Status of detector R&D

E. Iarocci (Frascati)

STATUS
OF
DETECTOR R&D

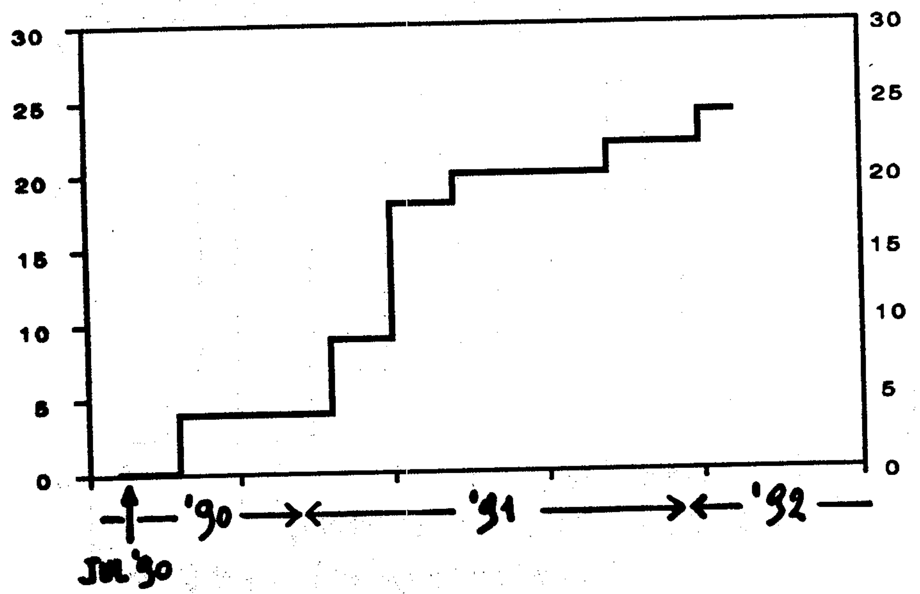
OUTLINE :

- THE R&D EFFORT (DRDC)
- CALORIMETRY
- TRACKING
- OTHER

EMPHASIS ON WHAT HAS NOT BEEN COVERED IN THE PRESENTATIONS OF EOI's.

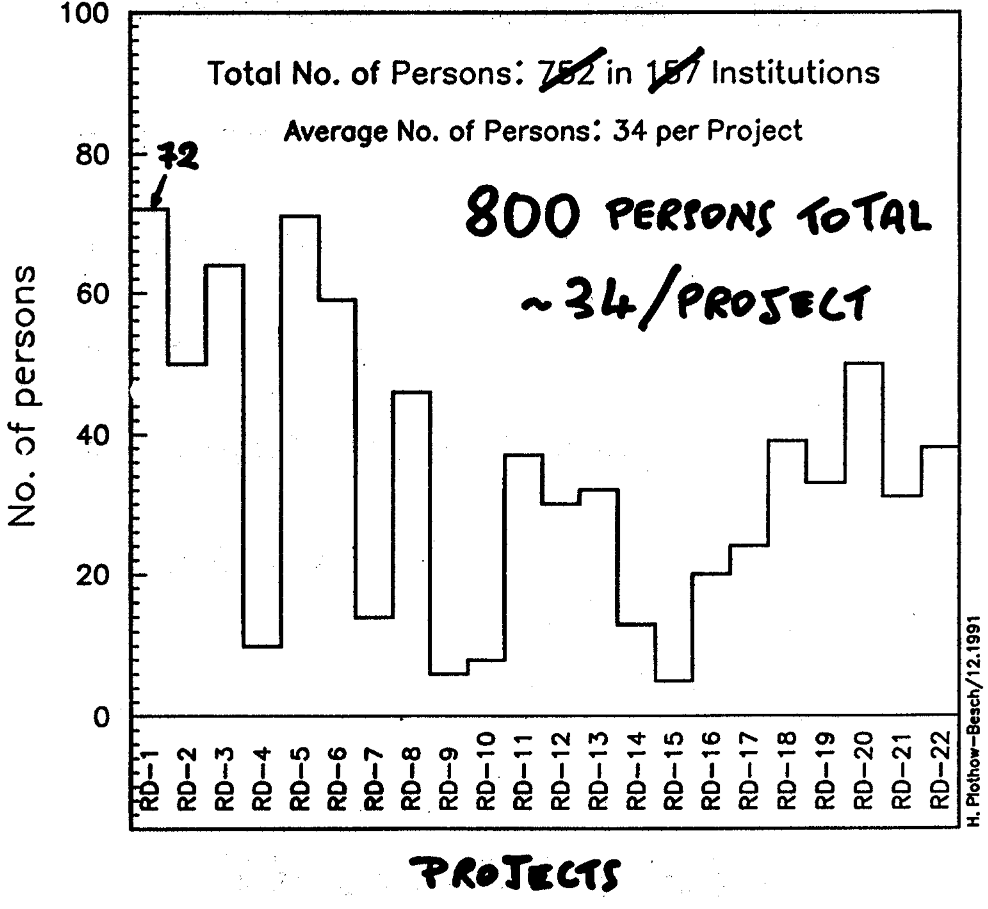
DRDC : SET-UP IN MID '90 TO STIMULATE AND COORDINATE THE R&D EFFORT IN VIEW OF LHC

35 PROPOSALS → 24 APPROVED PROJECTS

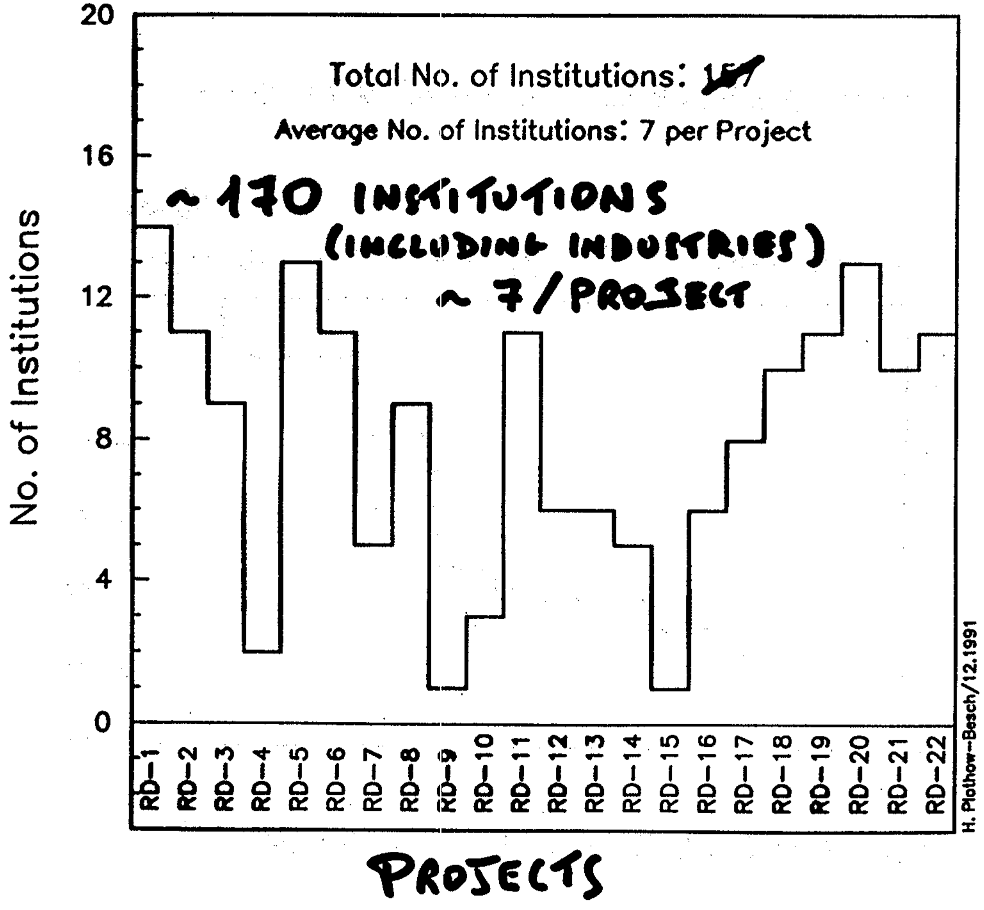


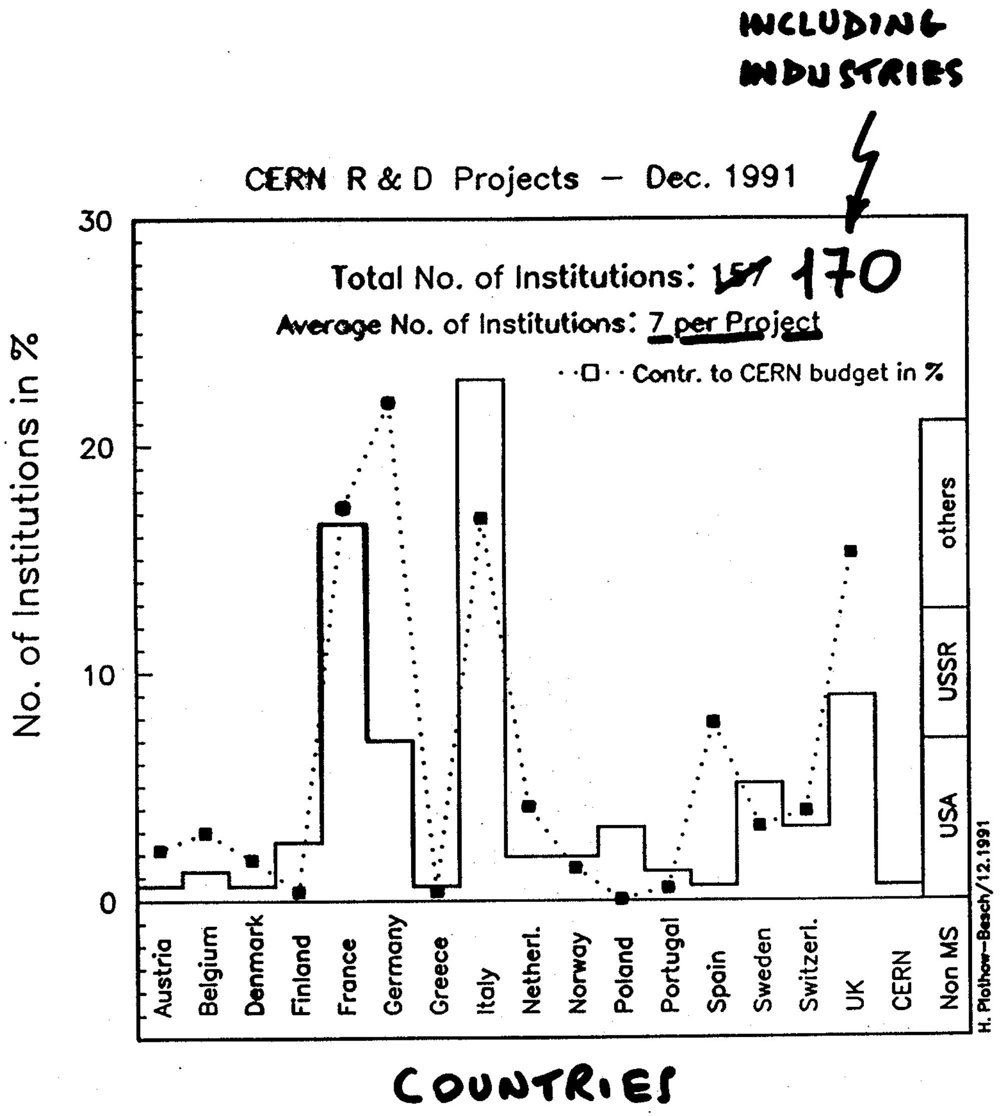
~ 5 NEW PROPOSALS FORESEEN IN '92

CERN R & D Projects – Dec. 1991



CERN R & D Projects – Dec. 1991





CALORIMETRY : THE BEST UNDERSTOOD AREA

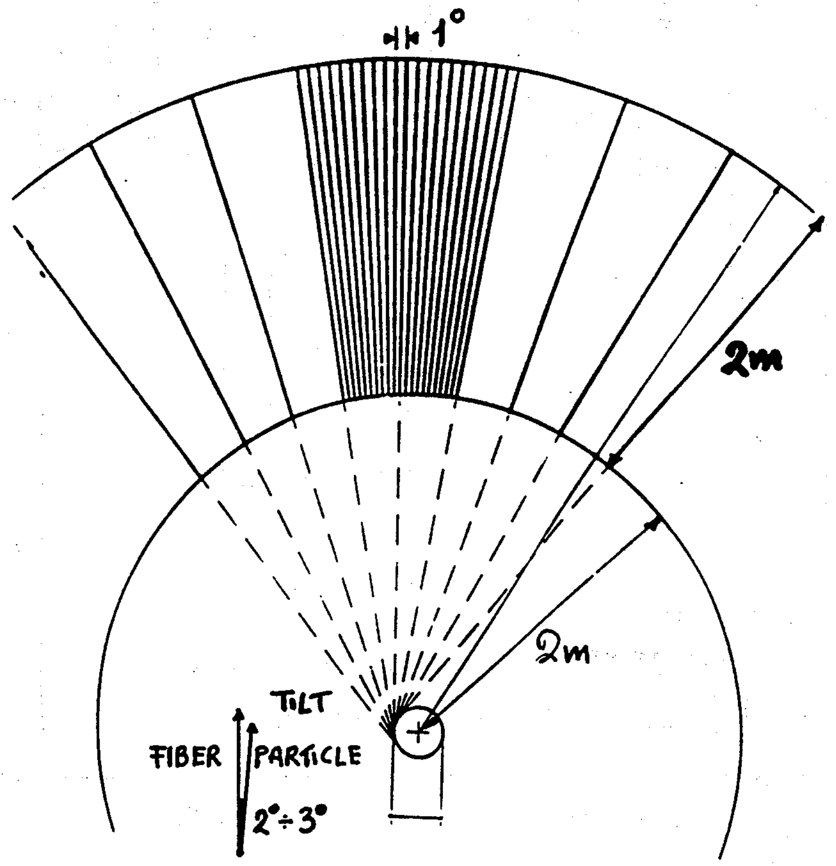
- ACCURACY, SPEED AND HOMOGENEITY: CHOICE OF GOOD CONCEPTS
- RAD. HARDNESS : GOOD CONFIDENCE
- HERMETICITY : MAJOR ENGINEERING PROBLEM : PROMISING GENERAL STUDIES

GENERAL PURPOSE
RD1 - SPACAL + P32
RD3 - ACCORDION RD4 - LAr DOPANTS
P34 - Si HADRON CAL.

HI-ACCURACY E.M.
RD18 - CRYSTAL
RD14 - LIQUID Xe OR Kr

RD1-SPACAL: CAGLIARI, CERN, CLERM.-FERR., ECOLE POLYTECH., LISBON, MARSEILLE, NAPOLI, PARIS VI, PAVIA, RIO DE JAN., UC SAN DIEGO, WEIZMANN INST.

ORIGINAL CONCEPT: INTEGRATED e.m.-h, POINTING, COMPENSATED BY SCI.FI./LEAD = 1/4



SPACAL : '91 PROTOTYPE STUDIES

① **INTEGRATED** POINTING PROTOTYPE

■ 1mm SCI.FI., 1/4 FILLING FI./LEAD

e TEST : $\sigma_E/E = 14.6\%/\sqrt{E} + 1.6\%$
UNSATISFACTORY

→ **SEGMENTED** e.m./h & FINER e.m. SAMPLING

② e.m. POINTING PROTOTYPE

■ 0.5mm SCI.FI., 1/4 FILLING

e TEST : $\sigma_E/E = 9.3\%/\sqrt{E} + 0.6\%$

'92 PROTOTYPES

1 e.m. PROTOTYPE

■ 1mm SCI.FI., 1/1.8 FILLING

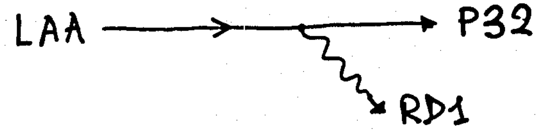
e M.C. : $\sigma_E/E = 8\%/\sqrt{E} + 0.2\%$

② hadr. PROTOTYPE WITH COARSE GRAIN

STUDIES
- RAD. HARDN.
- CALIBR. & MONITORING
- LIGHT DETECTOR
- ENGINEERING

P32 - LEAD/SCI.FI. CAL.: BOLOGNA, CERN-LAA, AIN-OUSSURA, BEIJING, MOSCOW, BUCHAREST, FRASCATI, NAPOLI, TORINO, CORNELL, WORLD LAB.

SPAGHETTI CALORIMETER:



- DIFFERENT ATTITUDE : $\sigma_E/E_{e.m.} \sim 15\%/\sqrt{E} + 1.5\%$ IS WORTH THE ADVANTAGES OF THE INTEGRATED e.m.-h CAL. (FAST e-π DISCR., COST,...)

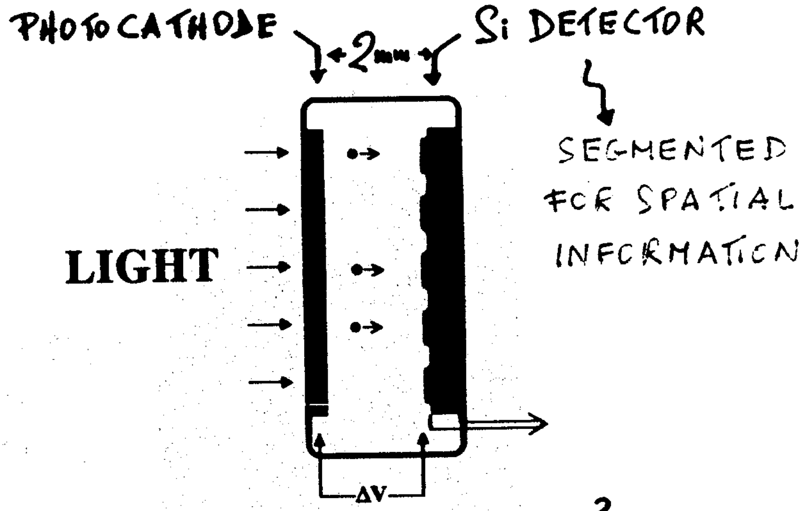
- DIFFERENT ENGINEERING

{
- RAD. DAMAGE STUDIES
- PERFORMANCE & ENGINEERING

being discussed in the DRDC

- SPACAL LIGHT YIELD ≳ 1 P.E./MeV

→ **NEW DEVICE BEING DEVELOPED:**
PROXIMITY FOCUSSING HYBRID PM

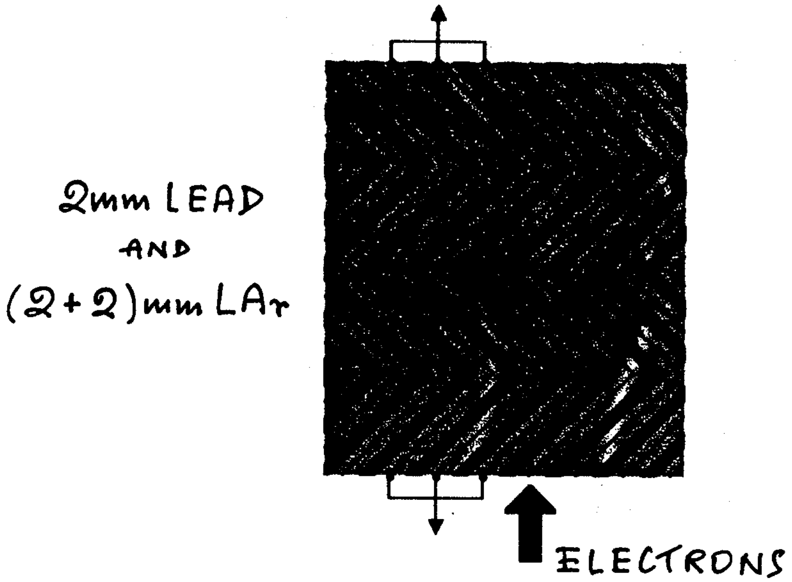


$10 \div 15\,\text{kV} \rightarrow \text{GAIN} \sim 10^3$
MAGN. FIELD INSENSITIVE

- OPTION : AVALANCHE PHOTODIODES

RD3-ACCORDION: LAPP, BNL, CERN, MILANO, LAL, SACLAY, STOCKHOLM

'90 PROTOTYPE

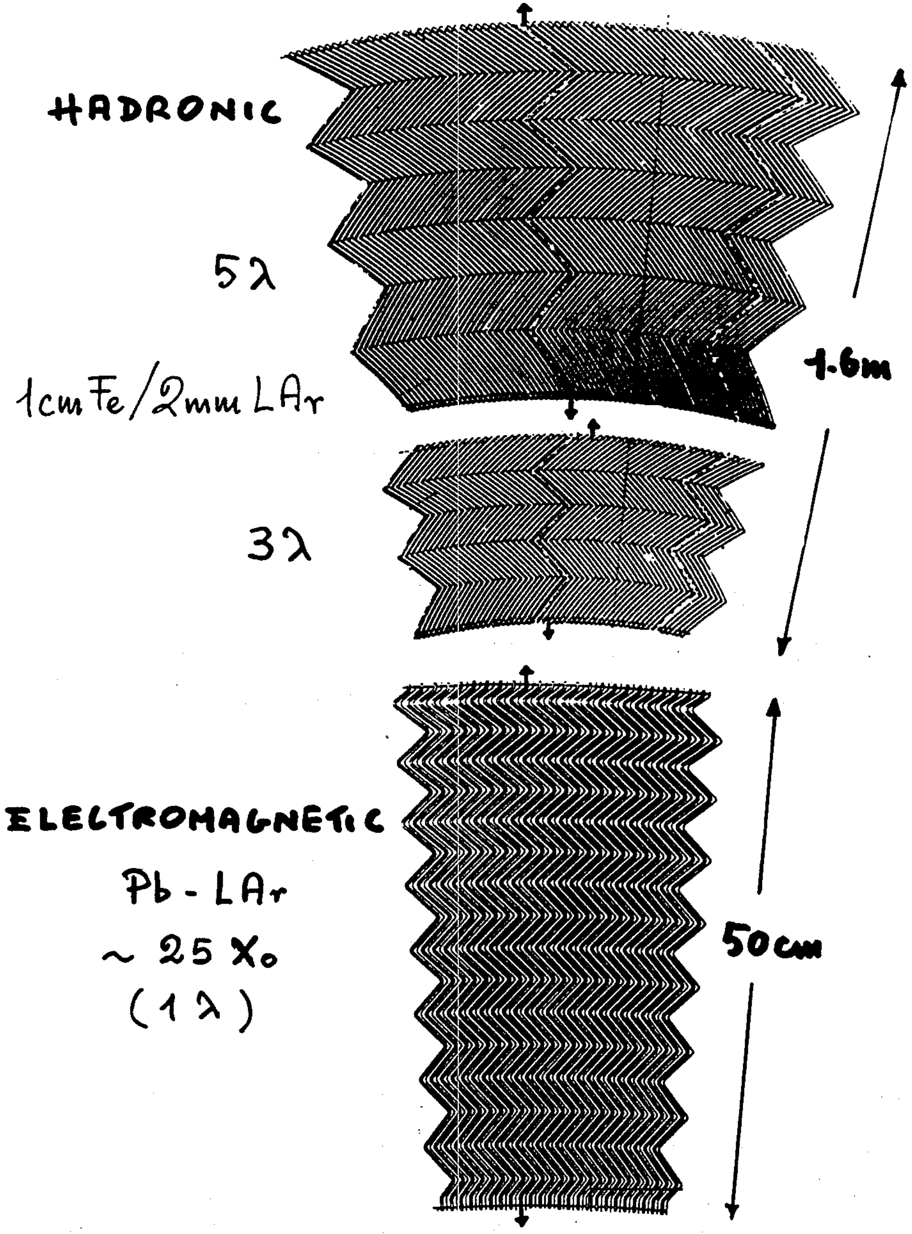


- PERFORMANCE WITH FAST ELECTRONICS : $t_p \sim 35ns$

$$\sigma_E/E = 9.6\%/\sqrt{E} + 0.3\% + 0.33/E$$

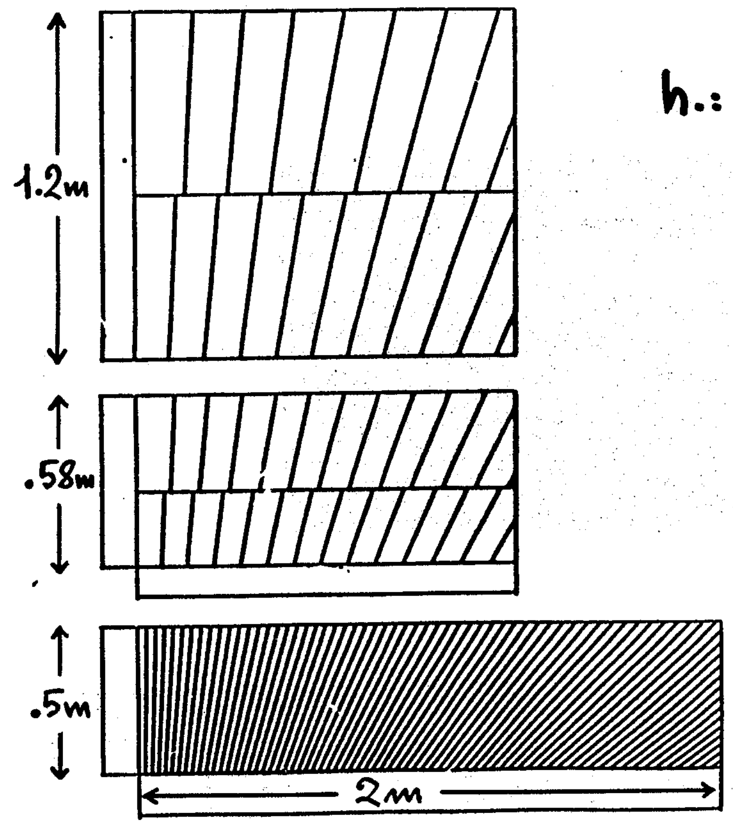
$$\sigma_x = 3.7mm/\sqrt{E}. \quad \sigma_\theta = 12mrad \text{ AT } 60GeV$$

ACCORDION : GENERAL DESIGN STUDY



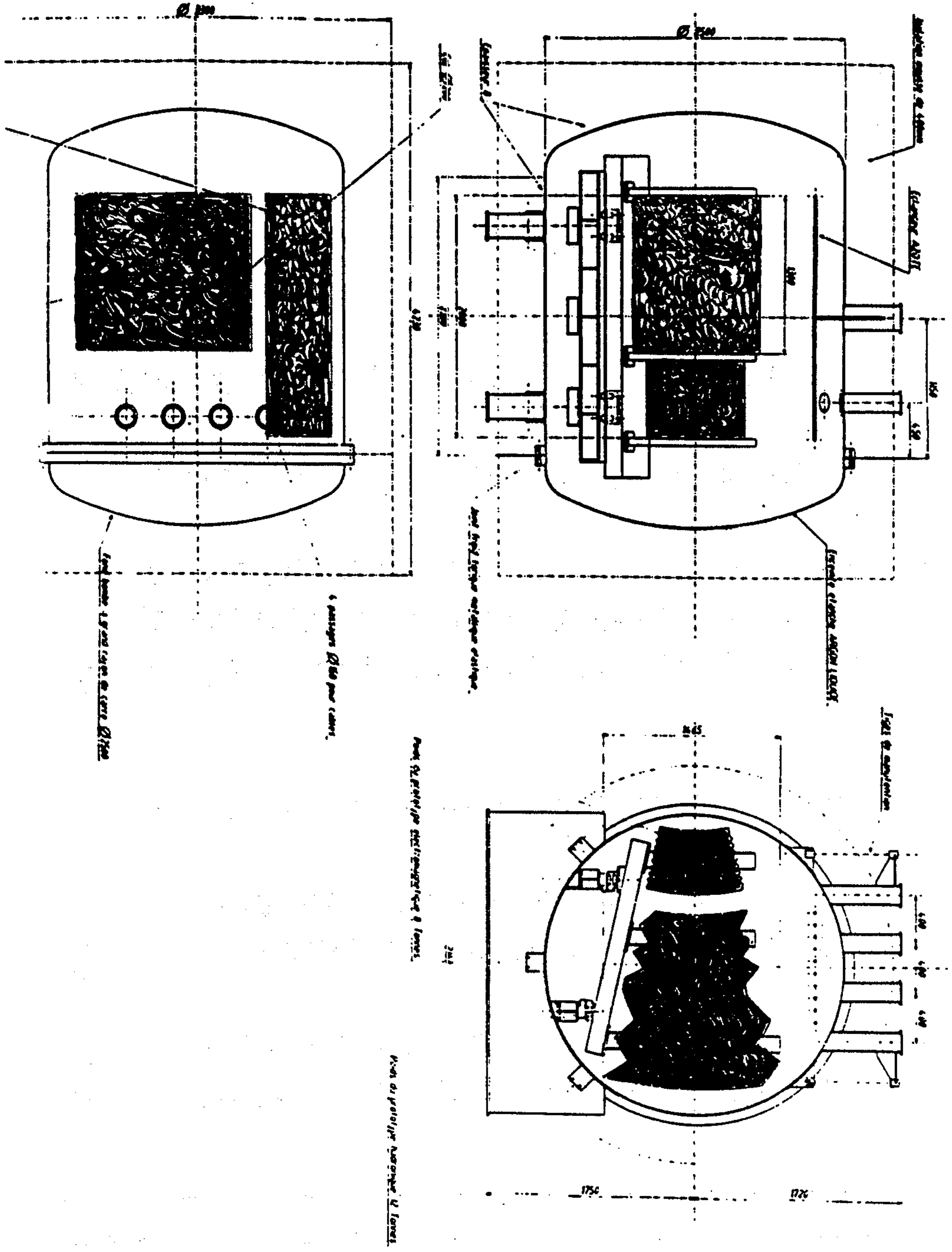
ACCORDION : POINTING PROTOTYPE
UNDER CONSTRUCTION

- ENGINEERING
- e.m. PERFORMANCE



h.: 400 Ch.

e.m.:
3-FOLD SEGM.
$\Delta\eta \times \Delta\phi = .02 \times .02$
3'600 Ch.



RD4 - LA$_r$ DOPANTS : CERN, STOCKHOLM

AIM : DOPE LA$_r$ WITH HYDROCARBON :
ETHYLENE, etc

① TO INCREASE DRIFT VELOCITY OF ELECTRONS TO IMPROVE (SIGNAL/NOISE) × 2

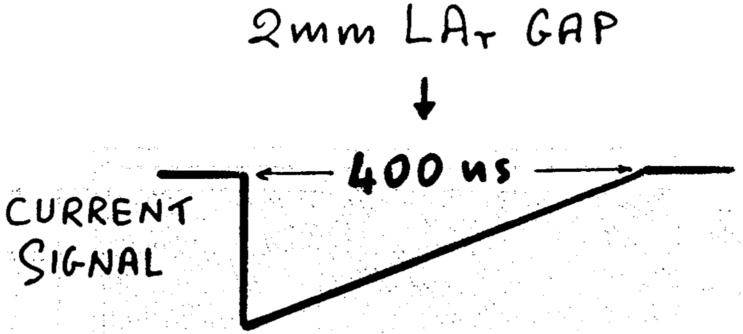
ACHIEVED AT CONCENTRATIONS $\gtrsim$ 0.2 % VOL

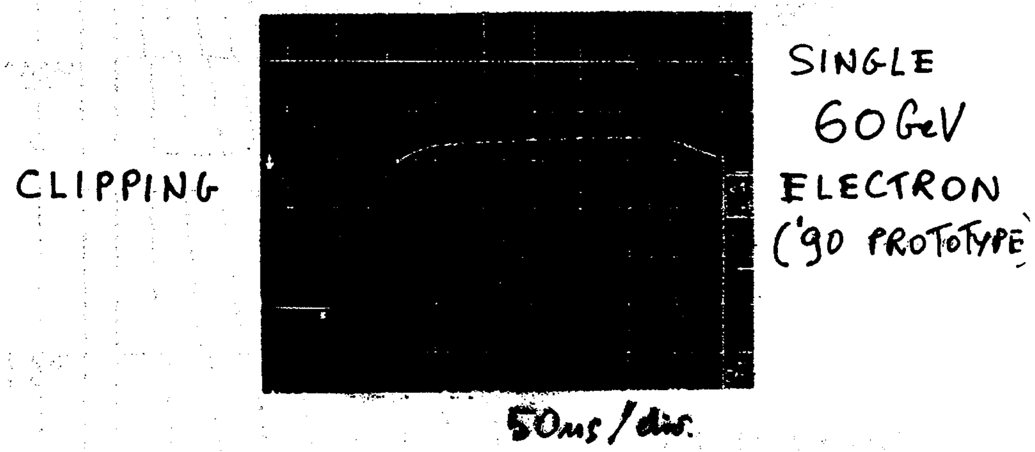
② TO INCREASE CHARGE COLLECTION FOR DENSELY IONIZING PARTICLES (BY PHOTOIONIZATION) TO GET COMPENSATION

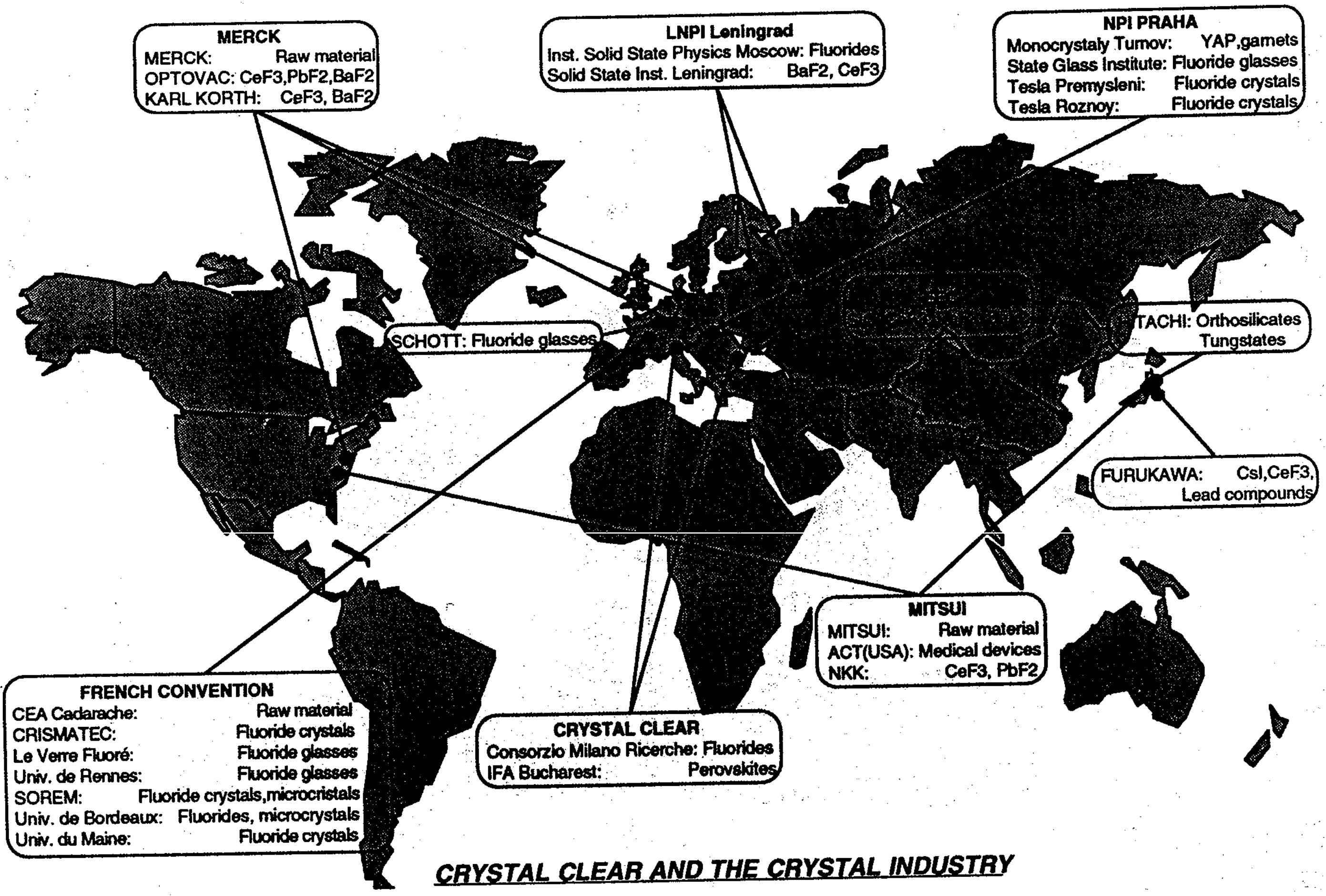
ACHIEVED AT CONCENTRATIONS $\lesssim$ 50 ppm

- BUT EITHER ① OR ②, NOT BOTH

CONCLUSION : ONLY MARGINAL BENEFIT







CRYSTAL CLEAR AND THE CRYSTAL INDUSTRY

RD18 - CRYSTAL CLEAR: CERN, MILANO, ANCONA, ROMA, BUCHAREST, LYON, LAPP, LENINGRAD, LUND, PRAHA, AACHEN, TATA

AIM: SYSTEMATIC STUDY & DEVELOPM. OF HI-YIELD, FAST, DENSE, RAD.HARD, T-INDEP. **CRISTALS** (HEAVY FLUORIDES OR TERN.COMP.) **OR HEAVY GLASSES**

'92 PROGRAMME:

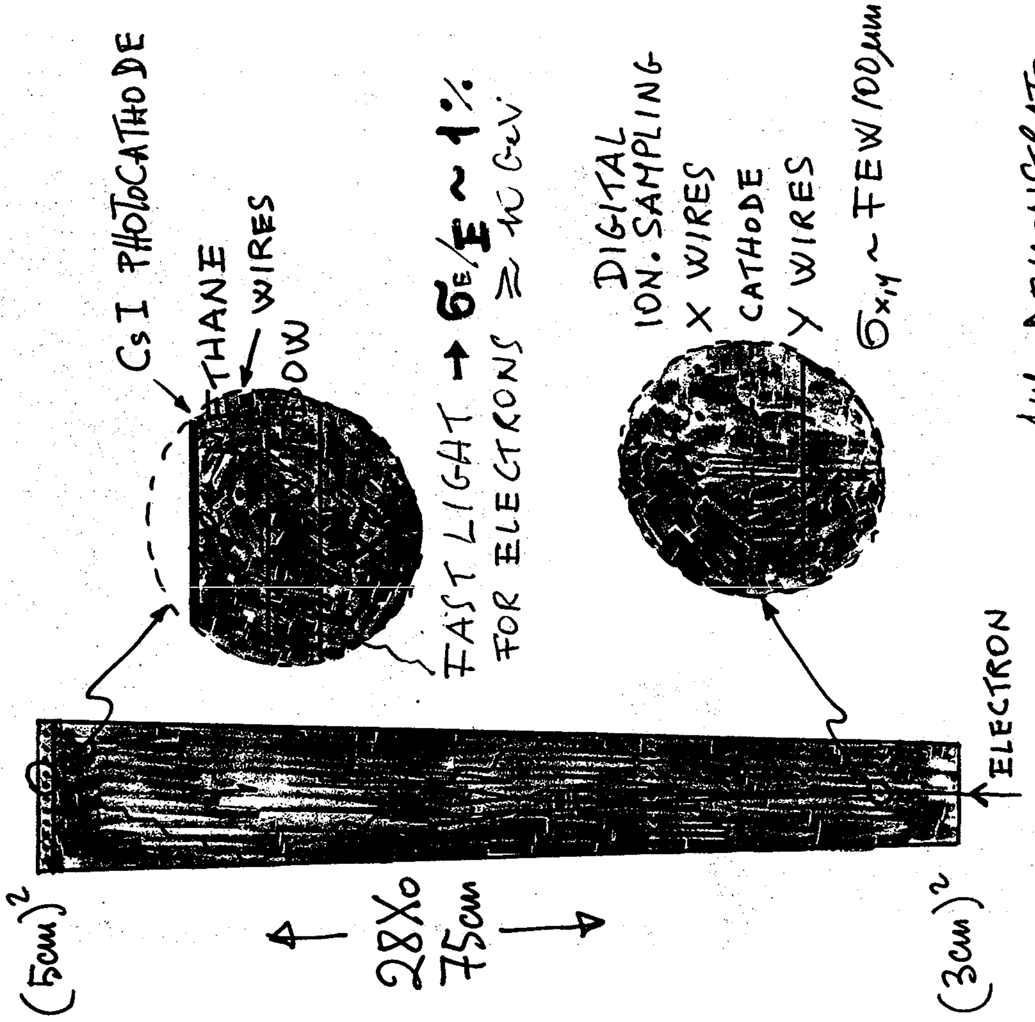
- MASS PRODUCTION STUDIES OF CeF_3
- SEARCH FOR BETTER CANDIDATES

FINAL CHOICE: 1-2 YEARS

RD14 - LIQUID Xe OR Kr : PARIS, CERN, COIMBRA, SERPUKHOV, WORL LAB.

TOTALLY ACTIVE

CONCEPT OF POINTING TOWER



FAST LIGHT → $\sigma_E/E \sim 1\%$ FOR ELECTRONS ≥ 10 GeV

DIGITAL ION. SAMPLING
X WIRES
CATHODE
Y WIRES
$\sigma_{x,y}$ ~ FEW 100 μm

AIM: DEMONSTRATE CONCEPT

~130 SAMPLES TESTED OF ~50 DIFFERENT TYPES

SOME CRYSTALS STUDIED BY "CRYSTAL CLEAR" COLLABORATION

Crystal	Density	Radiation length cm	Moliere radius cm	Decay time nsec	Peak emission nm	Radiation hardness(Gy)
[redacted]	7.13	1.11	2.33	[redacted]	480	10
[redacted]	4.89	[redacted]	3.39	[redacted]	210 310	> 10^4
[redacted]	6.16	[redacted]	2.63	[redacted]	300 340	> 10^4
YAP:Ce	5.35	2.83	2.82	35	390	> 10^5
GSO:0.5%Ce	6.71	1.39	2.42	55	435	> 10^6
GSO:2.5%Ce	6.71	1.39	2.42	31	450	> 10^6
ThF4	6.32	1.18	2.71	10 , 30	315,330,450	?
BaLiF3	5.24	2.13	3.13	2	435	?
LiYbF4	6.09	1.56	2.70	≤ 25	≈ 450	> 10^5
BaYb2F8	6.99	1.29	2.37	-	-	10^3 to 10^4
[redacted]	7.77	[redacted]	2.21	[redacted]	-	?

Also : Fluoroaluminate and fluorozirconate glasses

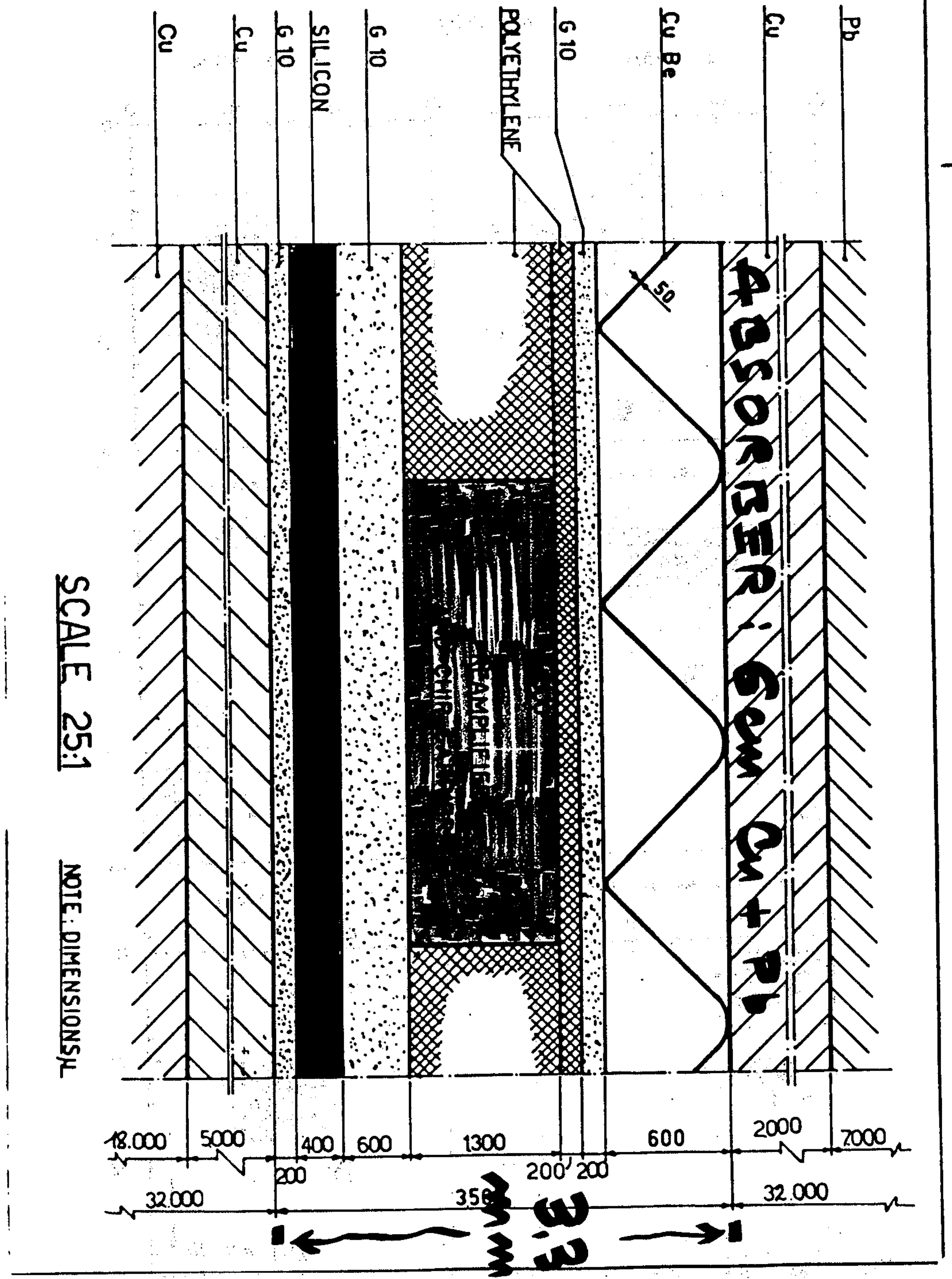
Results in CERN/PPE preprint 91-124

GLASS: COST = 0.2÷0.3 CRYSTAL

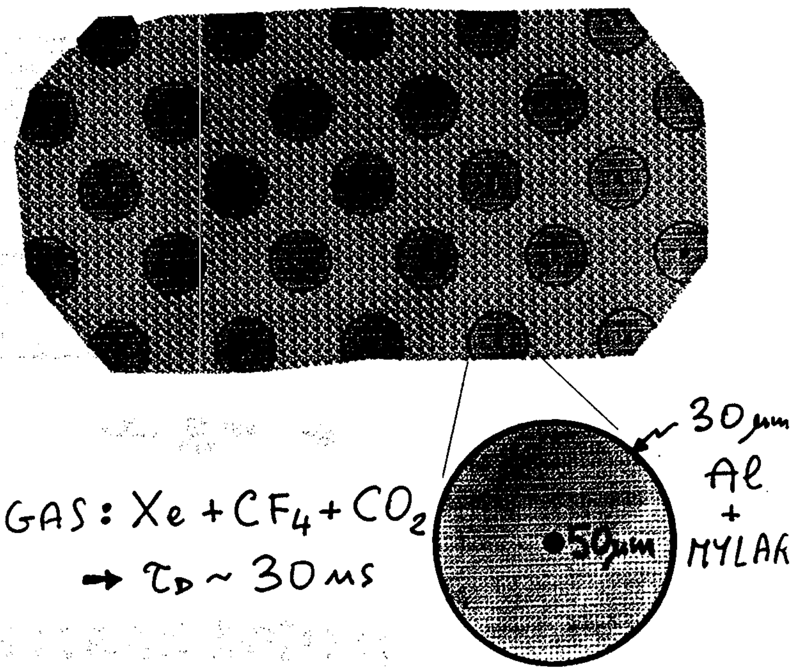
NOT ONLY JUST LOOKING FOR NEW SCINT. MAT. BUT ALSO TRYING TO **MAKE** NEW SCINT.

RD6 - INTEGRATED HIGH RATE TRD AND TRACKING: BNL, CERN, GLASGOW, DUBNA, LENINGRAD, MOSCOW, MPI-MUNICH, RAL

- IDENTIFICATION & TRACKING OF HIGH γ PARTICLES

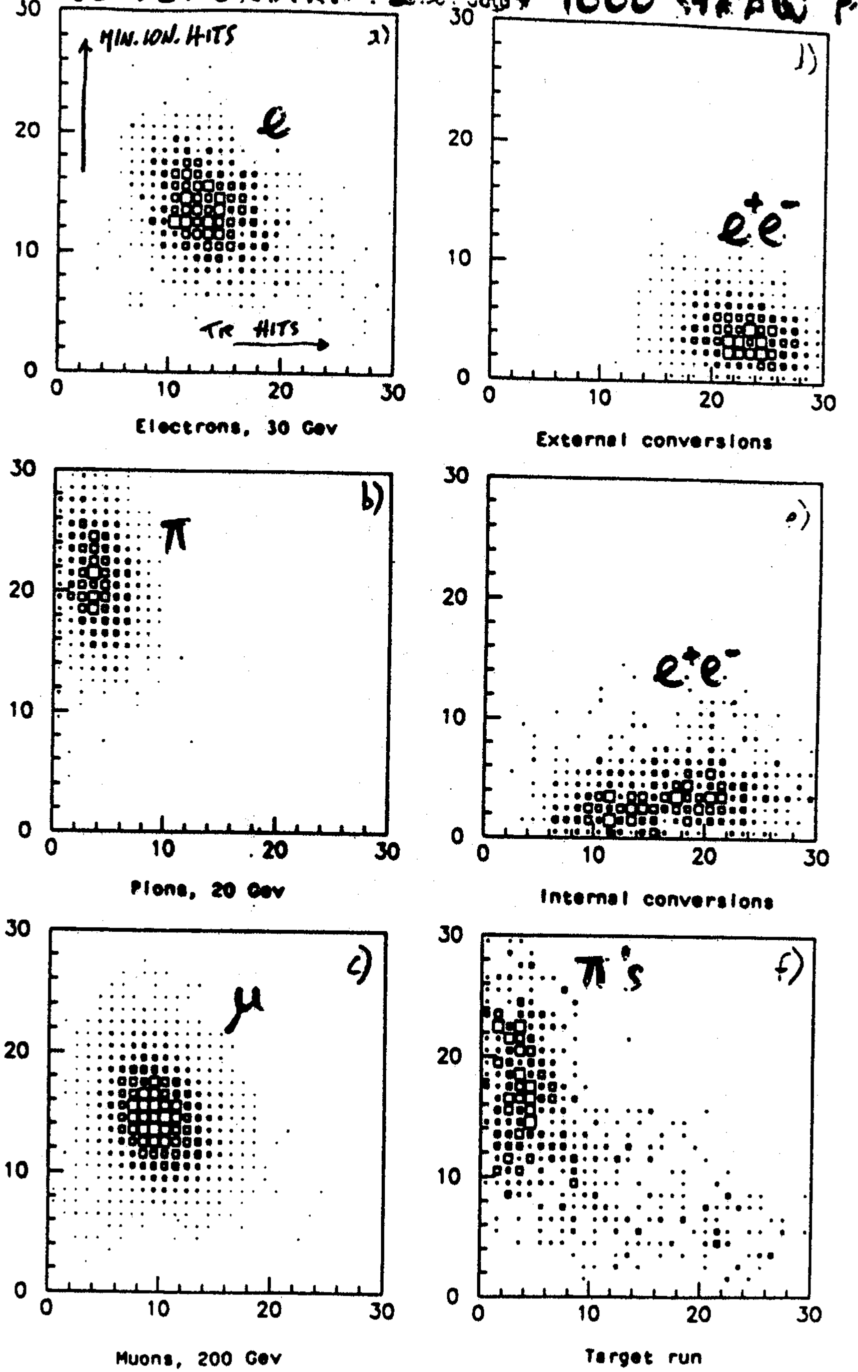


Ø4mm × 0.5m STRAWS
WITH
POLYETH.
SHEETS
AS
RADIATOR



GAS: $Xe + CF_4 + CO_2$
→ $\tau_D \sim 30$ ns

PRINCIPLE DEMONSTRATED BY 1000 STRAW PRO



Electrons, 30 Gev

External conversions

Pions, 20 Gev

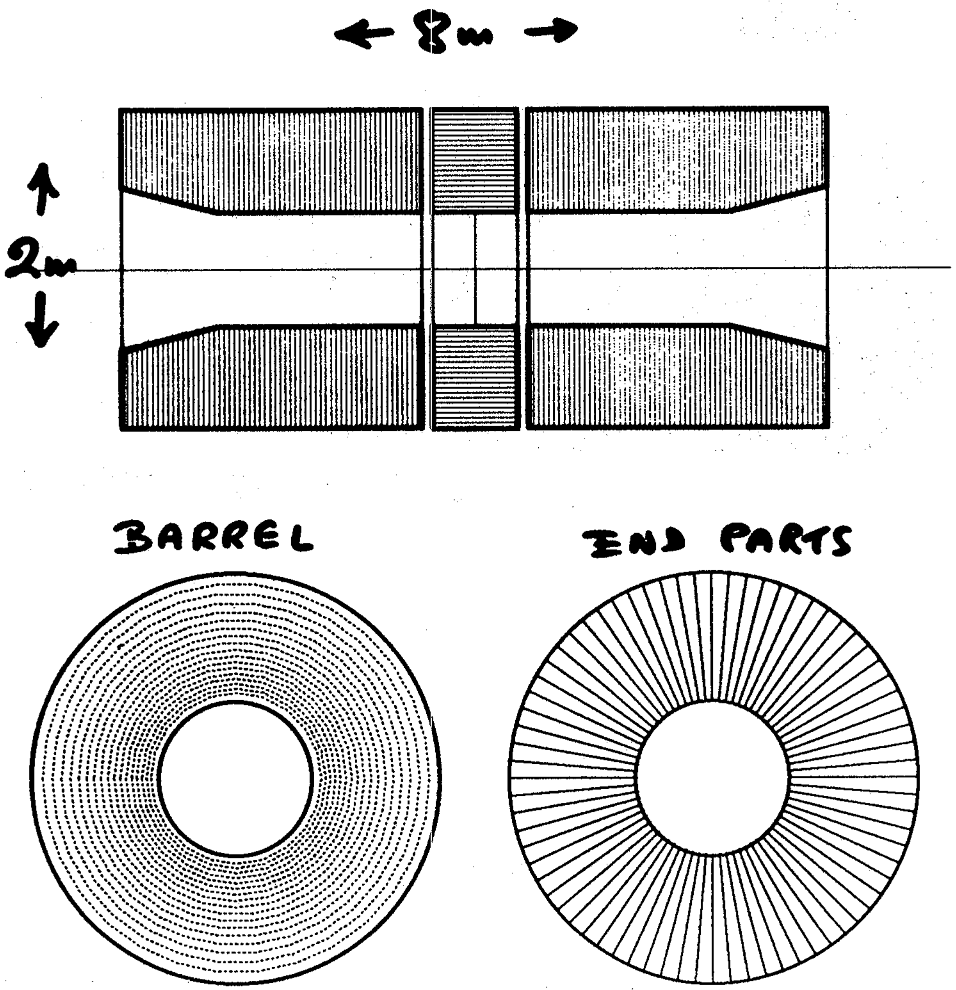
Internal conversions

Muons, 200 Gev

Target run

Figure 29

TRD TRACKER DESIGN



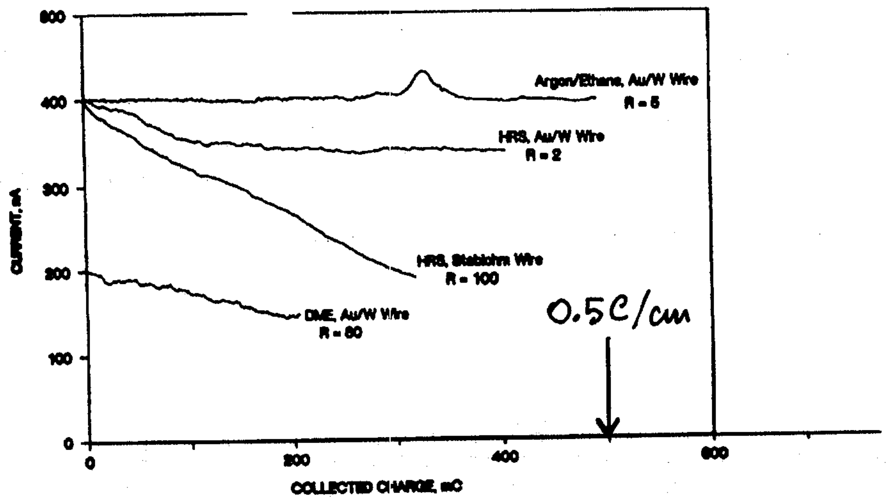
F. Sauli

AGING OF GASEOUS DETECTORS:

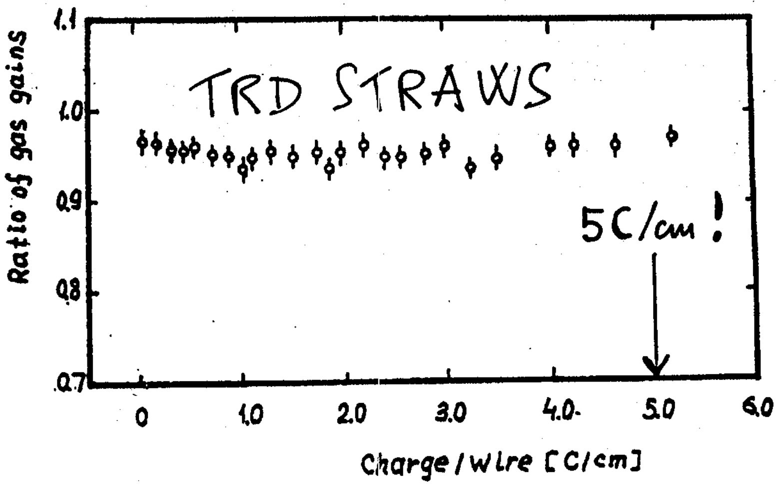
Gain drops at increasing collected charge

Terms of reference: Min.Ionizing Tracks: ≈100 e⁻ Gain 10^5 – 1pC/track
1C/cm of wire (1 mm spacing) – 10 C/cm² – 10^{13} min.ion./cm²

1 C/cm ≈ 1 MRad

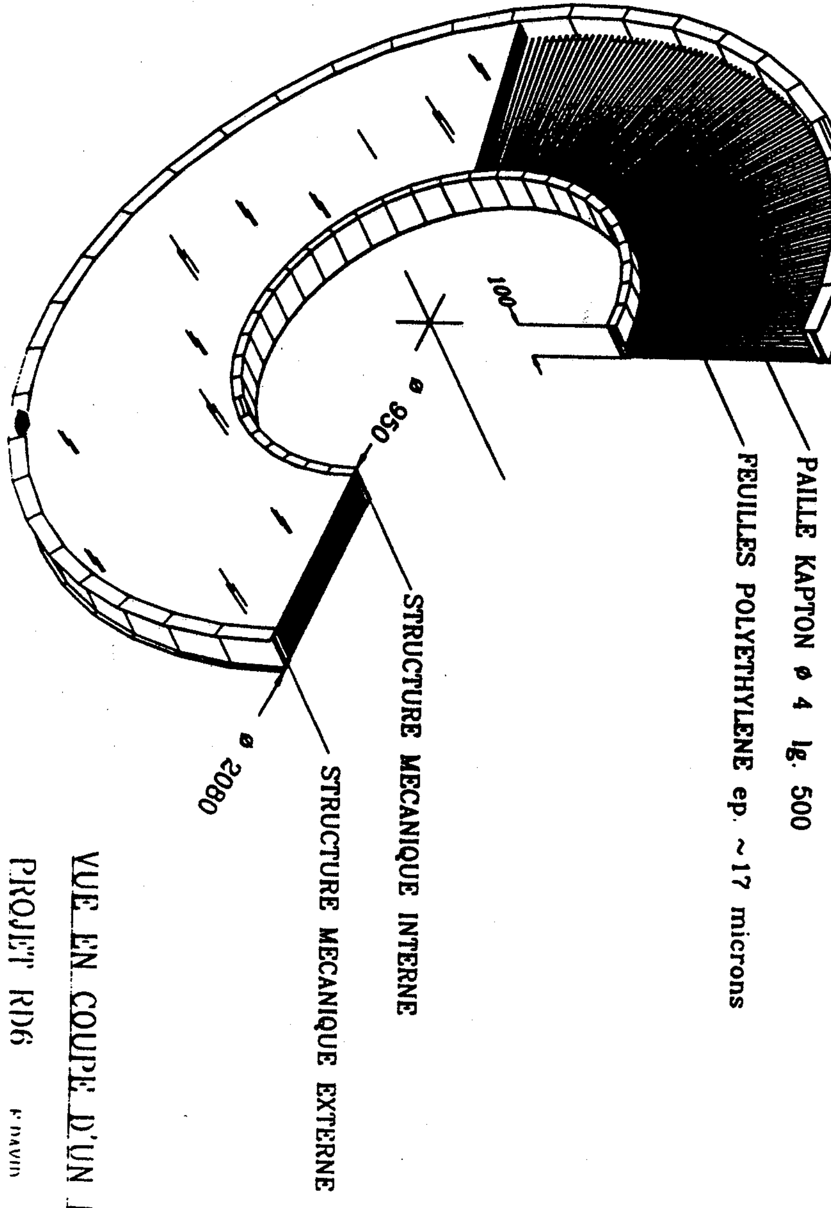


J. Kadyk et al, IEEE NS-37 (1990) 478



Bondarenko et al (Moscow TRD) (1991)

'92 PROTOTYPE:
10'000 STRAWS TO
DEMONSTRATE DETECTOR



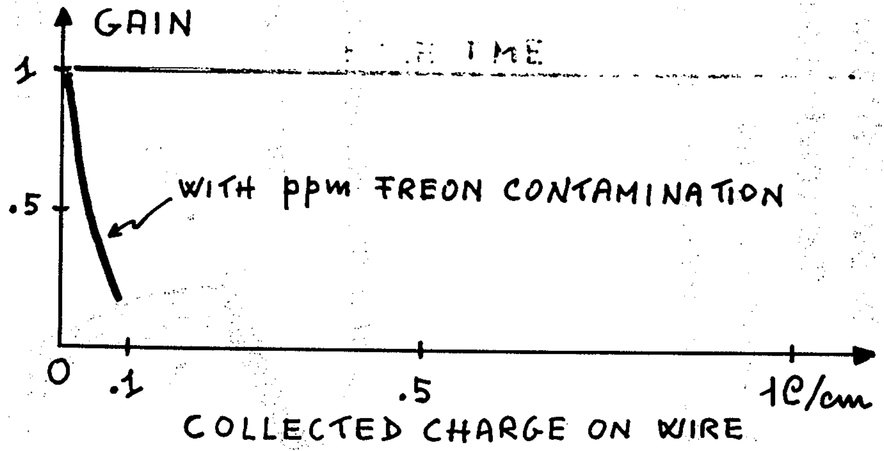
VUE EN COUPE D'UN MODUL

PROJET RD6 F. DAVID

Figure 34

- ✱ GAS AGING IS NOT AN INTRINSIC PROPERTY OF GASEOUS DETECTORS BUT IS DUE TO ppm POLLUTANTS

EXAMPLE



→ RD10 : RADIATION HARDNESS OF GAS DET.

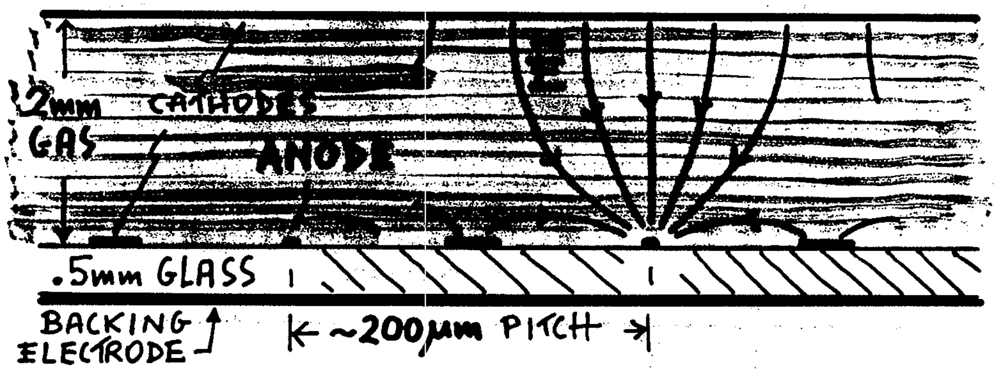
CERN, GLASGOW, EINDHOVEN

- UNDERSTAND PHENOMENA
- GIVE PRESCRIPTIONS
- MAKE AVAILABLE A TEST FACILITY

P29 : p EXTRACTION BY CRYSTAL CHANNELING

AARHUS, CERN, FRASCATI, LECCE, I.C. LONDON, PISA, ROMA, STRASBOURG, MPI-STUTTGART, TORINO, TRIESTE

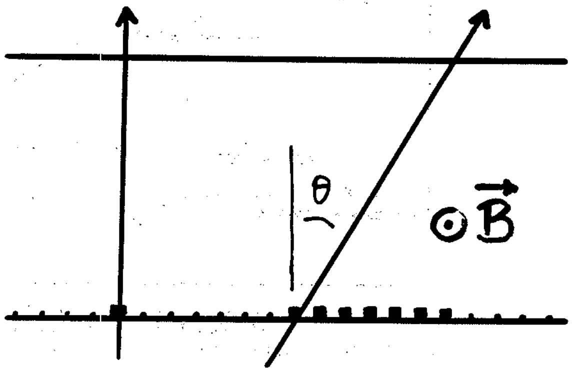
MICROSTRIP CHAMBER



LARGE $\frac{\text{GAP}}{\text{PITCH}}$

↓

ANGLE SENSITIVITY



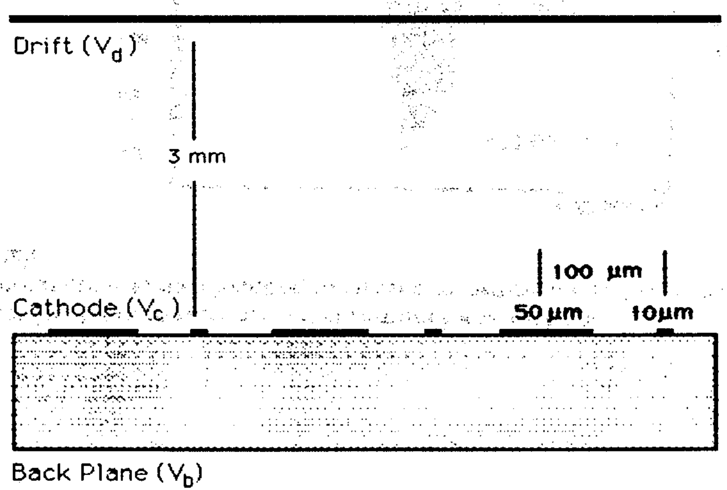
→ SINGLE HIT = HI-p_T → TRIGGER

PROPOSAL TO BE SUBMITTED TO THE DRDC

DEVELOPMENT OF MICROSTRIP GAS CHAMBERS ON GLASS AND PLASTIC SUPPORTS

R. Bouclier, J.J. Florent, J. Gaudaen, G. Million, A. Pasta+, L. Ropelewski, F. Sauli and L. Shekhtman++

CERN, Geneva, Switzerland; + Univ. Milano, Italy; ++ Inst. Nucl. Phys. Novosibirsk, USSR



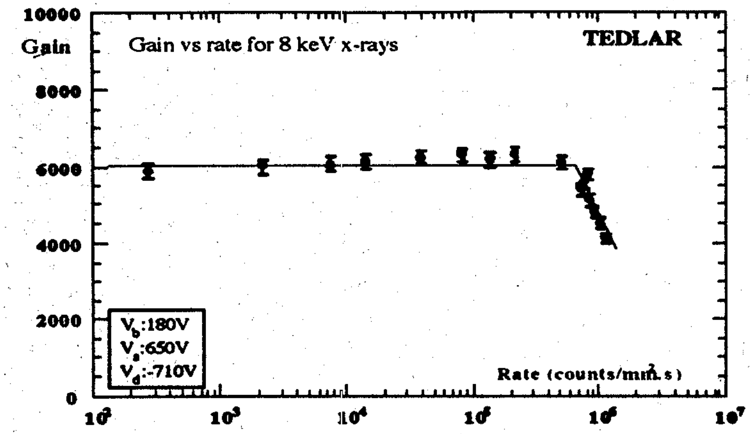
CROSS SECTION OF THE MICROSTRIP GAS CHAMBER

FOCUS ON LHC APPLICATION:

- LARGE AREA & LOW MASS STRUCTURE
- SPEED
- RAD. HARDN. (AGING)

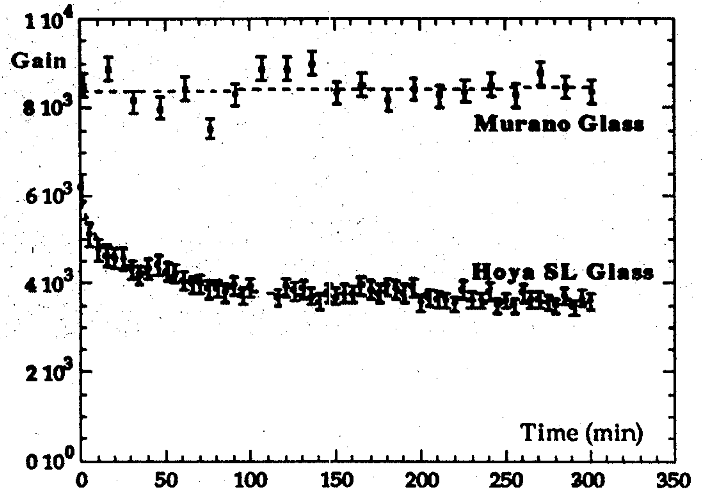
WCC 92

GMSC have very high intrinsic rate capability:



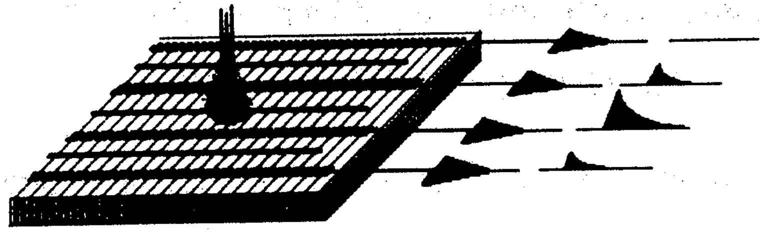
R. Bouclier, J.J. Florent, J. Gaudaen, G. Million, L. Ropelewski, F. Sauli, IEEE Trans. Nucl. Sci. NS-39 (1992)

Surface charging up problems at very high flux require the use of a slightly conductive support, either in the bulk or by ion implantation:

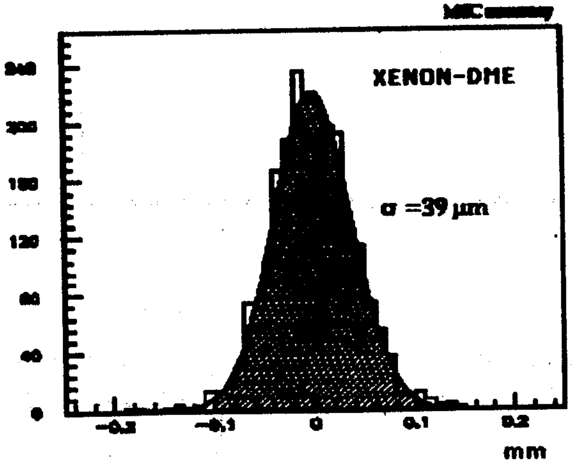


R. Bouclier, J.J. Florent, J. Gaudaen, G. Million, A.Pasta, L. Ropelewski, F. Sauli, L. Shekhtman, Vienna WCC 92

The charge profile induced by an avalanche on adjacent cathodes reflects the original position of the ionization:



Space localization accuracy for minimum ionizing tracks perpendicular to the chamber, measured recording the cathode charge signals:

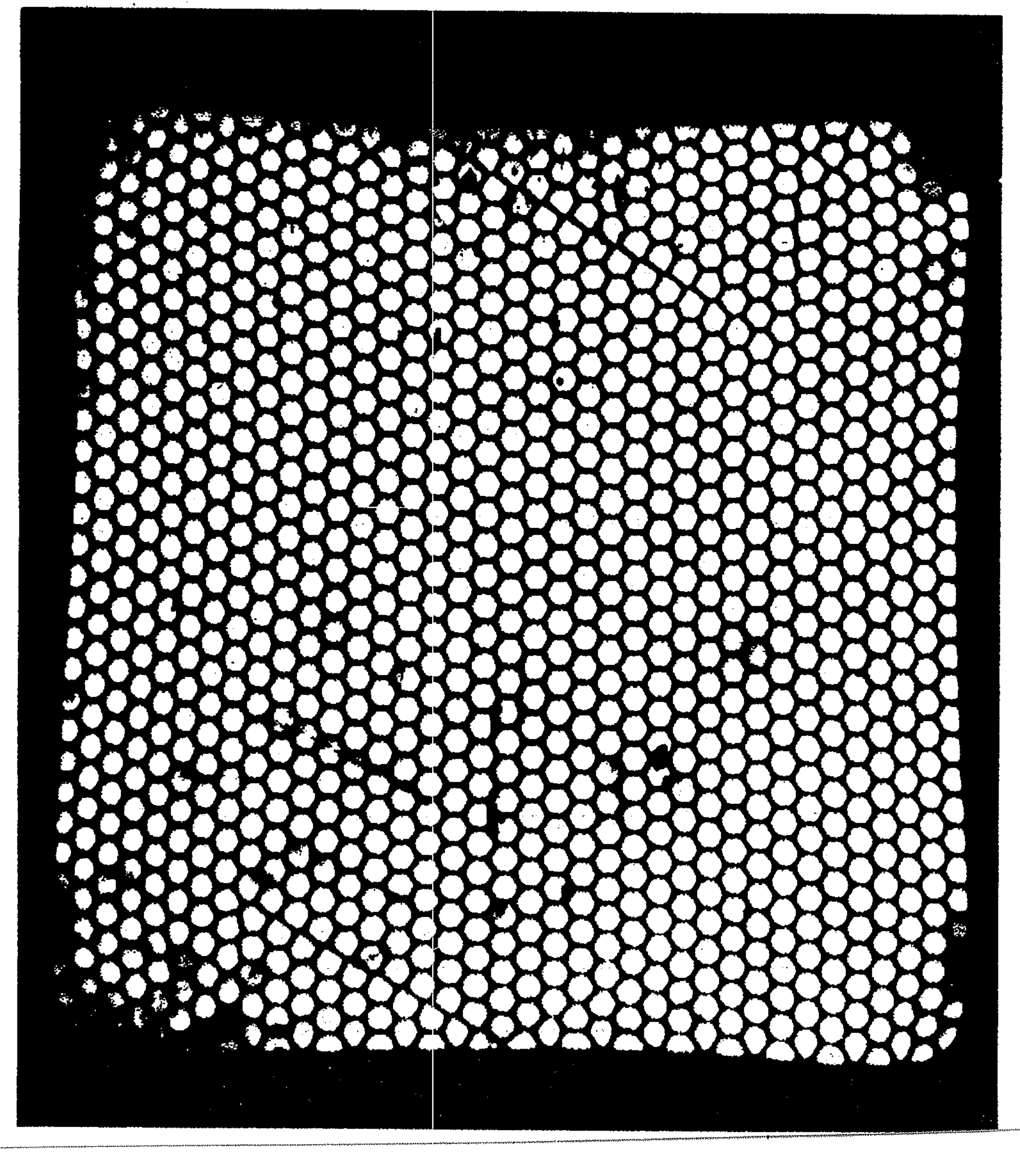


200µm
PITCH

F. Angelini et al, Nucl. Physics 23A (1991) 254

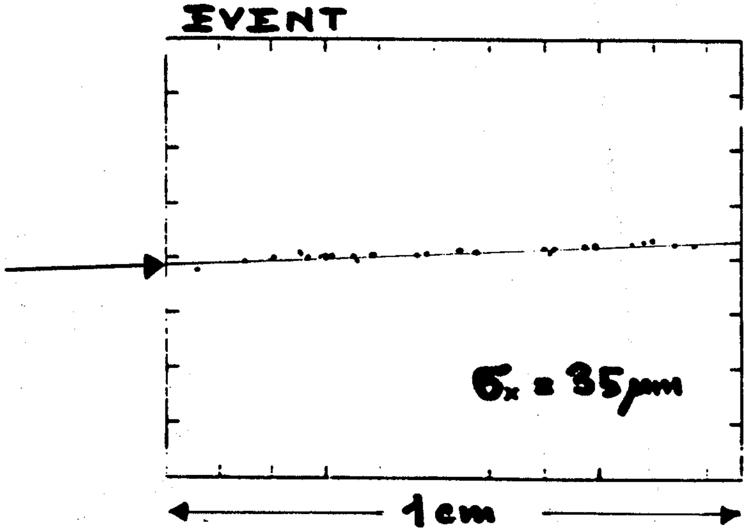
RD7 - TRACKING SCL.FI.: CERN-LAA,
ZEUTHEN, KARLSRUHE, TOULOUSE,
KURARAY-TOKYO, WORLD LAB.

1mm^2 COHERENT BUNDLE
OF ~800 30µm SCL.FL.

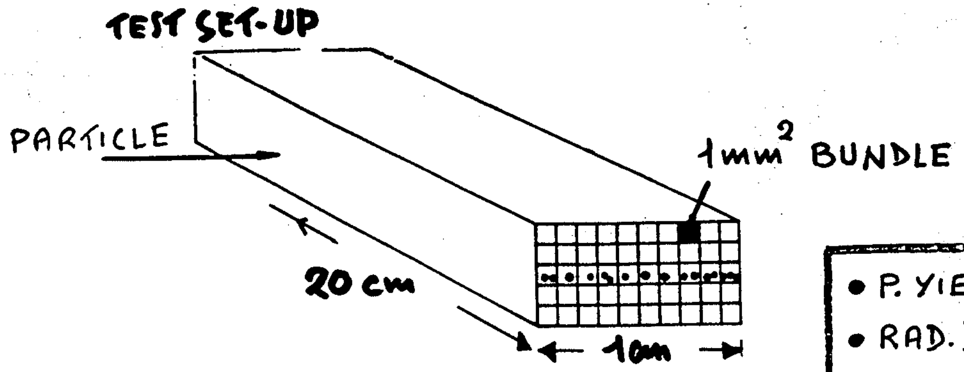


60μm FIBERS

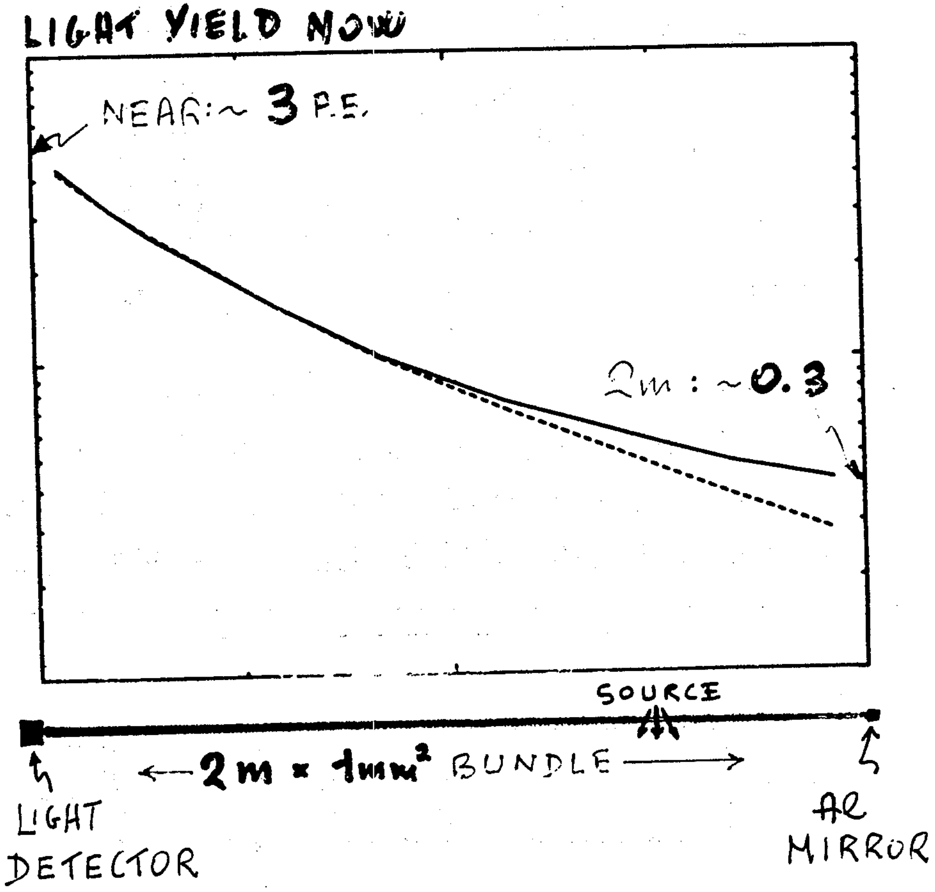
RD7 SCI.FI. TRACKER PROTOTYPE PERFORMANCE



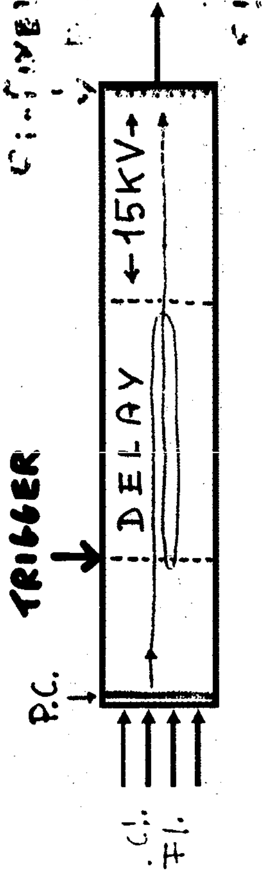
2 TRACK SEPARATION ~ 80μm



- P. YIELD
- RAD. DAM
- READOUT



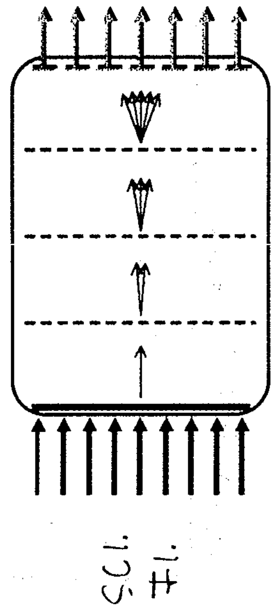
RD7 HI-SPACE ACCURACY SCI.FI. READOUT BY IMAGE INTENSIFIER TUBE



RD17 - FAST SCI.FI. READOUT BY P.S.P.M.:

LAPP, CERN, FERMILAB, IOWA, KYOTO-SANGYO, MESSINA, OSAKA, TRIESTE, SERPUKHOV

POSITION SENSITIVE PHOTON MULTIPLIER



$\sim 10^3$ PIXEL ANODES

(BUT CROSS-TALK: EFFECTIVE $\lesssim 10^3$)

- HI-TIME ACCURACY: $\lesssim 1$ ms → **TRIGGER**

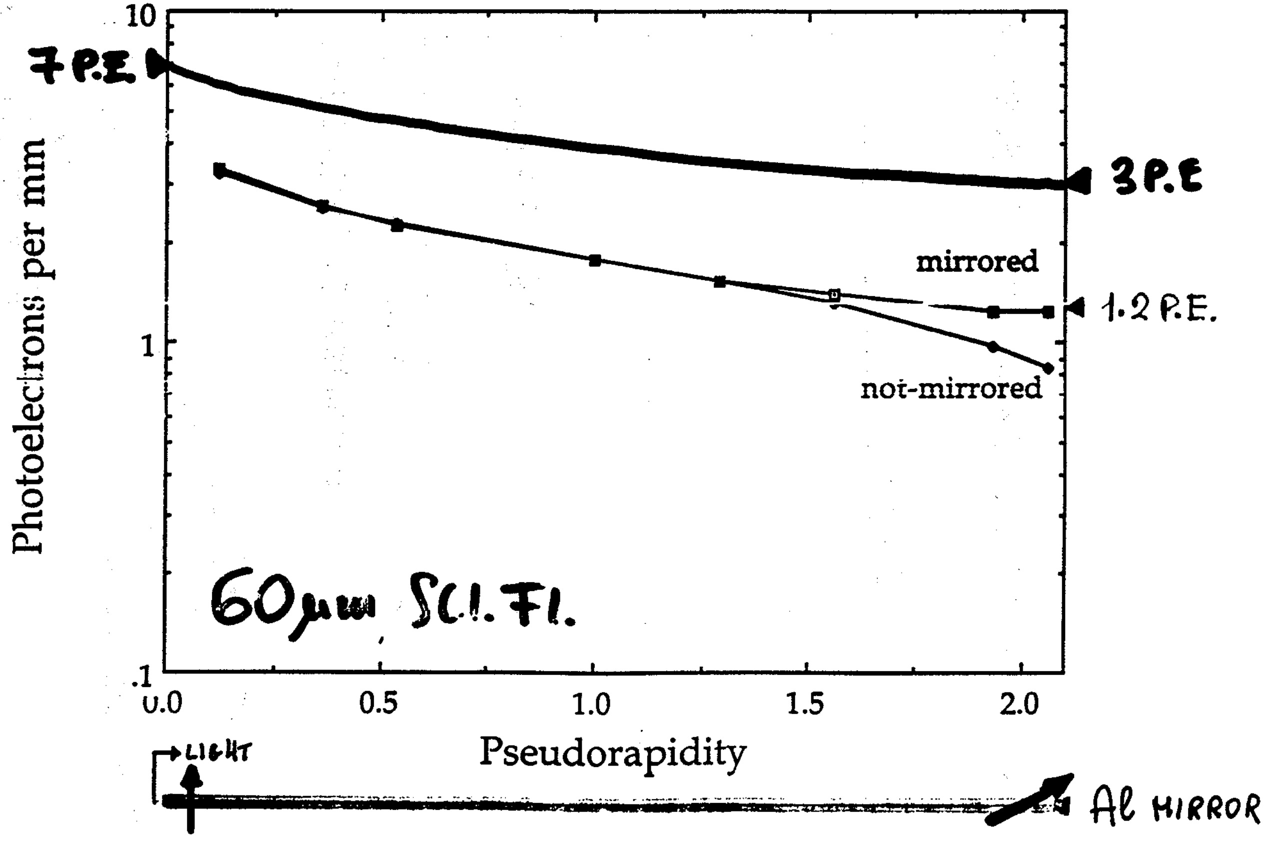
$\Delta x \cdot \Delta t \sim$ SF → SPACE ACCURACY LIMITED BY COST

GOAL '92 : 1) IMPROVE CLADDING : LIGHT × 2

2) IMPROVE DOPANTS : → LIGHT FAR × 1.5

↘ MORE RAD. HARD

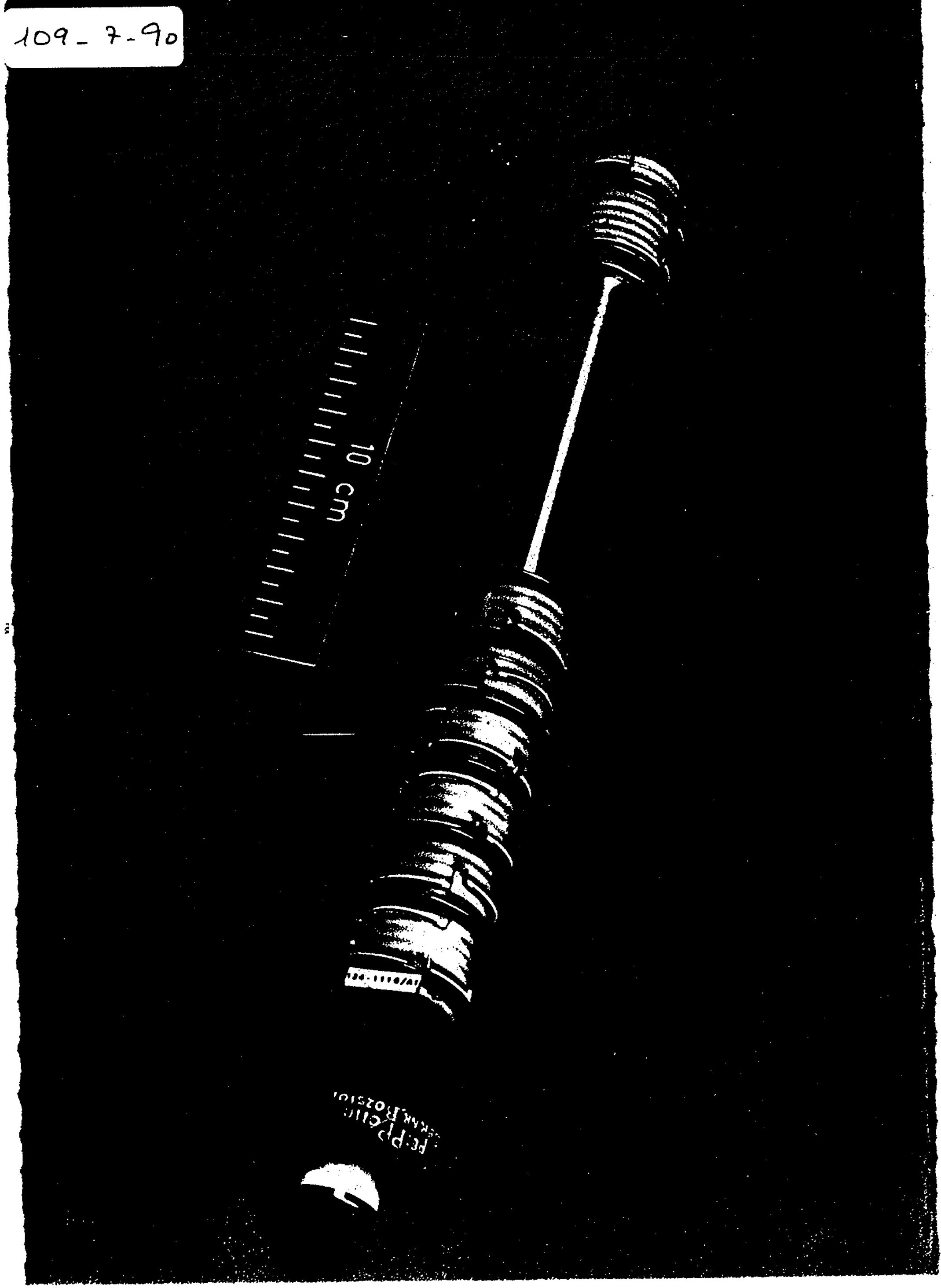
DRDC/P4 RD7
30.01.1992

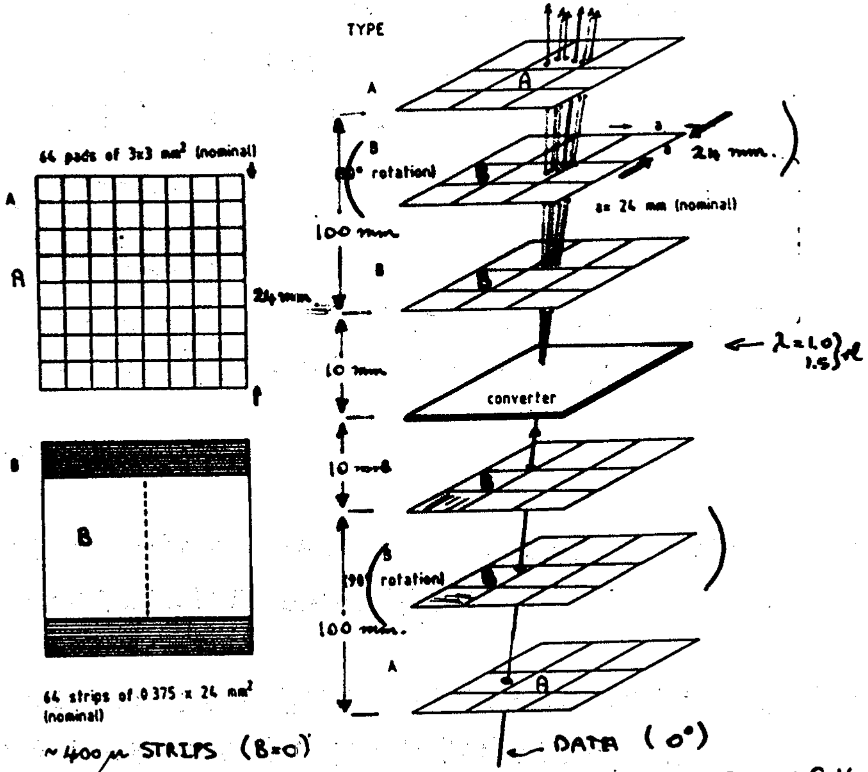


RD2- Si TRACKING PRESHOWER :

DORTMUND, HAMBURG, OSLO, PERUGIA, AUSTRALIA, SACLAY, CERN, GENEVA

GROWING EMPHASIS ON TRACKING



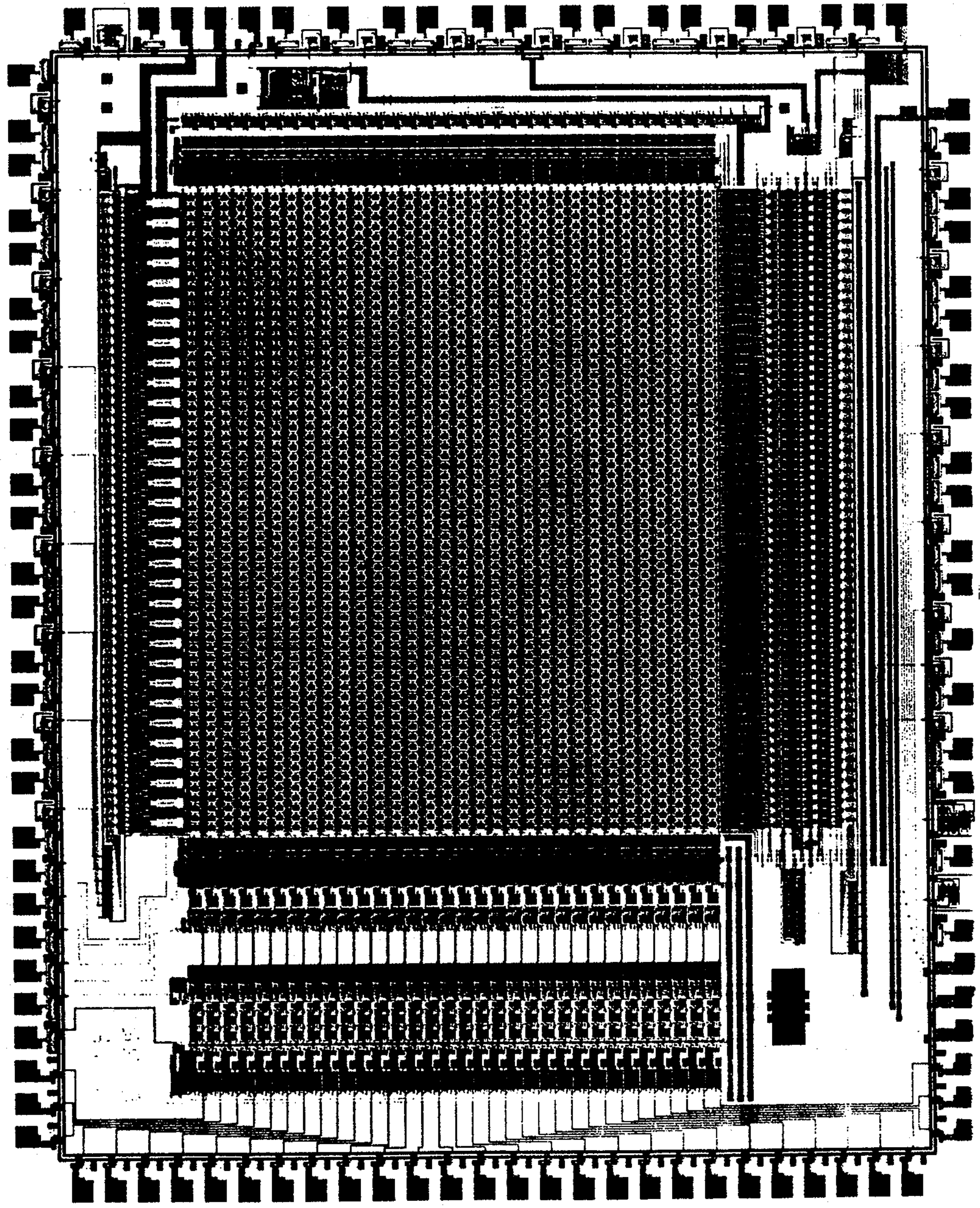


~400μ STRIPS (B=0)

~200μ " " (B≠0)

e : 10, 20, 40, 80, 150 GeV

π : 40 GeV



RD2 - SiTP : '91 ACHIEVEMENTS

- FULL SIMULATION PACKAGE IMPLEMENTED
- PROTOTYPE BUILT & TEST STARTED
- RAD. HARDNESS : GOOD CONFIDENCE
- READOUT EL.: 32 CH. × 64 CELLS BUILT & TESTED

KEY MILESTONE FOR '92:

- REALISTIC ASSESSMENT OF A POSSIBLE APPLICATION

THE ISSUES:

- SEVERAL 10^6 CH. REQUIRE LARGE DROP OF COST/CH.: POSSIBLE BY SCALING THE LEVEL OF INTEGRATION
- POWER DISSIPATION:

THEOREM { • FET PRINCIPLE
• DET. CAPACITANCE
• 2nd PR. OF THERMODYNAMICS

→ UNIVOCALLY DETERMINED

SiTP NOW : 50 ÷ 100 KW , LIMIT = $\frac{1}{2}$

COOLING BY LIQ. FLOW

RD20 - Si STRIPS: CERN, INP & INPT CRACOW, HELSINKI, I.C. LONDON, UN. & I.S. OSLO, RAL, STRASBOURG, TORINO, YALE, LIVERPOOL, MARSEILLE, VILLIGEN, UPPSALA

X-Y Si MICROSTRIPS:

- WELL ESTABLISHED TECH. FOR HIGH SPATIAL ACCURACY
- ALSO: ADEQUATE SPEED

R&D GOAL: UPGRADE THE TECH.
FOR LHC CONDITIONS

RD20 Goals - *elements* required for a high spatial precision tracking detector:

- radiation tolerant → PROBABLE **Silicon microstrip detectors**
- low power & low noise **front end** electronics
- low mass **mechanical structure** - ***coolable*** ~10 kW

Current status of *Detectors*

Planned programme of prototype fabrication to systematically study/improve ***radiation hardness***

i) irradiation of existing devices-
large body of data now exists => new results

ii) p-side prototypes - *manufacture complete*
iii) n-side prototypes - *design complete*

iv) double sided - *second half 1992*

Current status of *Electronics*

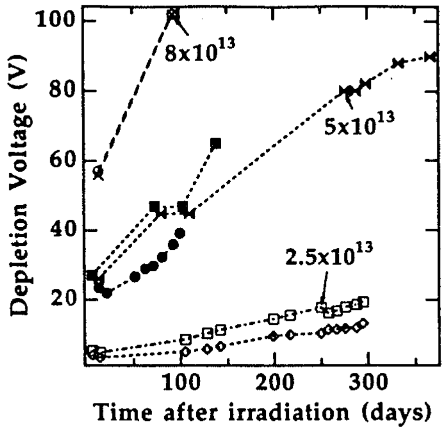
emphasis on essential elements of front end

- charge sensitive preamplifier/shaper -*exists*
  ENC ≈ 750e @ 6pF & 1.6mW/channel
  2nd iteration => lower noise & ***0.8mW/channel***
- analogue data buffer/pipeline - *in fabrication*
- analogue signal processor - *new concept* ***deconvolution***

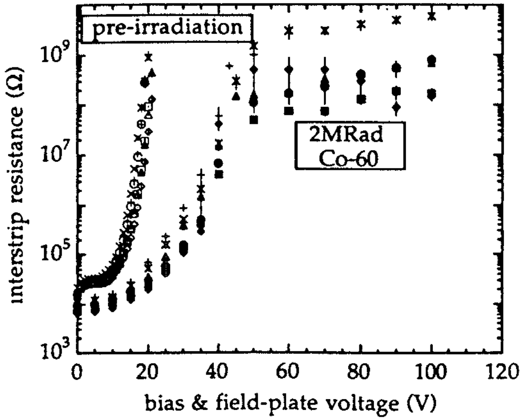
New results from radiation damage studies

Substrate doping changes
Surface charge accumulation

Annealing of doping

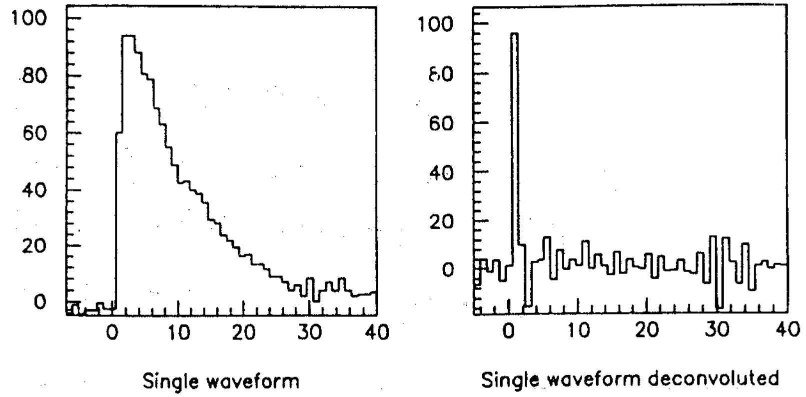


n-side interstrip resistance



Results from electronics

Deconvolution of shaped pulse
=> digital filter implemented in analogue form

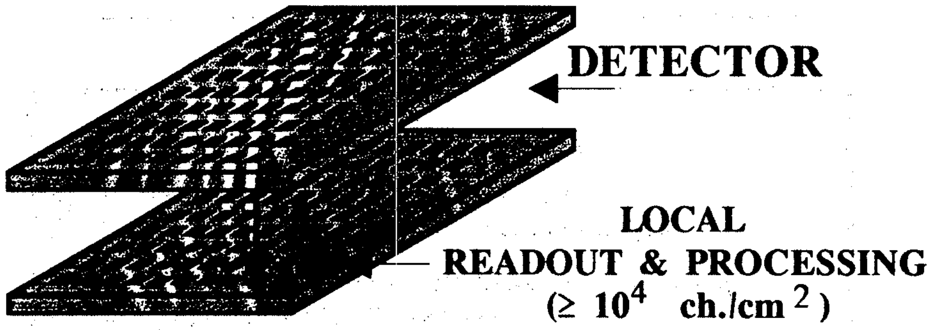


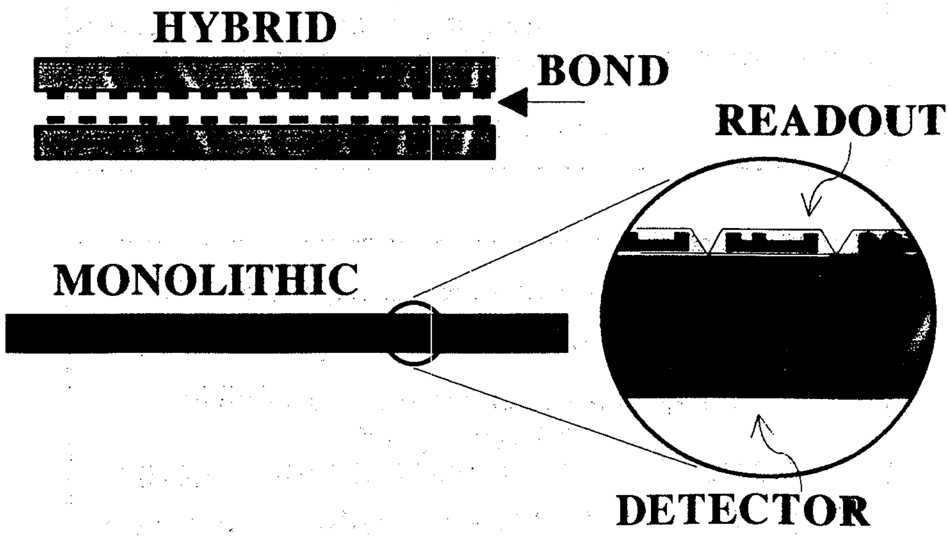
Deconvolution = fast pulse shaping
with low power (~100μW/channel)

only events passing level 1 trigger are processed

RD19 - Si PIXELS: CERN, COLL. DE FRANCE, MARSEILLE, ZURICH, IMEC, BARI, BOLOGNA, GENOVA, MILANO, MODENA, PADOVA, PISA, CANBERRA SEM., GEC-MARCONI, SMART SILICON SYSTEM

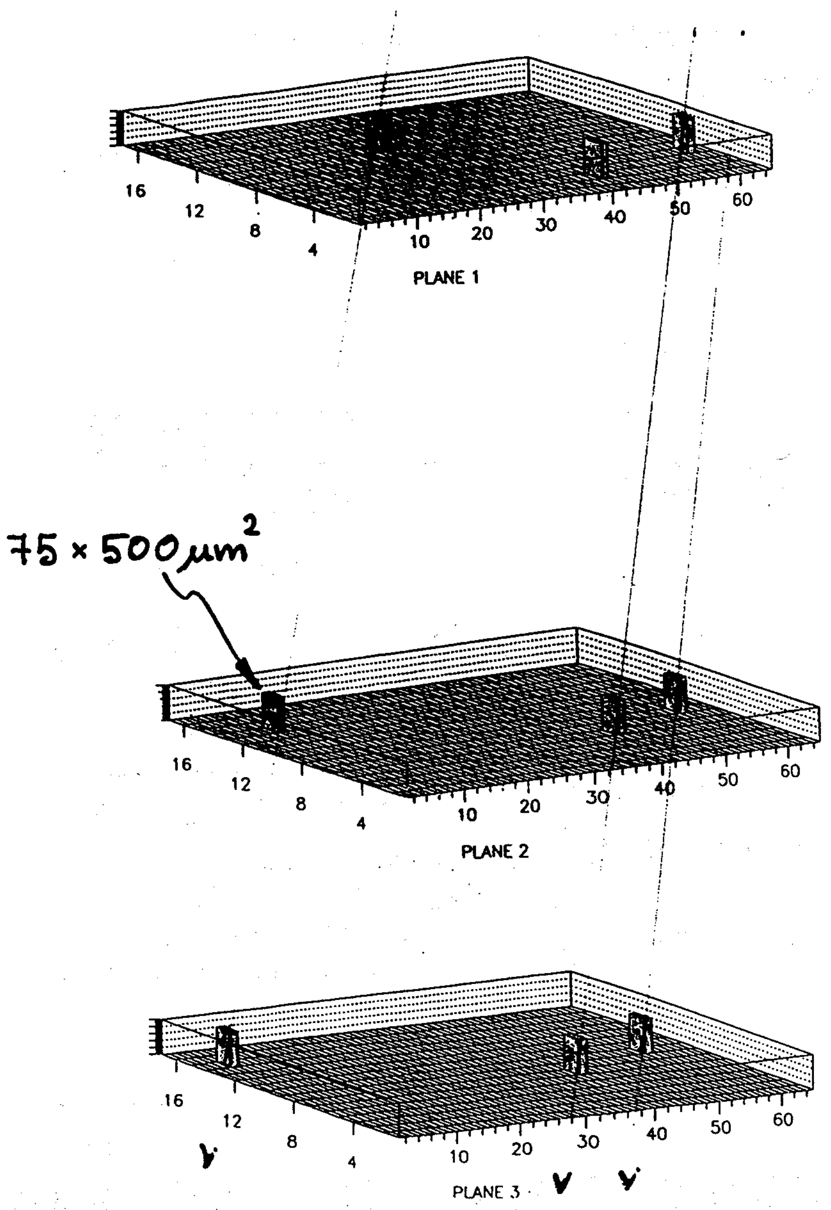
AIMS:
- ~ (100 μm)² UNAMB. FINE GRAIN
- FEW μm, FEW ns ACCURACY





Si-PIXEL DETECTORS TESTED IN WA94
OMEGA HEAVY ION

3 TRACK EVENT

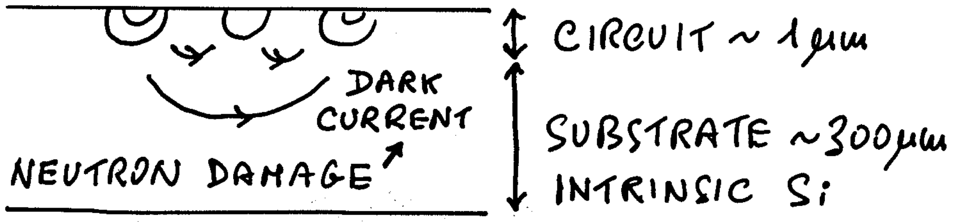


75 × 500 μm^2

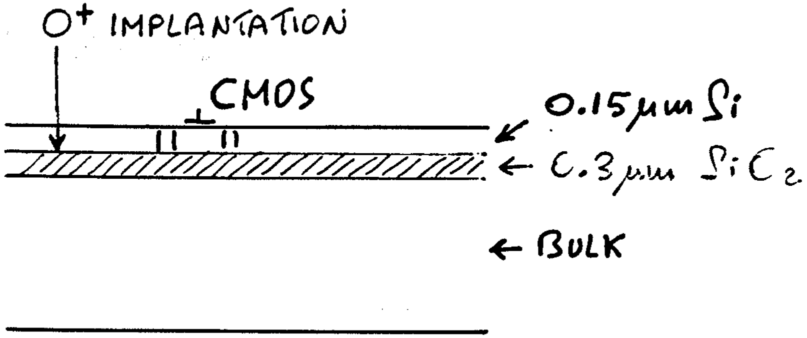
ALL THE COMPLEX CIRCUITRY
BEING DEVELOPED, MUST EVENTUALLY
BE IMPLEMENTED IN
RAD. HARD TECHNOLOGY

RD9 - SOI - CMOS RAD. HARD ELECTR.

CERN



SIMOX MATERIAL (THOMPSON)

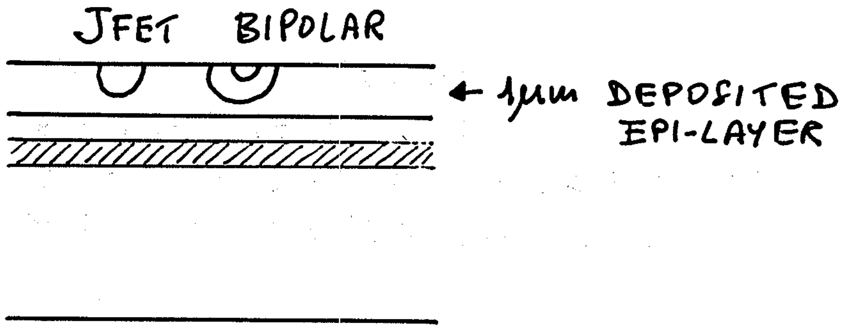


AIM : DEMONSTRATE THIS TECH. CAN BE IMPLEMENTED FOR DET. CIRCUITRY (ANALOGUE, etc.)

STATUS :

- RAD. TEST : 10 Mrad γ's , 2.5×10^{14} n's
  → REASONABLY GOOD
- ANALOG DEMONSTRATOR : END '92 - '93

- NEW PROPOSAL TO BE SUBMITTED BY MARSEILLE-SACLAY



- MORE FLEXIBLE BUT MORE EXPENSIVE

RD8: GaAs DETECTORS. BOLOGNA, CERN, FLORENCE, GLASGOW, RAL, LANCASTER, SHEFFIELD, MODENA

ADVANTAGES:

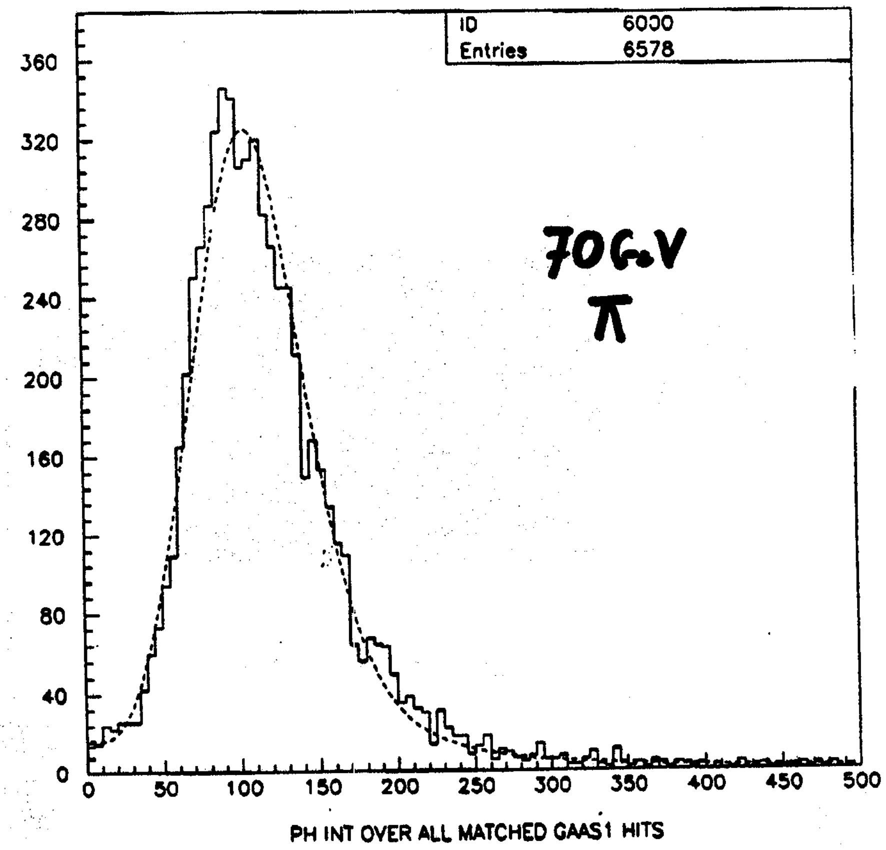
- ● RAD. HARDNESS (17 MRAD TEST)
- • SPEED

DISADVANTAGE:

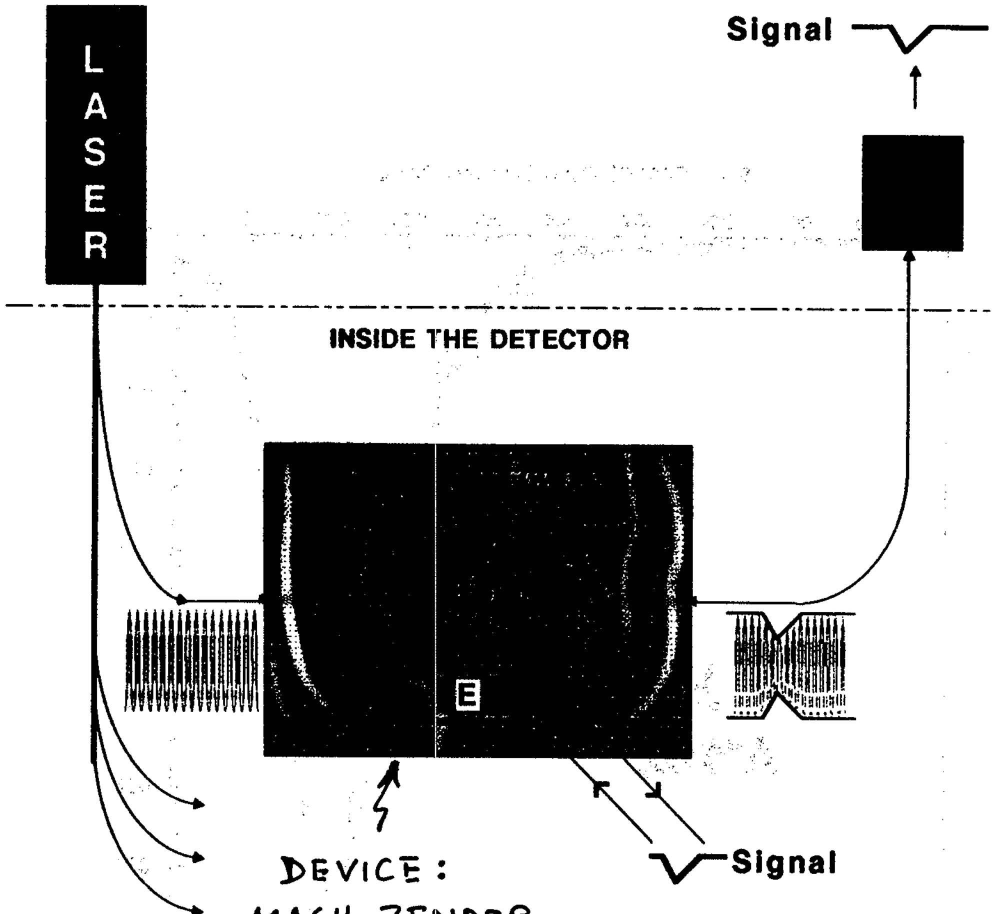
- • POOR MATERIAL → SMALL WAFERS
  → HIGH COST

RD8: ΔE/Δx SPECTRUM FOR 600μm THICK GaAs DET. WITH 290μm STRIPS

23/10/91 10.49

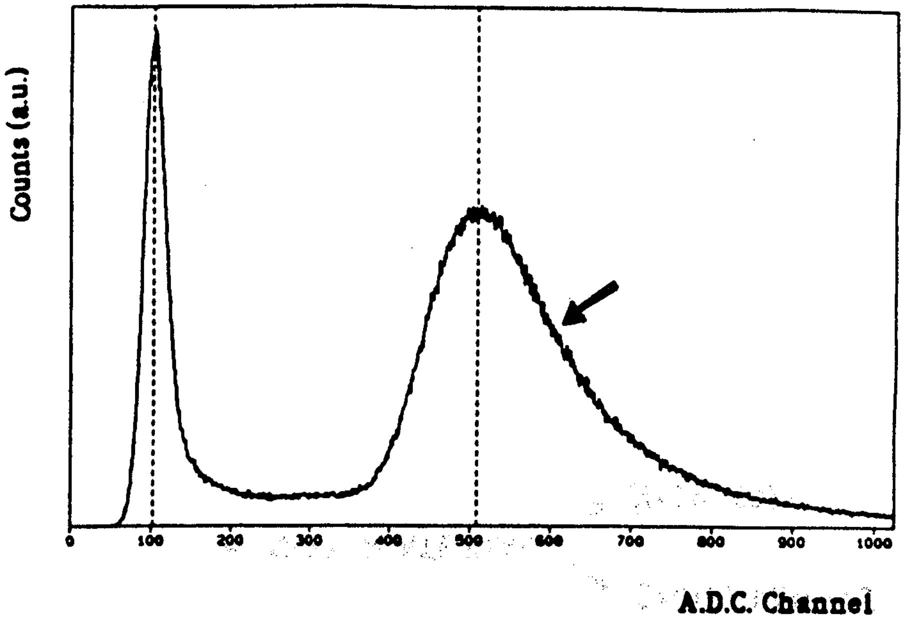


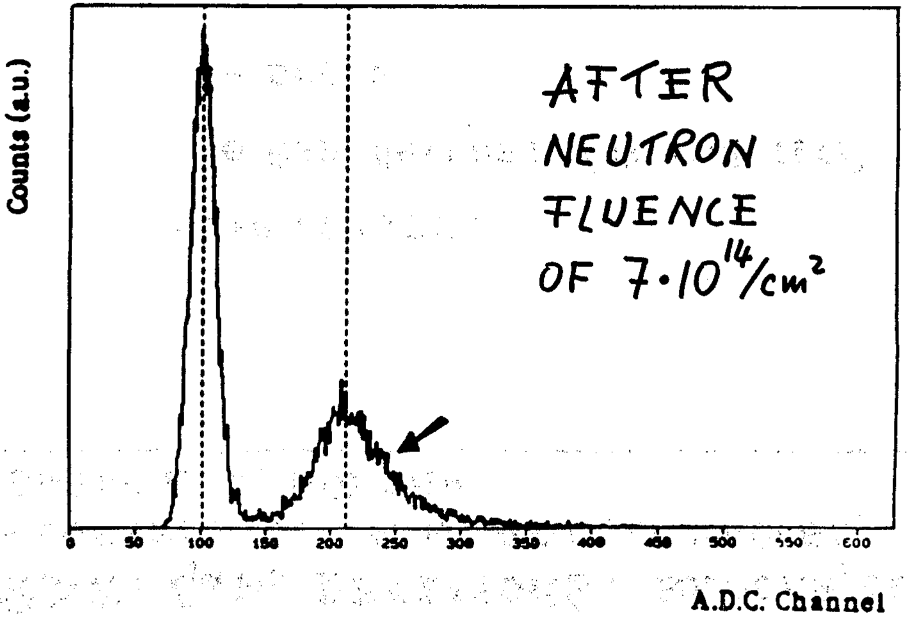
RD23-OPTOELECTRONIC ANALOGUE SIGN TRANSFER: BIRMINGHAM, CERN, LAUSANNE, GEC-MARCONI, IC LONDON, LUND, OXFORD, RAL



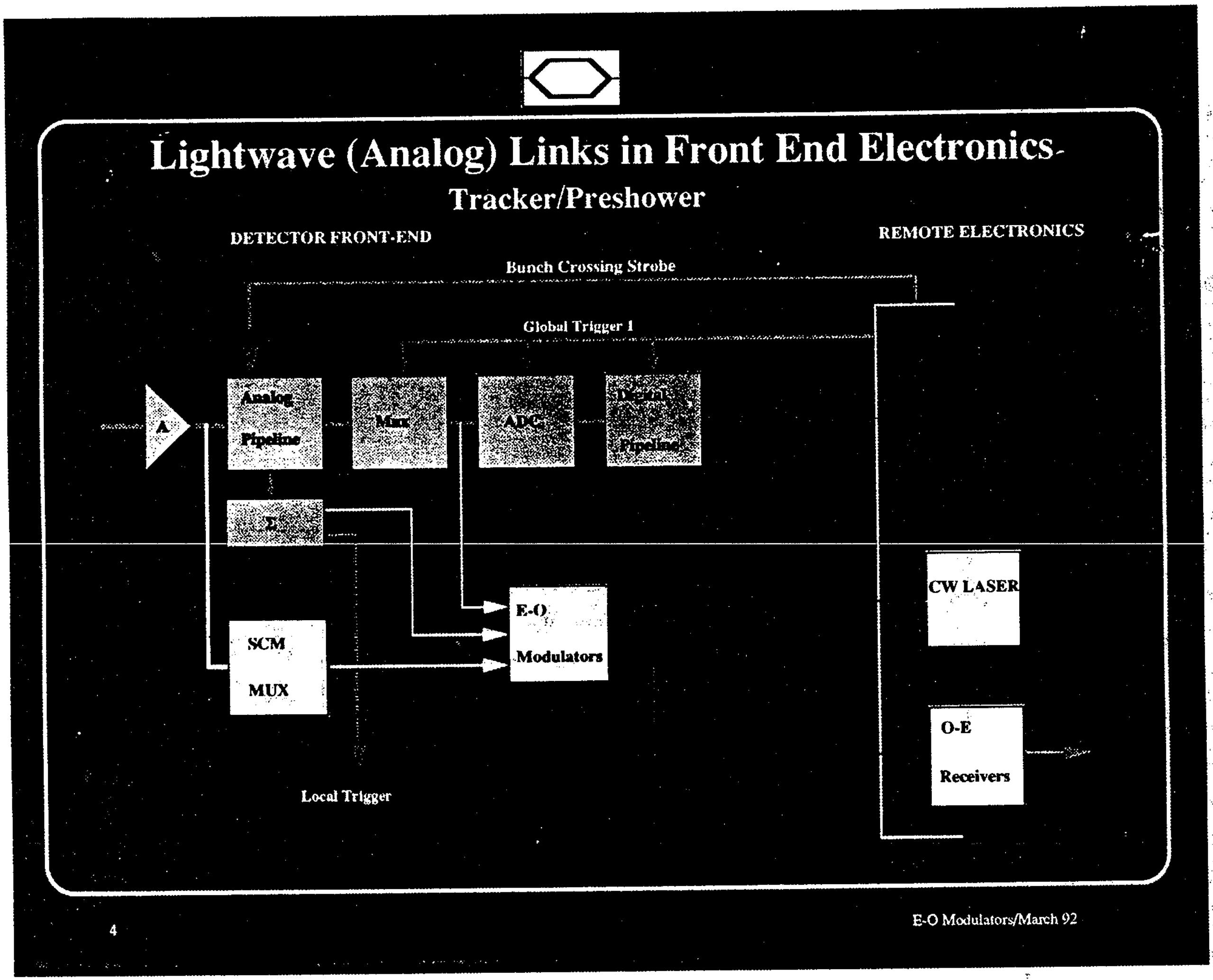
DEVICE:
MACH-ZENDER
INTERFEROMETER:
Ti DIFFUSION IN LITHIUM NIOBATE SUBSTRATE

LOW MASS, LOW POWER, RAD. HARD





AFTER
NEUTRON
FLUENCE
OF $7 \cdot 10^{14}/cm^2$



Lightwave (Analog) Links in Front End Electronics-

Tracker/Preshower

PERFORMANCE OF EXISTING DEVICE:

- INTERFERENCE → SINUSOIDAL TRANSFER CHARACTERISTIC

1% LINEARITY
1000/1 DYNAMICS

- SENSITIVITY : ~1mV OVER ~5pF
(NOISE ~ 3fC)

- GHz SPEED

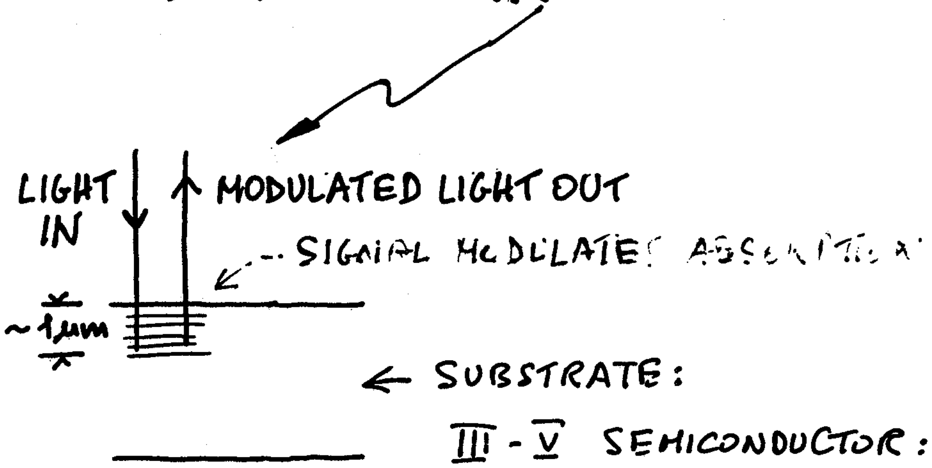
BUT EXPENSIVE NOW

- POSSIBLE REALISTIC GOAL:
TRANSFER OF MUX ANALOGUE DATA

- PROJECTED COST (GEC-MARCONI):
10 – 20 SF/OPT. CH.

RD23 PROGRAM

- DEVELOPE 16-CH. OPT. MODULATOR
- STUDY EXISTING **MQW** DEVICES



III - V SEMICONDUCTOR:

CAN BE INTEGRATED WITH ELECTR.

RD5 - STUDY OF µ. TRIGGER & MOMENT. RECONSTRUCTION IN A STRONG MAGN. FIELD, FOR A µ DET. AT LHC: AACHEN, CERN, MADRID, NIKHEF, PADOVA, ROMA, LOS ANGELES, RIVERSIDE, VIENNA, WARSAW

→ M. Della Negra

DAQ AREA

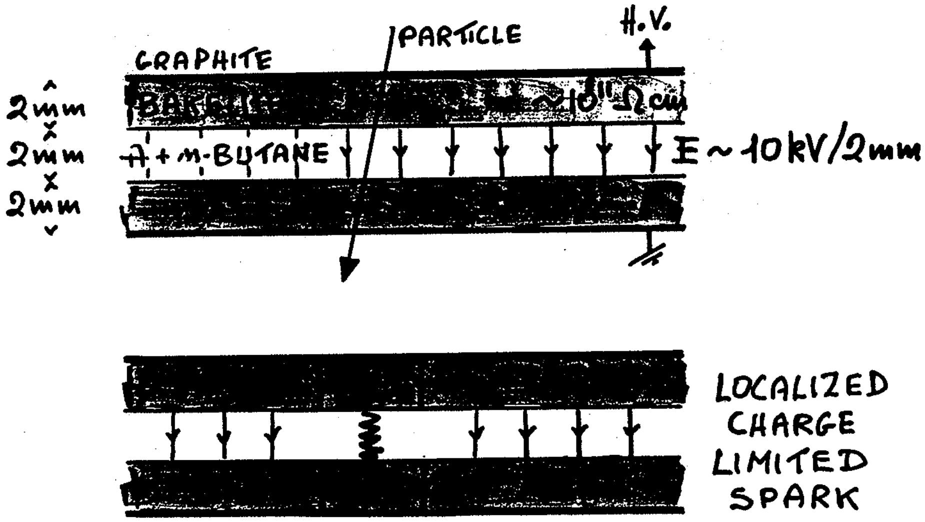
GENERAL: RD11, RD12, RD13, RD24 → S. Cittolin

DET. SPECIFIC: **RD16**

RD21 - R&D FOR COLLIDER b-PHYSICS AT LHC

→ P. Schlein

RESISTIVE PLATE CHAMBERS

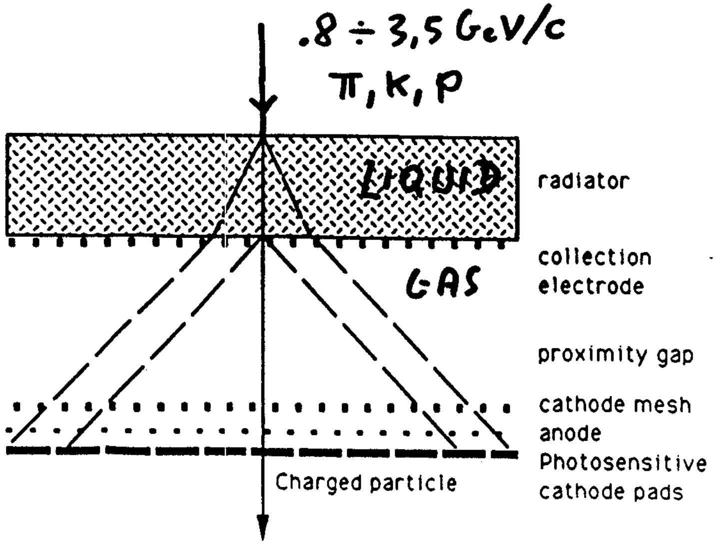


2-DIM. LOCALIZATION BY **x-y PICK-UP STRIPS**

- POTENTIAL HIGH SPACE ACCURACY < 1mm
- INTRINSIC HIGH TIME ACCURACY ~ 1ns

P35 - DEVELOPMENT OF A LARGE AREA ADVANCED FAST RICH DETECTOR FOR PART. IDENTIFICATION AT LHC OPERATED WITH HEAVY IONS: BARI, CERN, COIMBRA, GIESSEN, MUNICH, PADOVA, ZAGREB

AIM: TEST OF PHOTOSENSITIVE CATHODE PADS IN A WIRE CH. RICH DETECTOR



RD22 - BEAM EXTRACTION BY CRYSTAL CHANNELING AT SPS : A FIRST STEP TOWARDS BEAM EXTRACTION AT LHC :

AARHUS, CERN, FRASCATI, LECCE, I.C. LONDON, PISA, ROMA, STRASBOURG, MPI-STUTTGART, TORINO, TRIESTE

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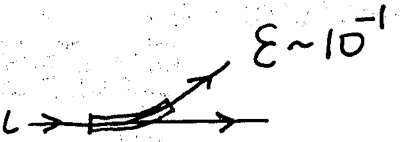
* STANDARD METHODS FOR BEAM EXTRCTION ARE DIFFICULT AT LHC

- RD22 AIM : USE SPS TO DEMONSTRATE HI-E EXTRACTION POSSIBLE BY BENT CRYSTAL WITH BEAM CONDITIONS SIMILAR TO LHC
- FINAL AIM AT LHC :

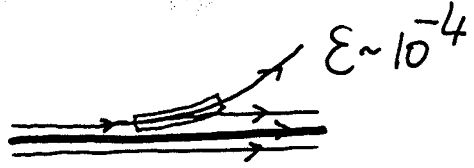
$4 \cdot 10^9$ p/s HALO → $4 \cdot 10^8$ p/s BEAM

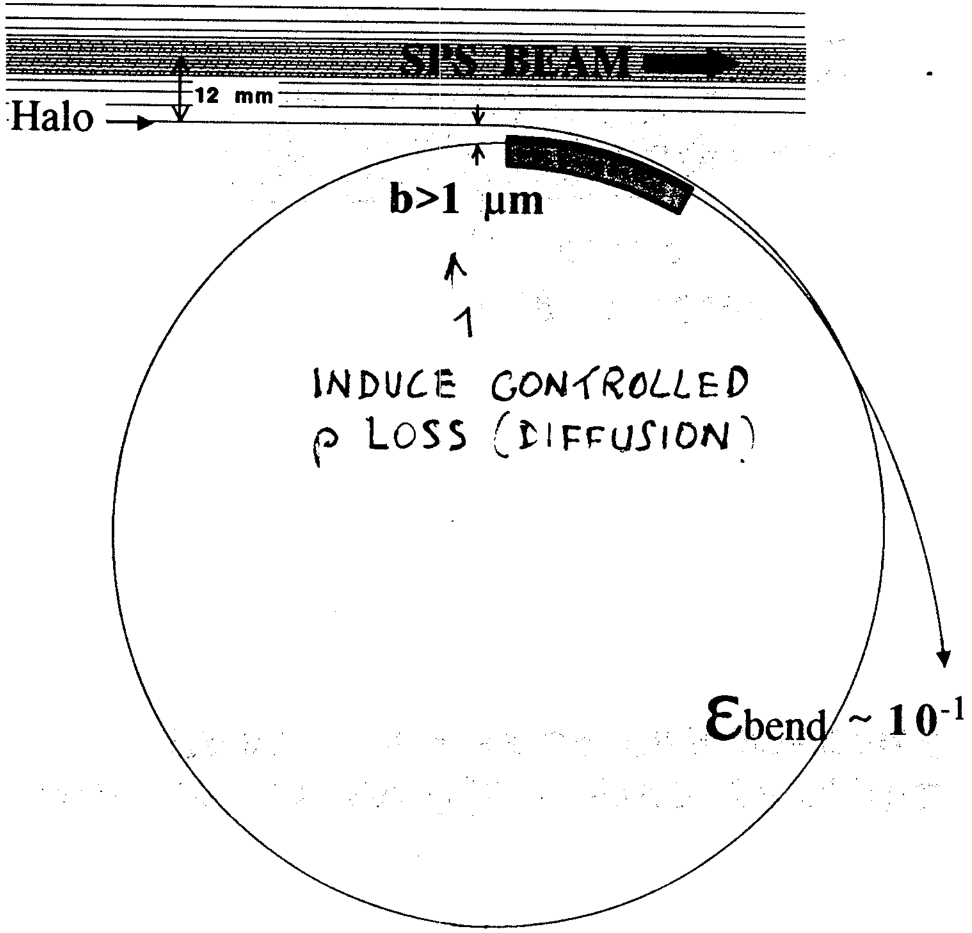
DONE

- BEAM ON CRYSTAL (H8, CERN)



- IN THE HALO (SERPUKHOV)





- CRYSTAL : $1 \times 10 \times 30\ mm^3$, $\Delta\theta = 8{,}5\ mrad$
- EXTRACTED BEAM MEASURED BY GAS µ-STRIP & SCINT. HODOSCOPE

CONCLUSIONS

- PARTICIPATION IS INTENSE & ENTHUSIASTIC, PROGRESS IMPRESSIVE: MOST OF THE 1st YEAR GOALS HAVE BEEN ACHIEVED, IN SOME CASES FASTER OR BETTER THAN PLANNED

- SEVERAL NEW POWERFUL DETECTORS ARE ALREADY AVAILABLE FOR LESS DEMANDING APPLICATIONS

- HOWEVER FURTHER PROGRESS IS NEEDED FOR LHC

- VISIBLE INFLUENCE OF PROTOCOLLABORATIONS:

  POSITIVE ASPECT : BETTER FOCUSSING ON REALISTIC GOALS

  NEGATIVE ASPECTS SHOULD BE MINIMIZED (A HOPE ...)