Performance of Preshower and Shower-maximum Detectors

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representing **HpCAL (T912)** collaboration

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Outline

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Introduction

Preshower detector (PSD) and
Shower-maximum detector (SMD)

- improve the calorimeter performance in
  - e/γ separation from hadrons
  - e/γ incident position resolution
- Requirements depend on physics ;
  - $r_\pi \geq$ several hundred at $\epsilon_e = 90 \sim 95\%$
  - $\sigma_x \sim$ a few mm

  are reasonable targets.
- Beam test of a prototype in 1999 September at FNAL
  - together with the HCAL module
  - using good e/π samples at 50–100 GeV (no good samples at lower energies)

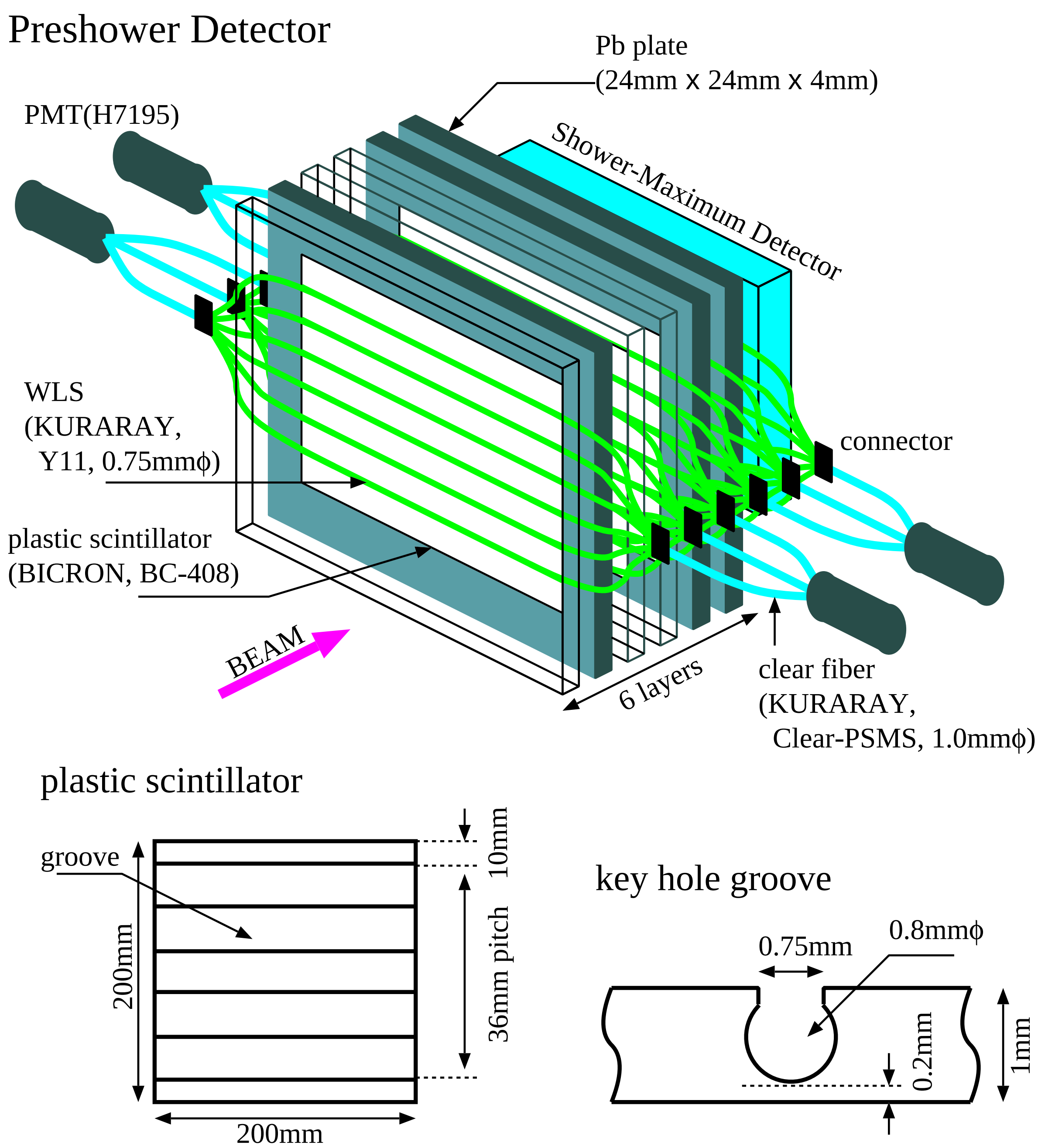
Detector

- Based on common technology to the HCAL
  - Lead and scintillator sandwich
  - Tile/Fiber readout technique
- Cross section of $20 \times 20\text{cm}^2$ to cover the central tower of the HCAL module

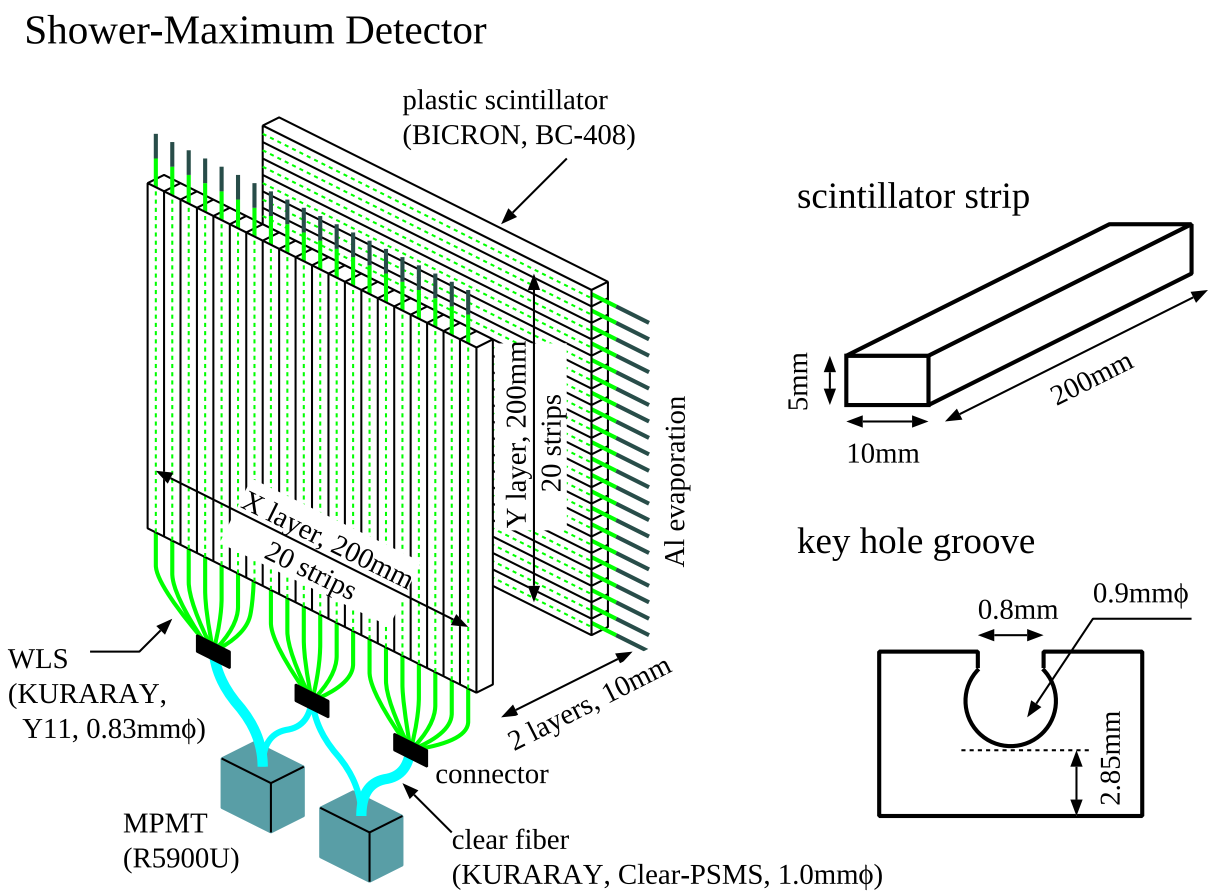
PSD
- Six layers of Lead plates (4 mm thick) and Scintillator plates (1 mm thick)
- A total thickness of $4.3X_0$
- $< n.p.e. > \sim 1.6$/scinti. plate for a MIP
- read out 1-3 layers and 4-6 layers separately (PS_1 and PS_2)

SMD
- Two layers of Scintillator Strips
- 20 strips/layer, $200 \times 10 \times 5$ mm^3 each
- individually read out by MAPMT's
- $< n.p.e. > \sim 3.5$/layer for a MIP

Preshower Detector (PSD)



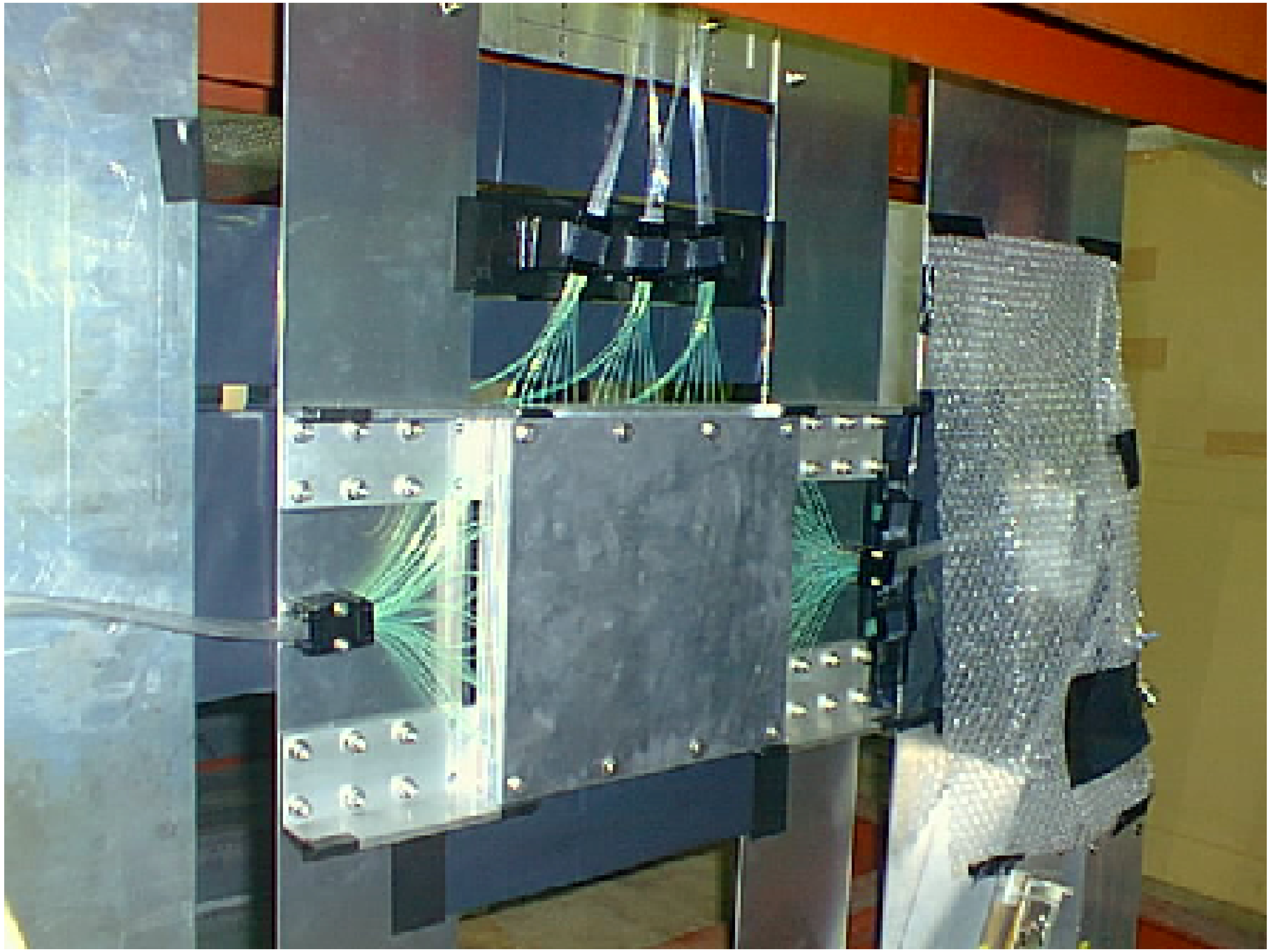
Shower-Maximum Detector (SMD)



Signals were read out by MAPMT's.
The following effects had to be taken into account off-line.

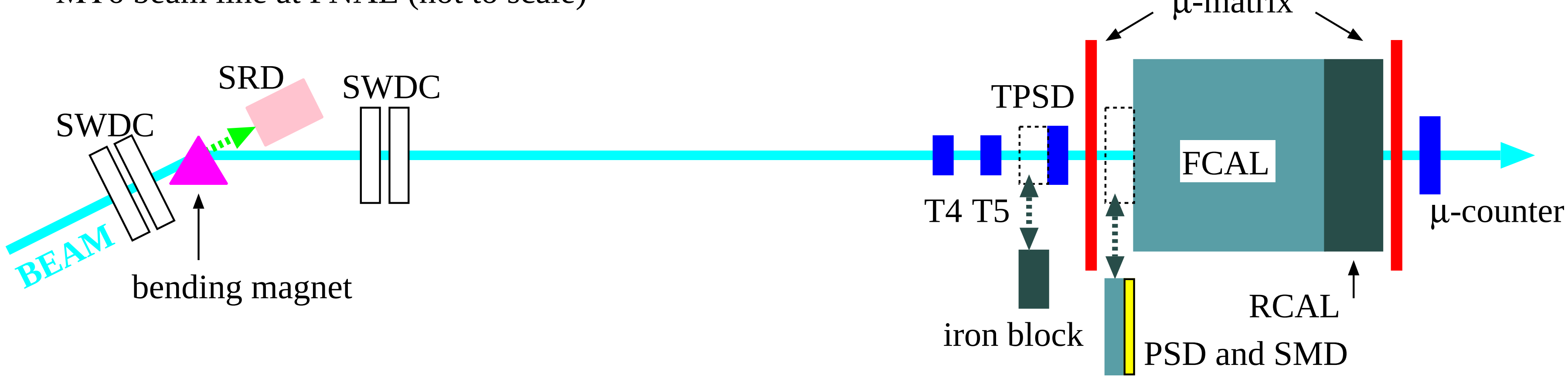
- Saturation effect ($> O(100)$ photoelectrons)
- Cross talks (a few % to neibouring channels)

A Picture of PSD/SMD



The Beam Test (FNAL T912)

MT6 beam line at FNAL (not to scale)



T4,5 & TPSD	Trigger Counters
SWDC	Single Wire Drift Chambers
SRD	Synchrotron Radiation Detector

cf. Material of $\sim 0.5X_0$ thickness between the final SWDC and the T4 counter

$\rightarrow$ remove multi-track events off-line

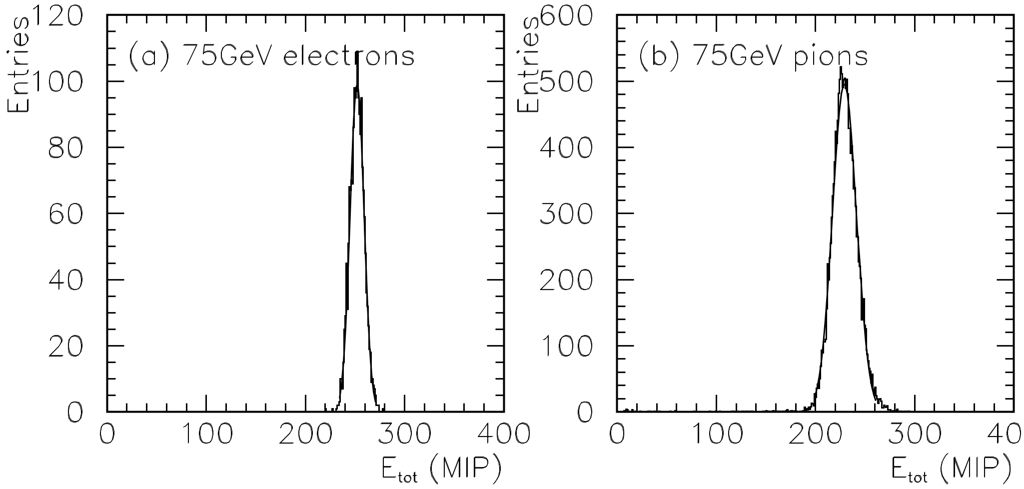
Event Samples

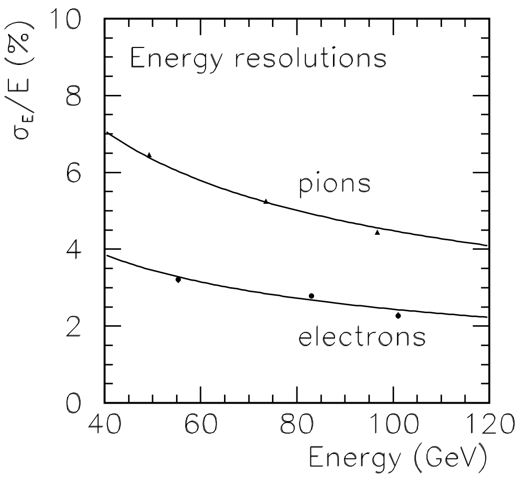
- Triggered by T4 & T5
- SWDC's are used for
  - incident position determination
  - single track selection
  - momentum measurement
- Electron samples
  - 1 MIP signal in TPSD
  - A good signal in SRD (useful only for $E \simeq 50$ GeV)
  - Pion contamination $< 0.02\%$ (from data)
- Pion samples
  - 1 MIP signal in TPSD with iron block filter
  - Electron contamination $< 0.01\%$ (from MC)

	electron-run		pion-run	
nominal energy (GeV)	measured energy (GeV)	electron sample	measured energy (GeV)	pion sample
50	55.3	1,157	49.2	16,557
75	83.0	1,776	73.5	15,100
100	101.1	637	96.7	9,842

Results

Energy resolution





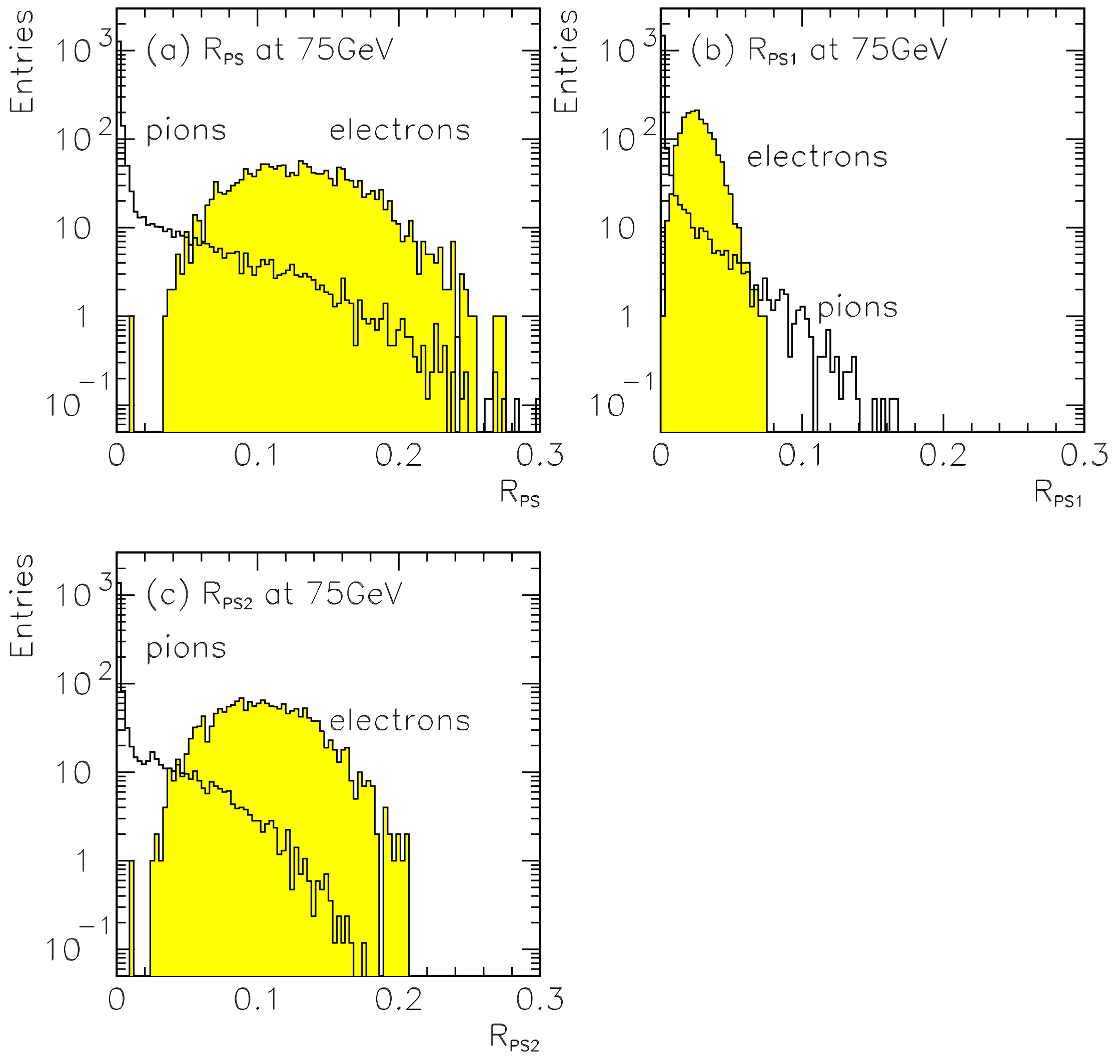
$\sigma_E/E = (24.4 \pm 0.5)\%/\sqrt{E} \oplus (0.0 \pm 1.9)\%$ for electrons

$\sigma_E/E = (44.8 \pm 0.2)\%/\sqrt{E} \oplus (0.0 \pm 0.4)\%$ for pions

$\rightarrow$ consistent with HCAL results

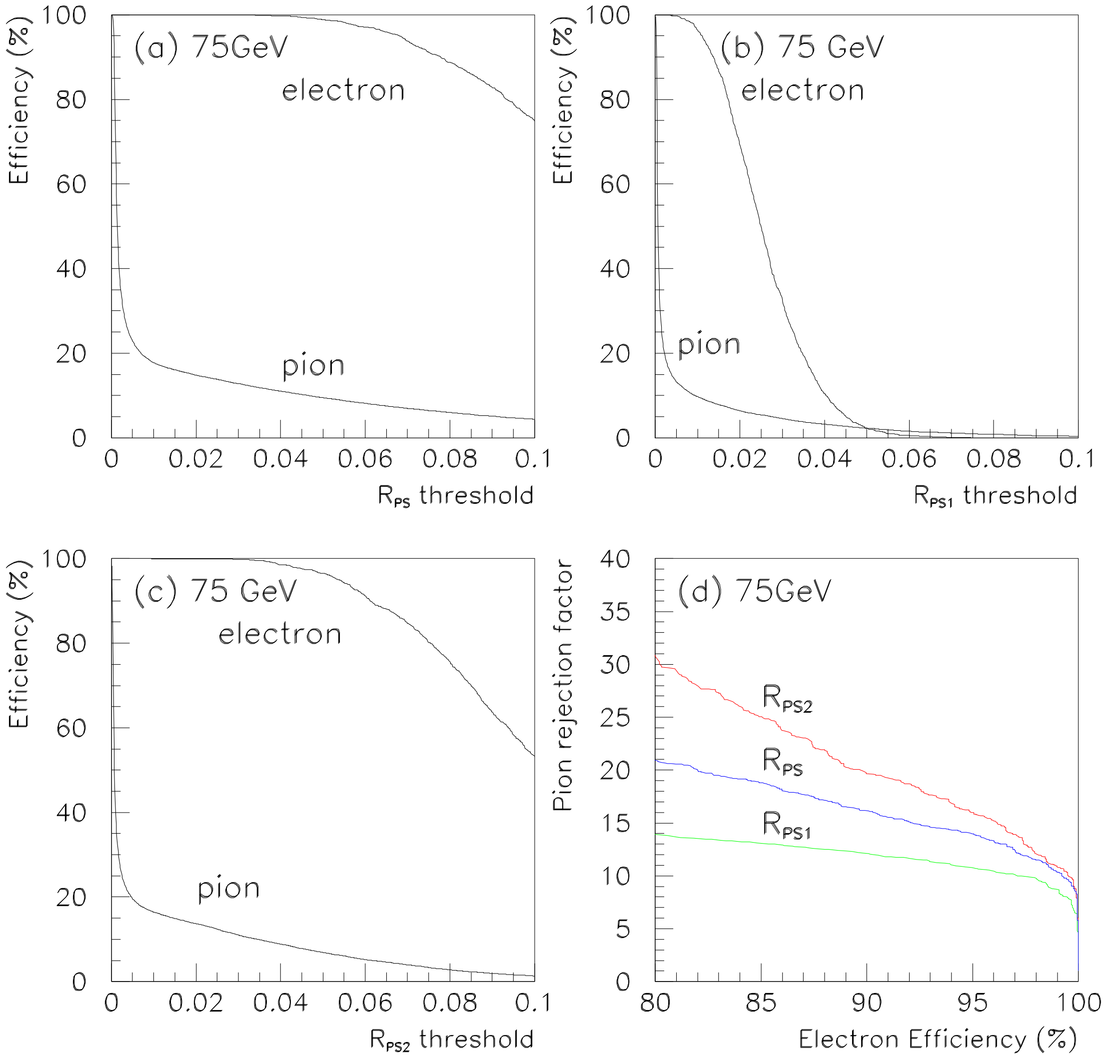
PSD energy ratios

$$R_{PS} = (E_{PS1} + E_{PS2})/E_{tot}$$
$$R_{PS1} = E_{PS1}/E_{tot}$$
$$R_{PS2} = E_{PS2}/E_{tot}$$



Performance of PSD energy ratios

R_{PS2} shows the best pion rejection factor
(closer to the shower maximum point)

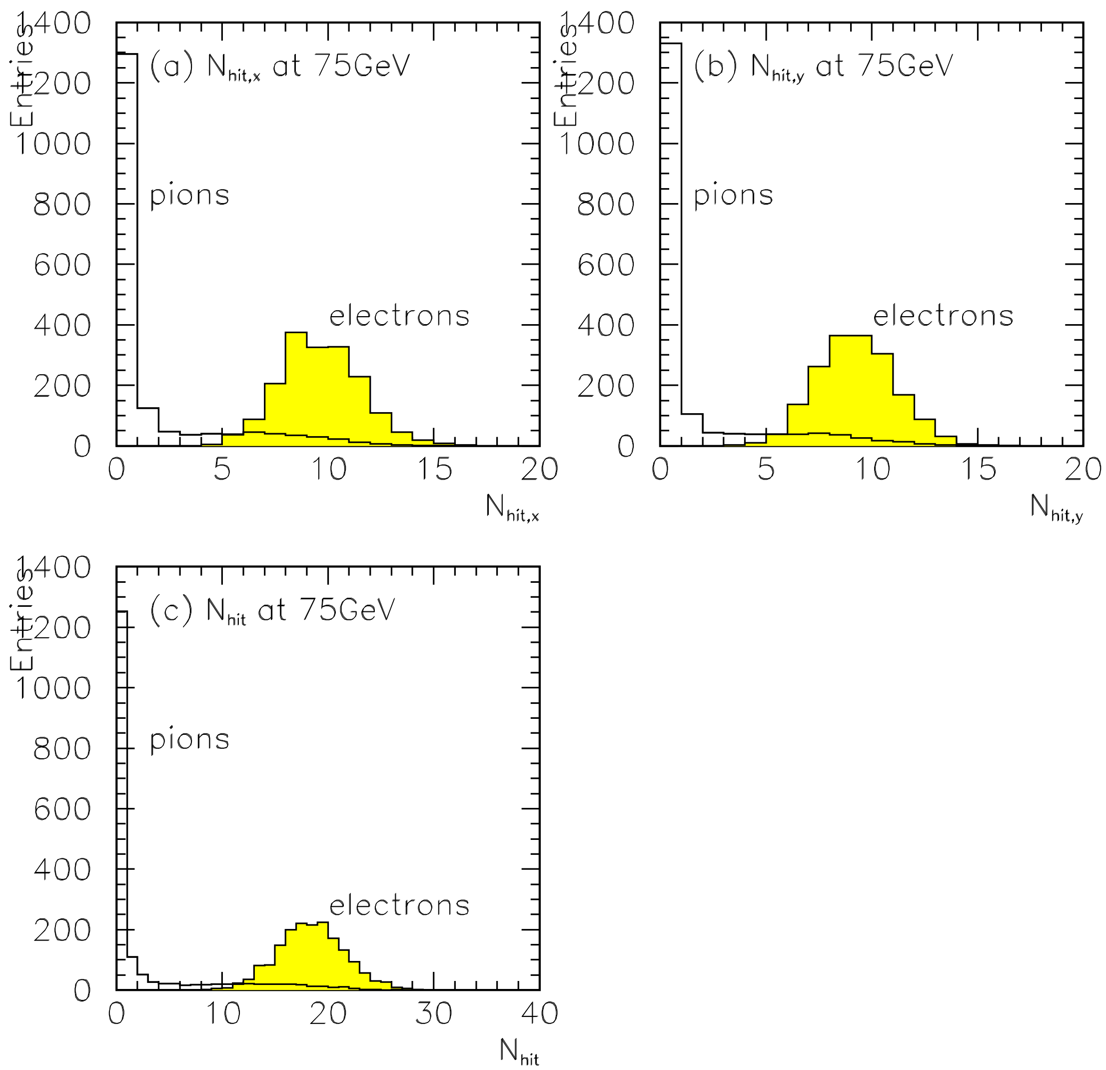


Performance of PSD energy ratios (cont'd)

Method	R_{PS1}			R_{PS2}			R_{PS}		
ϵ_e (%)	90	95	98	90	95	98	90	95	98
r_π at 50 GeV	12.4	10.8	9.4	21.9	15.6	12.2	16.5	13.2	11.0
r_π at 75 GeV	12.1	10.8	9.7	19.6	16.0	12.1	16.1	14.0	11.5
r_π at 100 GeV	10.8	9.5	8.4	18.9	12.3	10.3	14.7	11.2	10.0

The SMD hit multiplicity

- threshold of a hit = 5 MIP
  (to avoid MAPMT crosstalk effect)
- $N_{x(y)}$ = number of hit strips in the x-(y-) plane
- $N_{hit} = N_x + N_y$



Performance of the SMD hit multiplicity

Energy	50 GeV		75 GeV		100 GeV	
N_{hit}	ϵ_e (%)	r_π	ϵ_e (%)	r_π	ϵ_e (%)	r_π
≥ 10	98.9	9.4	99.6	8.1	99.7	7.0
≥ 11	97.6	10.5	99.2	8.9	99.4	7.6
≥ 12	94.6	12.2	97.8	10.0	98.3	8.3
≥ 13	91.0	14.2	95.8	11.3	97.0	9.2
≥ 14	84.4	17.2	91.2	13.0	95.3	10.3
≥ 15	74.4	21.6	86.5	15.2	90.4	11.8
≥ 16	63.6	27.5	78.2	18.3	83.4	13.7

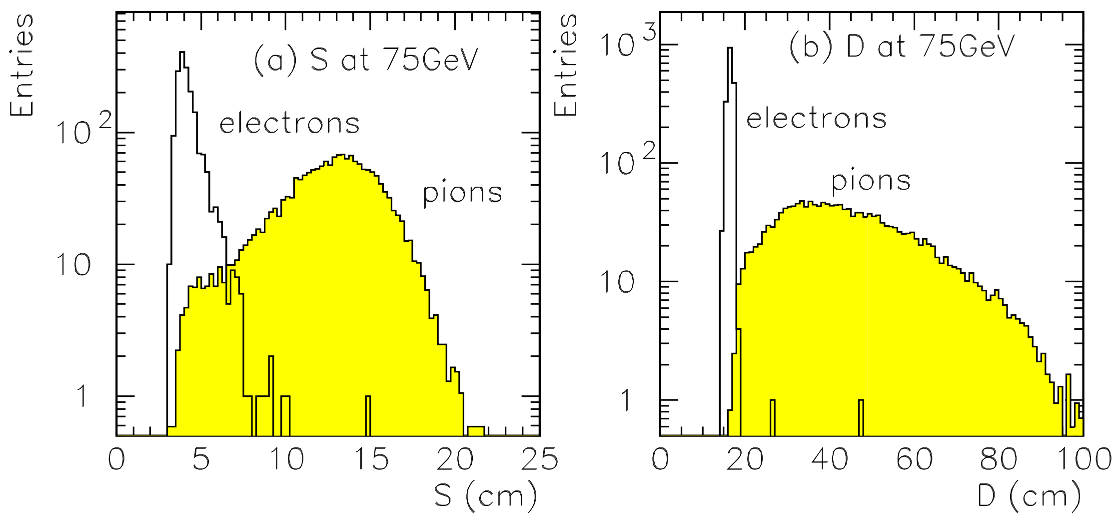
S and D values

S: lateral shower spread calculated by FCAL only ;

$$S = \sqrt{\frac{\sum_i d_i^2 E_{FC}(i)}{E_{FC}}}$$

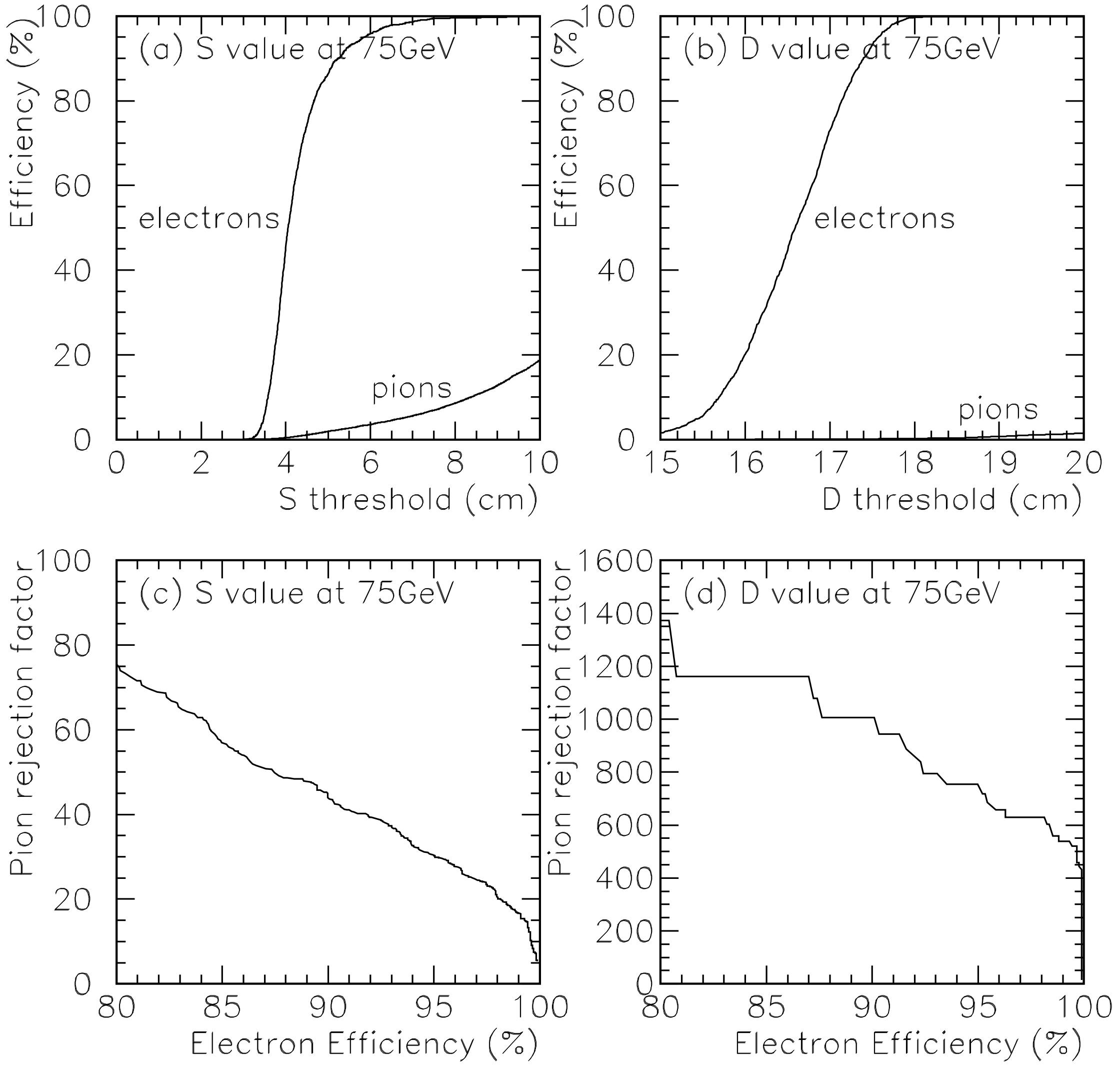
D: longitudinal shower depth calculated by PSD, FCAL and RCAL ;

$$D = \frac{\sum_j z_j E_j}{E_{tot}}$$



Performance of S and D

D is much more powerful than S in our detector.



Performance of S and D (cont'd)

Method	S value		
ϵ_e (%)	90	95	98
r_π at 50 GeV	33.2	21.3	13.3
r_π at 75 GeV	43.8	30.2	20.5
r_π at 100 GeV	43.6	31.3	19.8

Method	D value		
ϵ_e (%)	90	95	98
r_π at 50 GeV	828	571	502
r_π at 75 GeV	1001	719	629
r_π at 100 GeV	984	820	703

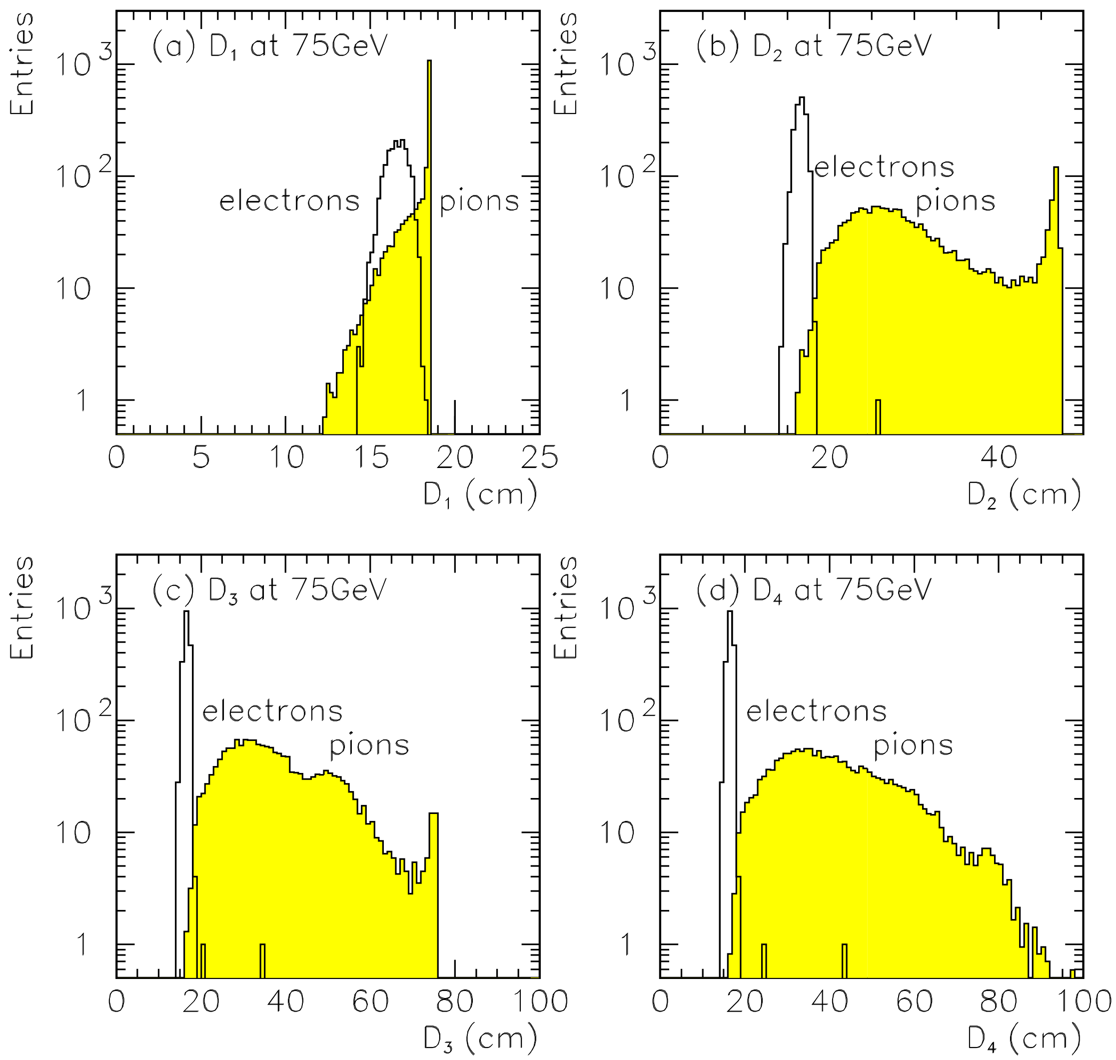
Other D values

$D_1 = D$ value with PSD and FCAL Section 1

$D_2 = D$ value with PSD and FCAL Sections 1, 2

$D_3 = D$ value with PSD and FCAL Sections 1, 2, 3

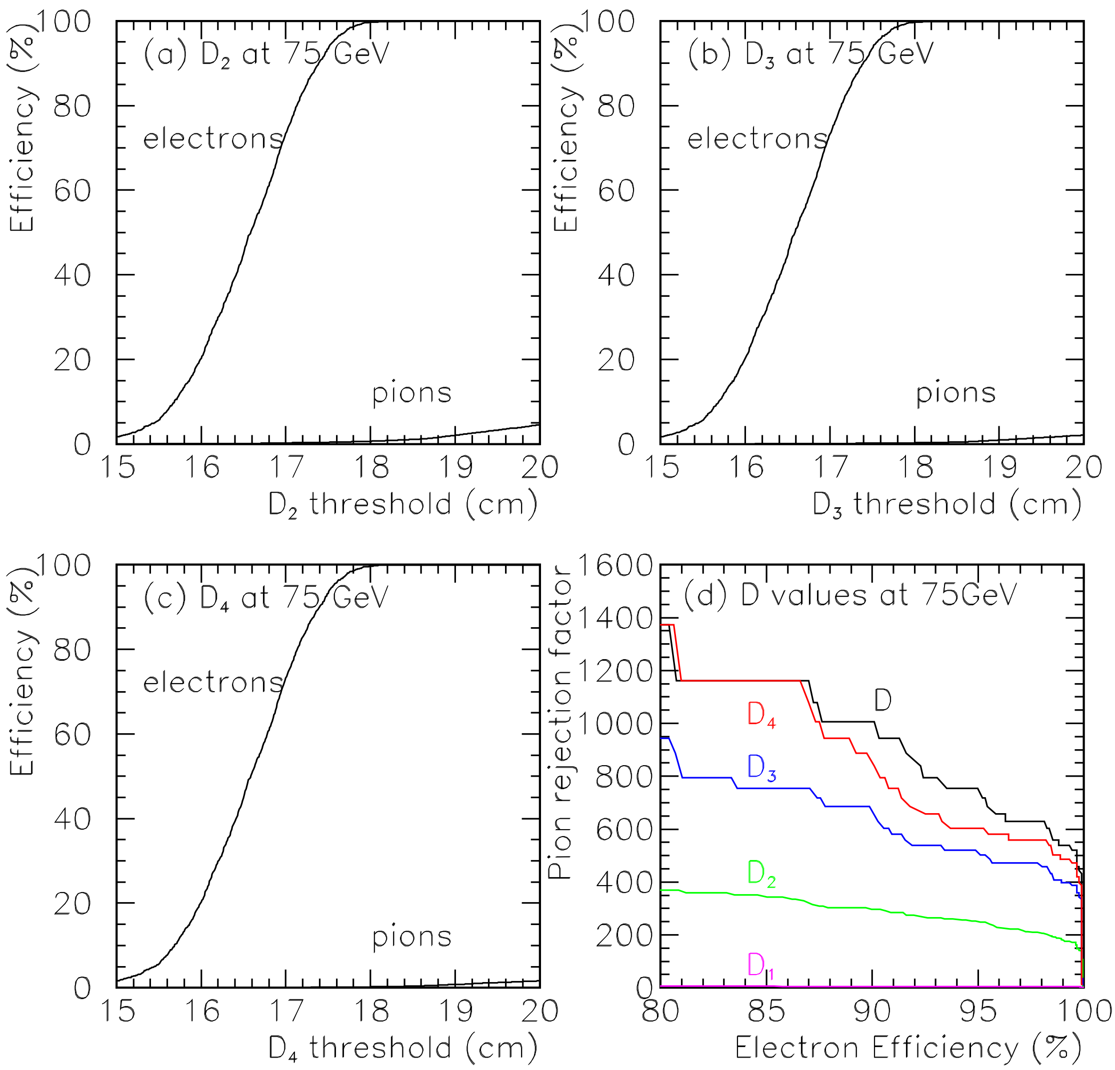
$D_4 = D$ value with PSD and FCAL Sections 1, 2, 3, 4



Performance of D values

$$D_1 \ll D_2 < D_3 < D_4 \sim D$$

Even D_2 is very powerful.



Performance of D values (cont'd)

Method	D_1			D_2		
ϵ_e (%)	90	95	98	90	95	98
r_π at 50 GeV	4.8	4.1	3.6	210	158	128
r_π at 75 GeV	5.0	4.5	4.0	296	248	207
r_π at 100 GeV	4.9	4.3	4.0	317	246	229

Method	D_3			D_4		
ϵ_e (%)	90	95	98	90	95	98
r_π at 50 GeV	591	436	318	752	551	460
r_π at 75 GeV	629	503	458	839	604	559
r_π at 100 GeV	656	547	469	894	703	615

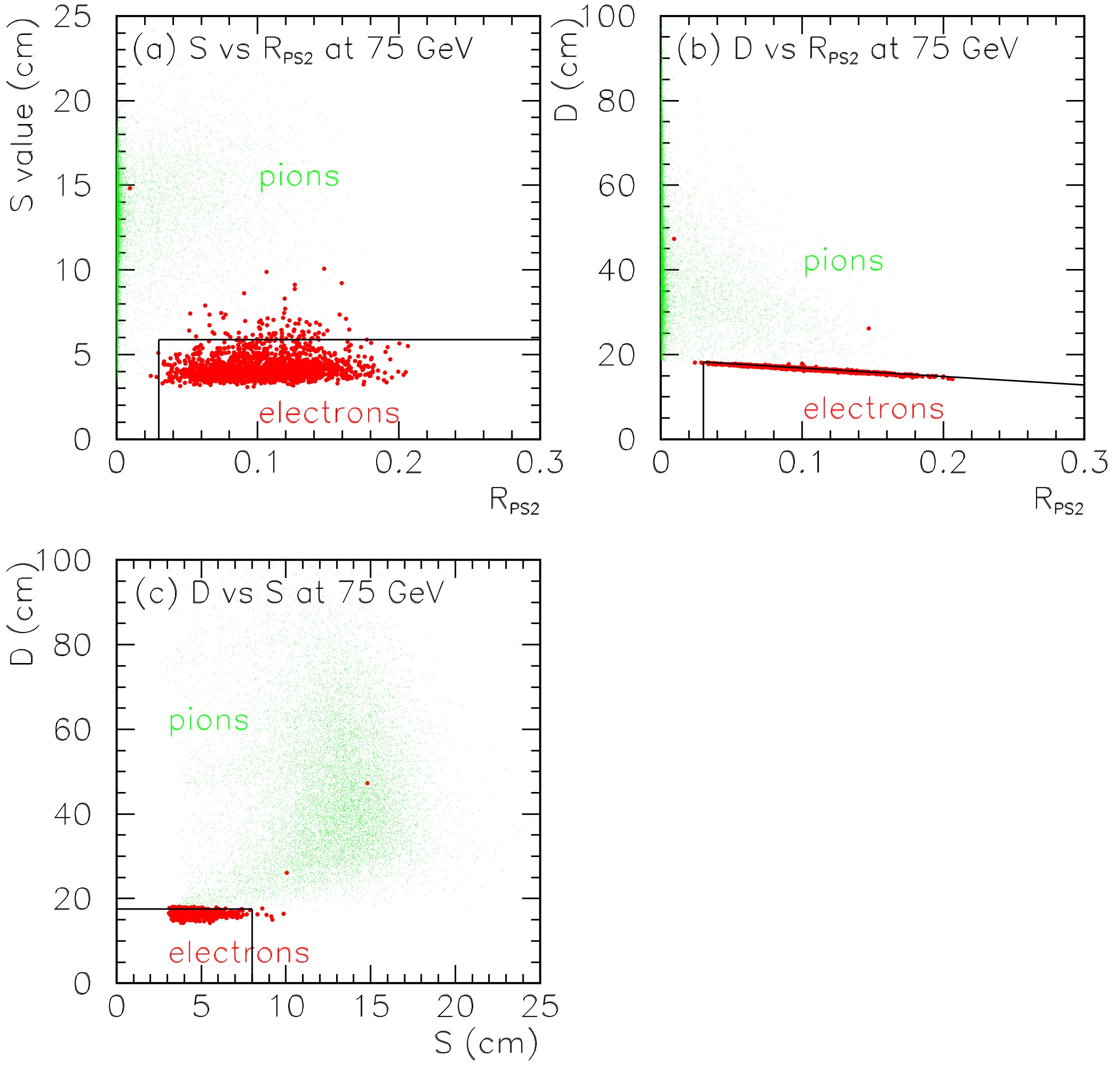
Combinations

(a) S and R_{PS2}

(b) D and R_{PS2}

(c) S and D values

95% electron efficiency zones are shown in the plots.



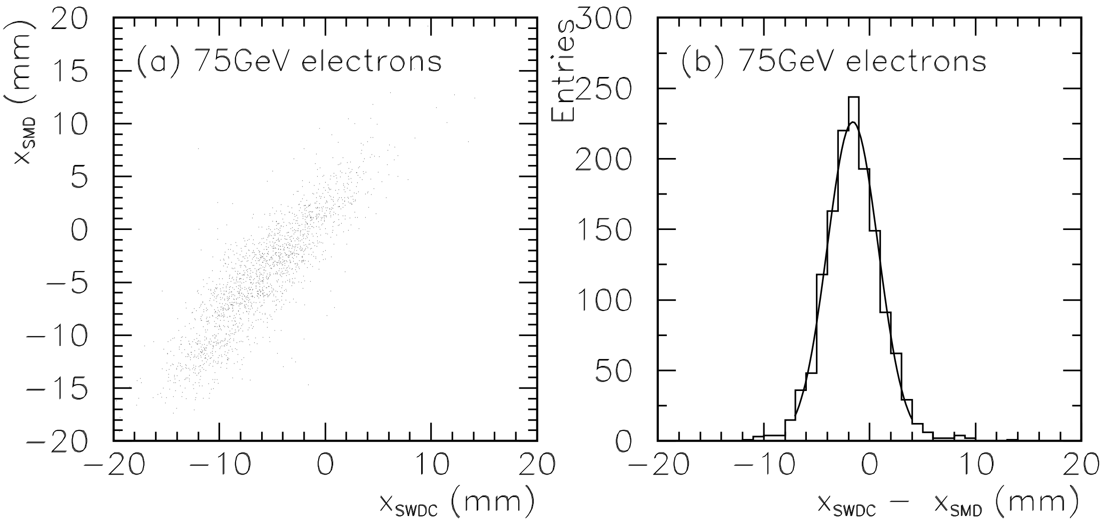
Performance of combinations

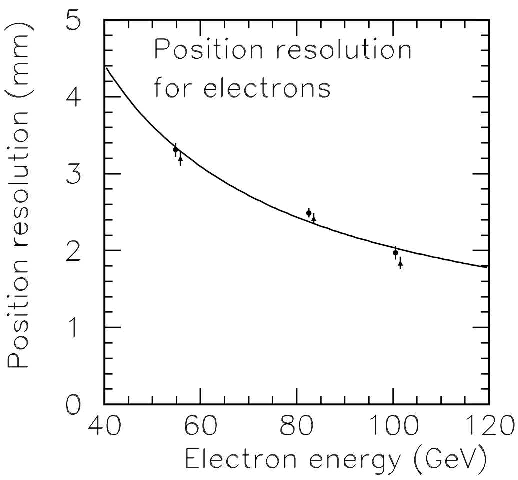
Method	S value and R_{PS2}		
ϵ_e (%)	90	95	98
r_π at 50 GeV	473	312	180
r_π at 75 GeV	657	487	343
r_π at 100 GeV	984	656	281

Method	D value and R_{PS2}		
ϵ_e (%)	90	95	98
r_π at 50 GeV	1274	1104	720
r_π at 75 GeV	1258	1162	944
r_π at 100 GeV	1640	1406	1406

Method	D and S values		
ϵ_e (%)	90	95	98
r_π at 50 GeV	1183	828	753
r_π at 75 GeV	1510	1162	888
r_π at 100 GeV	984	820	656

Position resolution





$$\sigma = \frac{(1.58 \pm 0.11) \times 10^2}{E} + (0.46 \pm 0.14)\,\mathrm{mm}$$

Summary

- PSD/SMD prototype was tested with high energy beam (50 $\sim$ 100 GeV)
- Excellent e-ID capability for single particles

Method	r_π at ϵ_e=95% (75GeV)
R_{PS2}	14.0
N_{hit} in SMD	$\geq$ 11.3
S (spread)	30.2
D (depth)	719
S and R_{PS2}	487
D and R_{PS2}	1162
S and D	1162

- Reasonable position resolution for electrons

Future Prospect

- Performance test with low energy beam ?
- R&D of multi-pixel photo devices
- R&D of scinti-strip PSD / EMC to see 3-dim. EM shower development