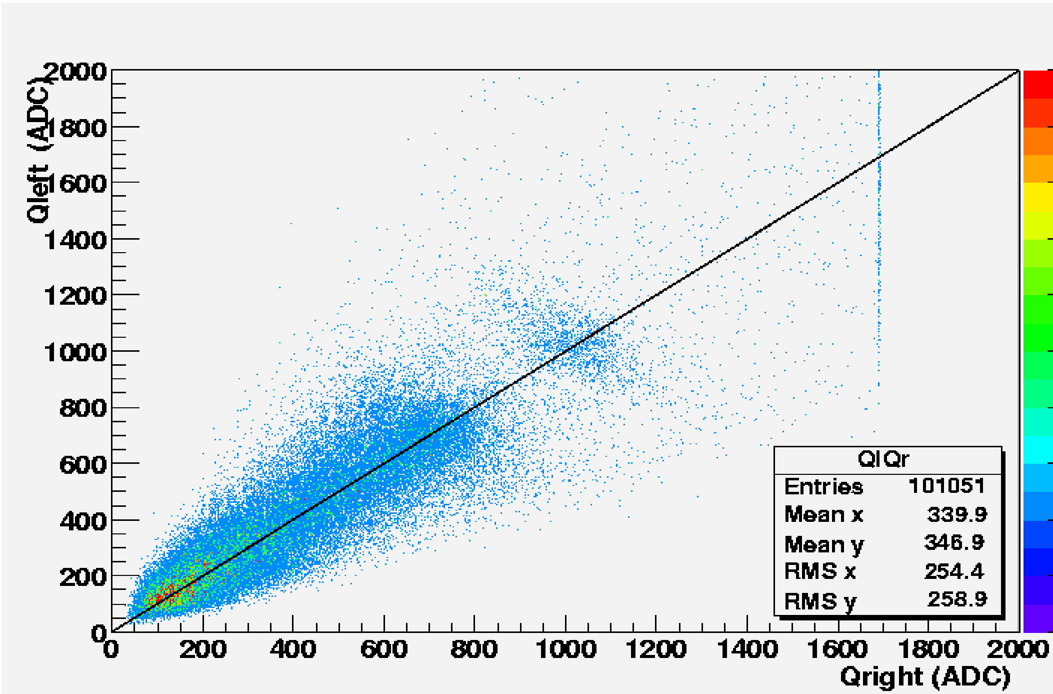
^{137}Cs Spectra

Source located at 5 cm from Q_R;Q_L (at the mid length of the crystal)





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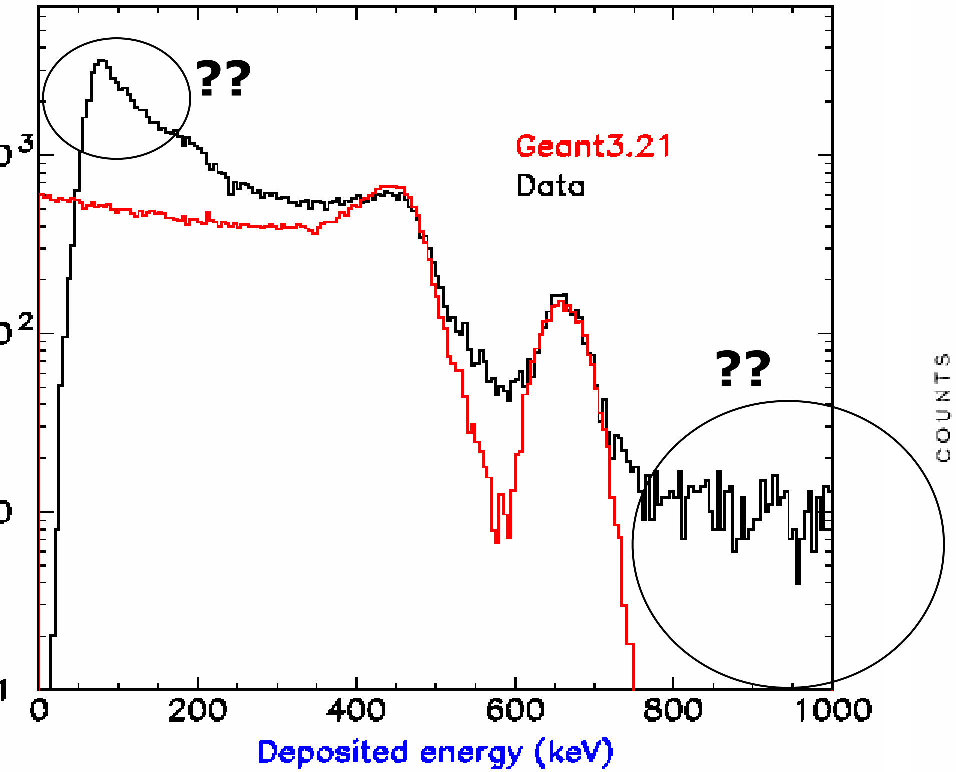
Comparison with MC



S. Baccaro et al. / Nucl. Instr. and Meth. in Phys. Res. A 361 (1995) 209–215

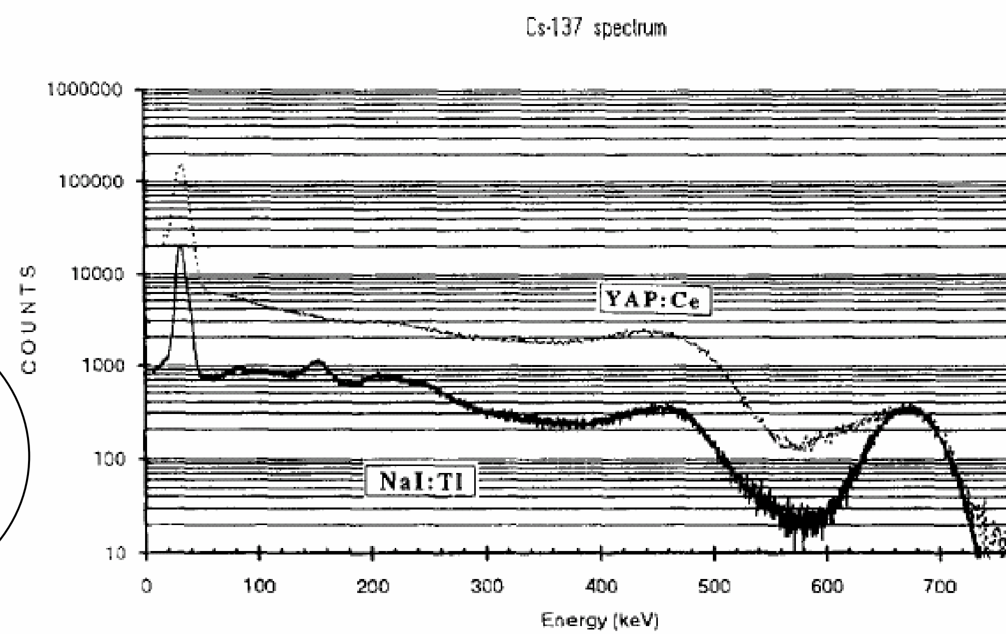


Fig. 5. Energy spectra for NaI : Tl compared with YAP : Ce for ^{137}Cs source.

NB: energy resolution in the photopeak: 4.3% !!

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Is σ_E/E = 4.3 % plausible ?

Intrinsic resolution of YAP at 662 keV: σ_E/E = 1.83% (literature)

→ contribution of PMT = $(4.3^2 - 1.83^2)^{1/2}$ = 3.9%

Gain fluctuation in a PMT $\sigma_N = ENF \cdot N^{1/2}$ → $\sigma_E/E \sim \sigma_N/N = ENF \cdot N^{-1/2}$

Excess Noise Factor (ENF) of a PMT ~ 1.18 (average)

Detected photo electrons: $N_{pe} = (1.16 / 0.039)^2$ = **884**

How many N_{pe} do we roughly expect ?

E_γ = 662 keV → $N_{scint.}$ = 11880

Transport efficiency = 0.4 / side

Non-absorbed fraction = 0.79

Non reflected fraction at YAP/glass interface = 0.175 / side (for isotropic illumination. Too pessimistic !)

Quantum efficiency = 0.25

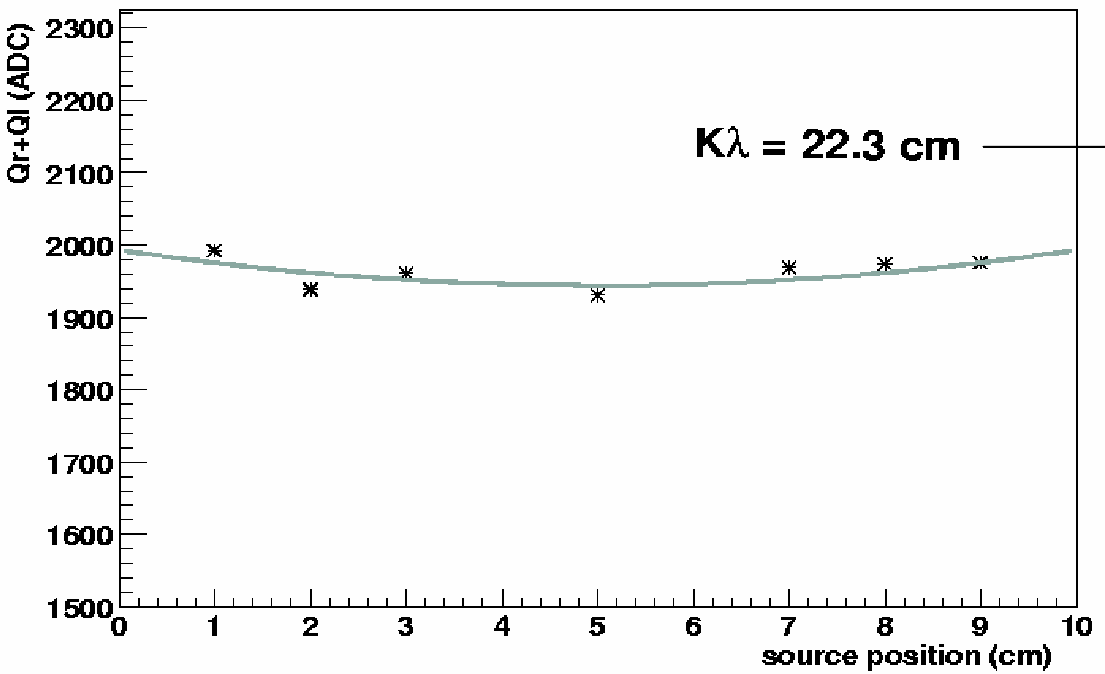
Expect $N_{pe} > 11880 \times 0.8 \times 0.79 \times 2 \times 0.175 \times 0.25$ = **657**

(2×0.175: Too pessimistic)

Looks reasonable !

Preliminary results

$$Q_R + Q_L \propto e^{-L/2k\lambda} \cosh\left(\frac{z}{k\lambda}\right)$$; z=source position



k=0.8

λ=27.9 cm

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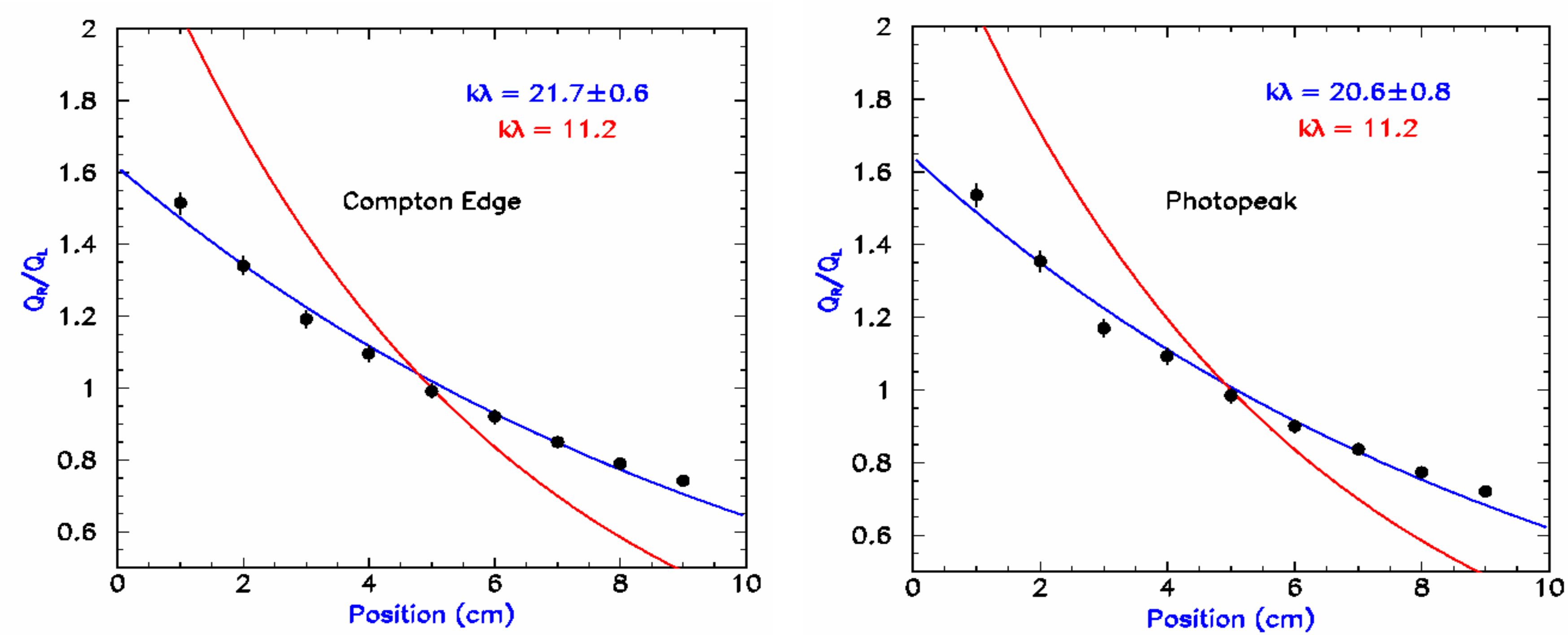
Further evaluation



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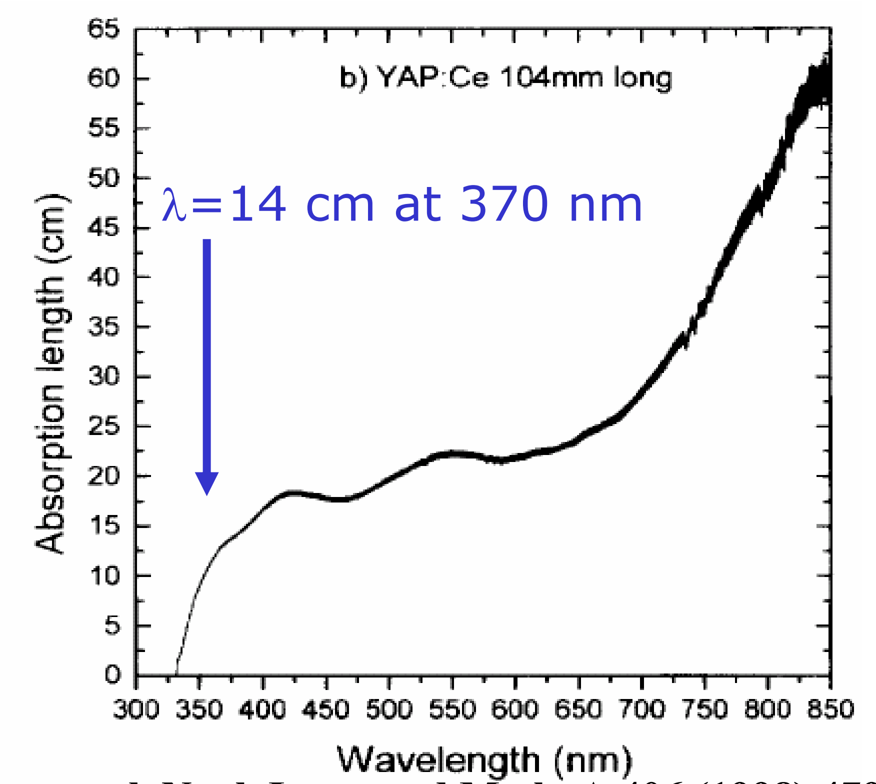
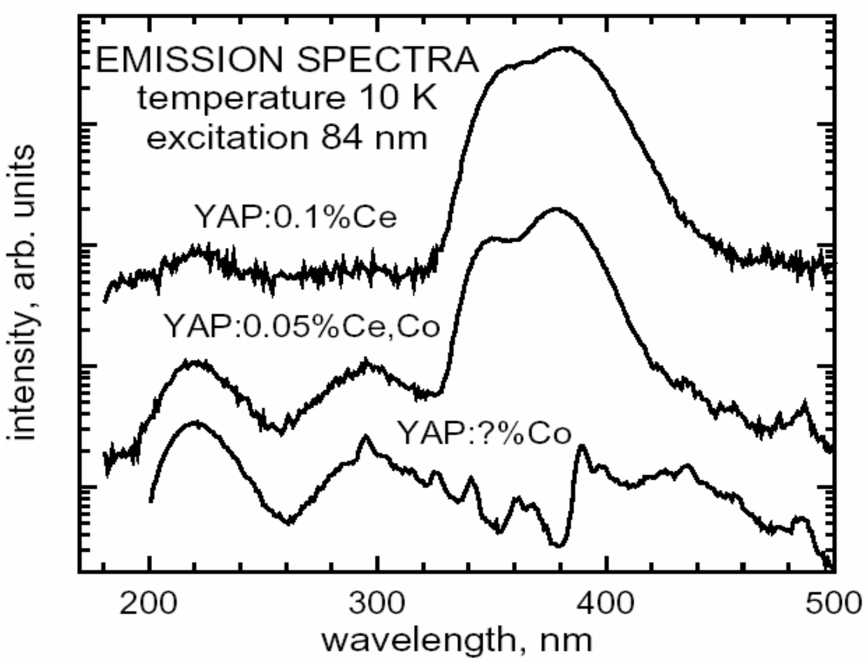
Value quoted in literature

A.J. Wojtowicz et al., unpublished



Baccaro et al. Nucl. Instr. and Meth. A 406 (1998) 479



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