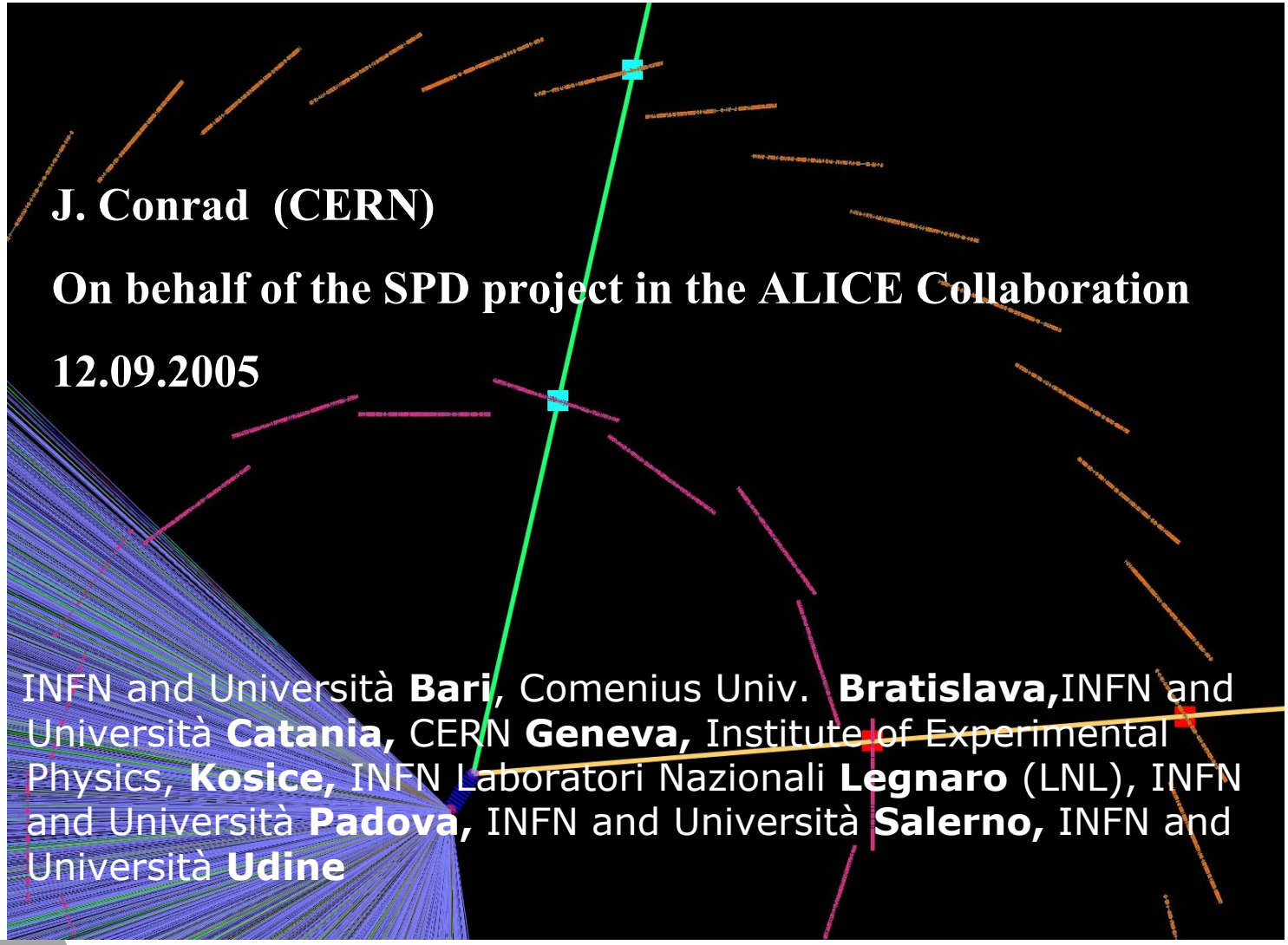
Beam Test Performance and Simulation of Prototypes for the ALICE Silicon Pixel Detector



J. Conrad (CERN)

On behalf of the SPD project in the ALICE Collaboration

12.09.2005

INFN and Università **Bari**, Comenius Univ. **Bratislava,** INFN and Università **Catania,** CERN **Geneva,** Institute of Experimental Physics, **Kosice,** INFN Laboratori Nazionali **Legnaro** (LNL), INFN and Università **Padova,** INFN and Università **Salerno,** INFN and Università **Udine**

Content

- Introduction:
  - ALICE@LHC → Inner Tracking System (ITS) → Silicon Pixel Detector (SPD)
- Beam tests at CERN SPS
  - 2002+2003 (SPD)

    Prime goal: validation of electronics

    Spin off : efficiencies, intrinsic precisions
  - 2004 (ITS)

    Integration: detectors used to test DAQ/triggers etc…
- Simulation of the Silicon Pixel Detector
- Conclusions

The ALICE experiment @ LHC

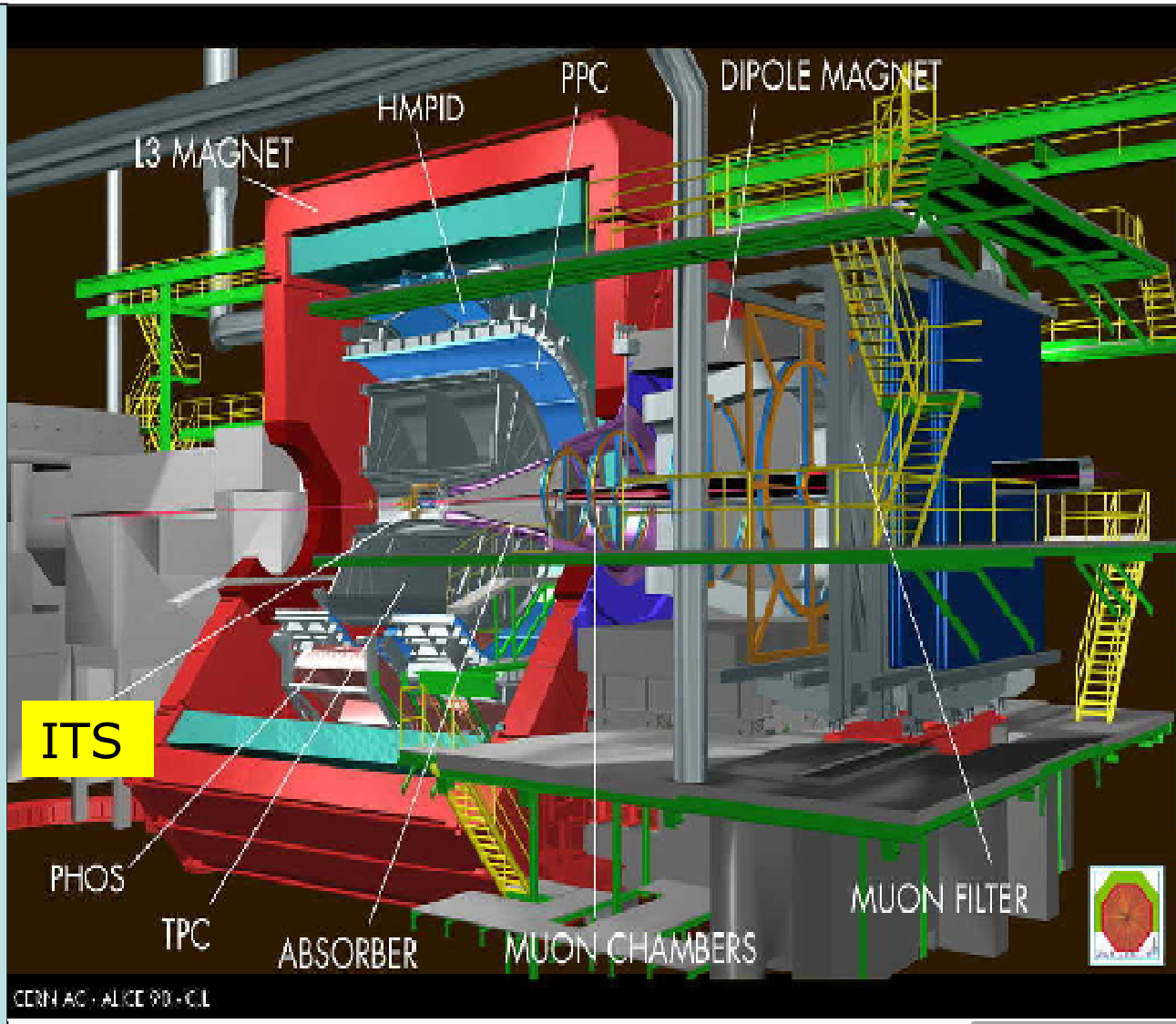
- **ALICE is dedicated to Heavy Ion Physics**

  - PbPb @ 5.5 TeV

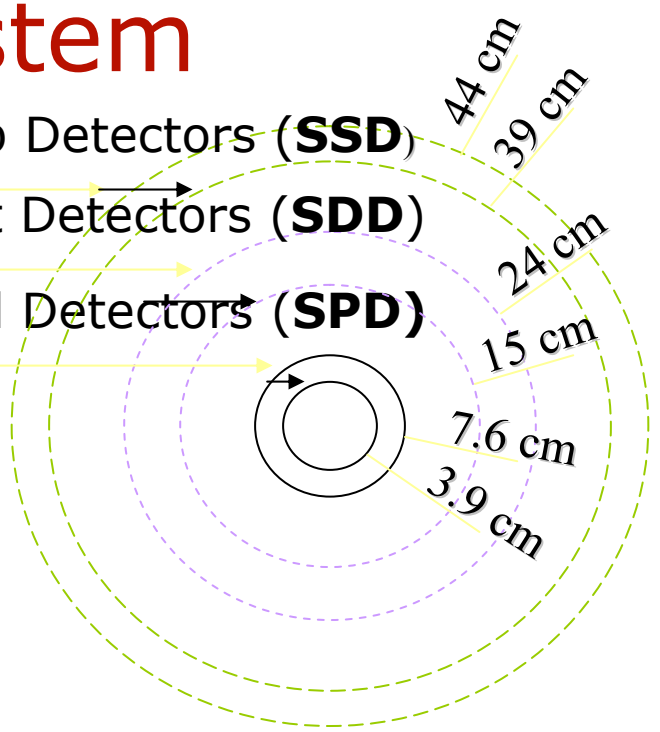
  - cope with high multiplicity (up to 8000 /unit rapidity)
  → high granularity

  - measure large range in p_t
  → low magnetic field B < 0.5 T
  → low material budget

- **Initially interesting p-p physics**



The Inner Tracking System



The ITS Physics Tasks

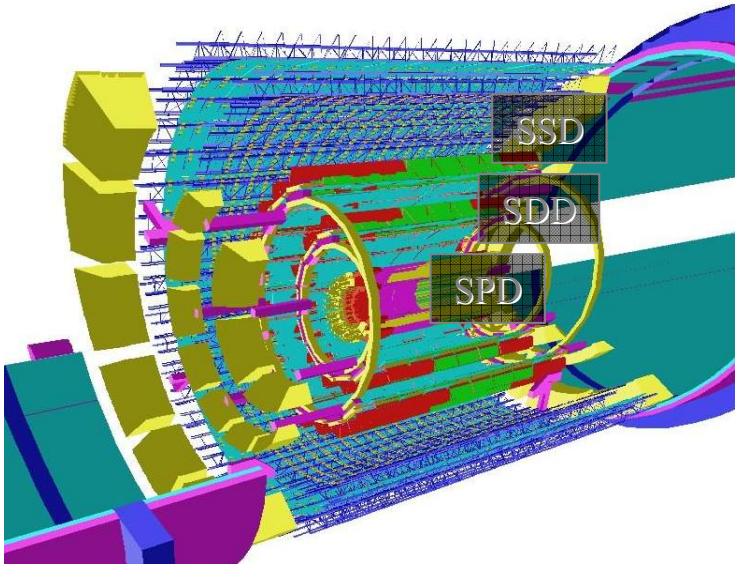
-primary vertexing to better than 100 μm
-secondary vertices: (ex. D0 → K- π+)
-low momentum tracking (p < 100 MeV)
-high p_T tracking improvement
-minimum bias trigger in pp mode (SPD)

SPD: digital r/o

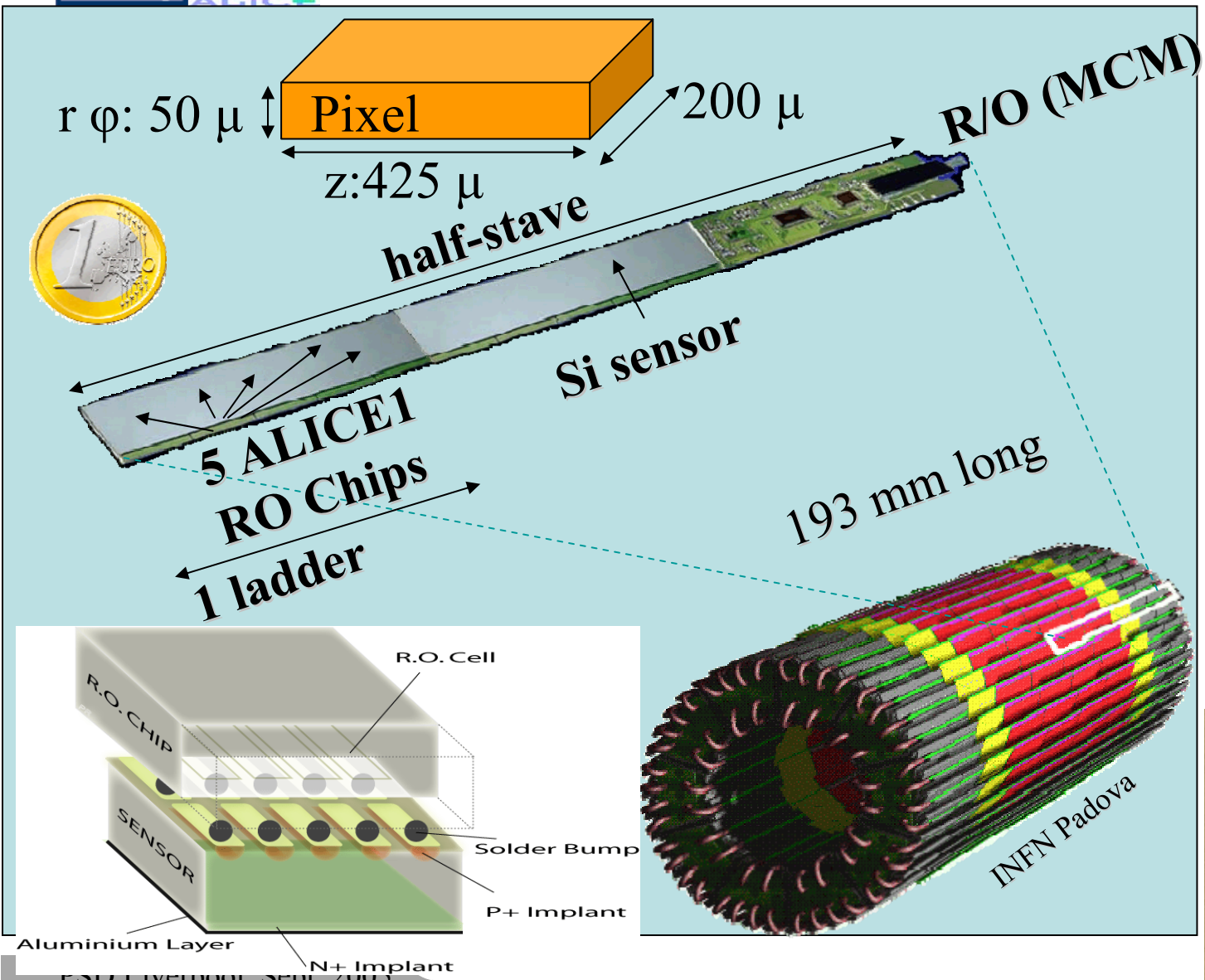
SDD/SSD: analog r/o

The ITS in numbers:

- 6 barrel layers
- 2 Silicon Pixel (hybrid), 2 Silicon Drift (true 2 dimensional r/o)
- 2 double sided Silicon Strips
- in total 12.5 Million sensitive cells (75 % SPD)
- material budget reduced to minimum
- $|\eta| < 0.9$
- 220 krad, 3 x 10^{12} (1 MeV n)/cm^2 , 10 years integrated (SPD layer)

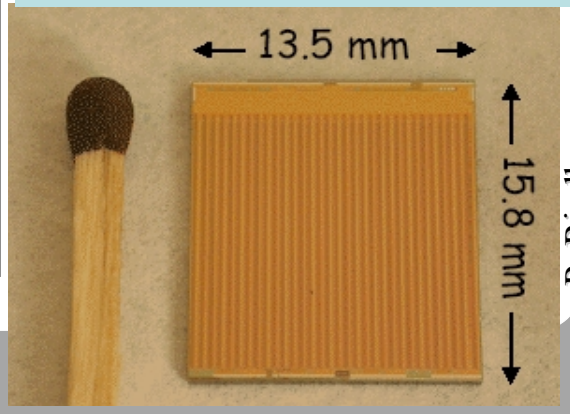


The (hybrid) Silicon Pixel Detector



The SPD in numbers

- 2 barrel layers,
- 240 silicon sensors 5 r/o-chips/sensor (a "ladder"),
- 9.83 million pixels, (32x256 = 8192)/chip
- 2 ladders and r/o = half stave
- 8 inch wavers, bumped, thinned down to 150 μ
- -Alu-Polyimide Pixel Bus

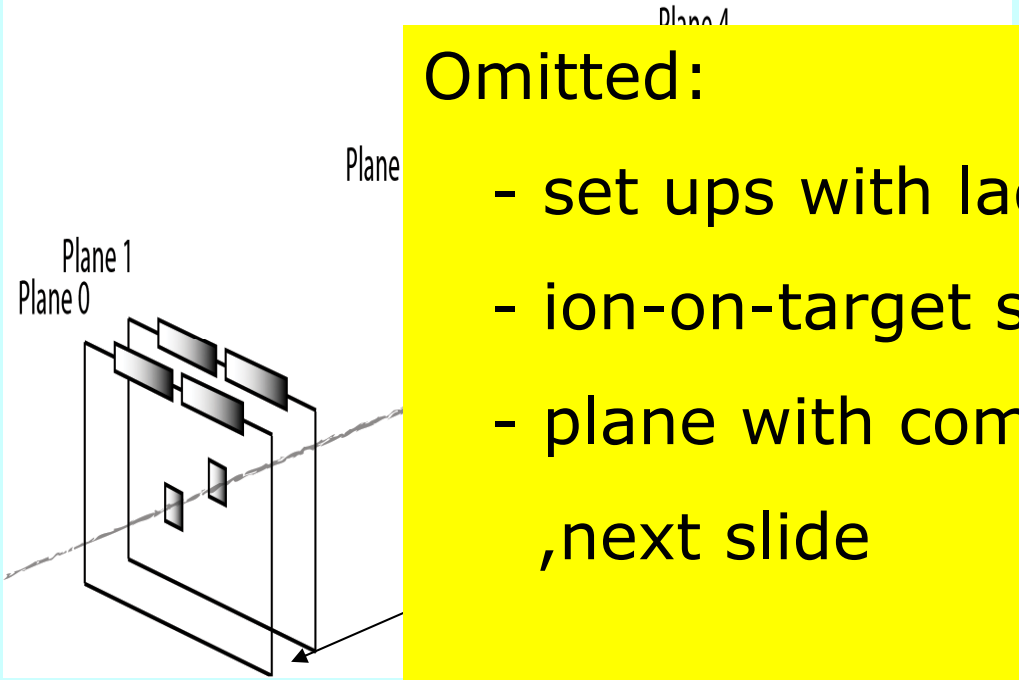


ALICE1 readout chip

P. Riedler

Beam Tests: 2002 and 2003

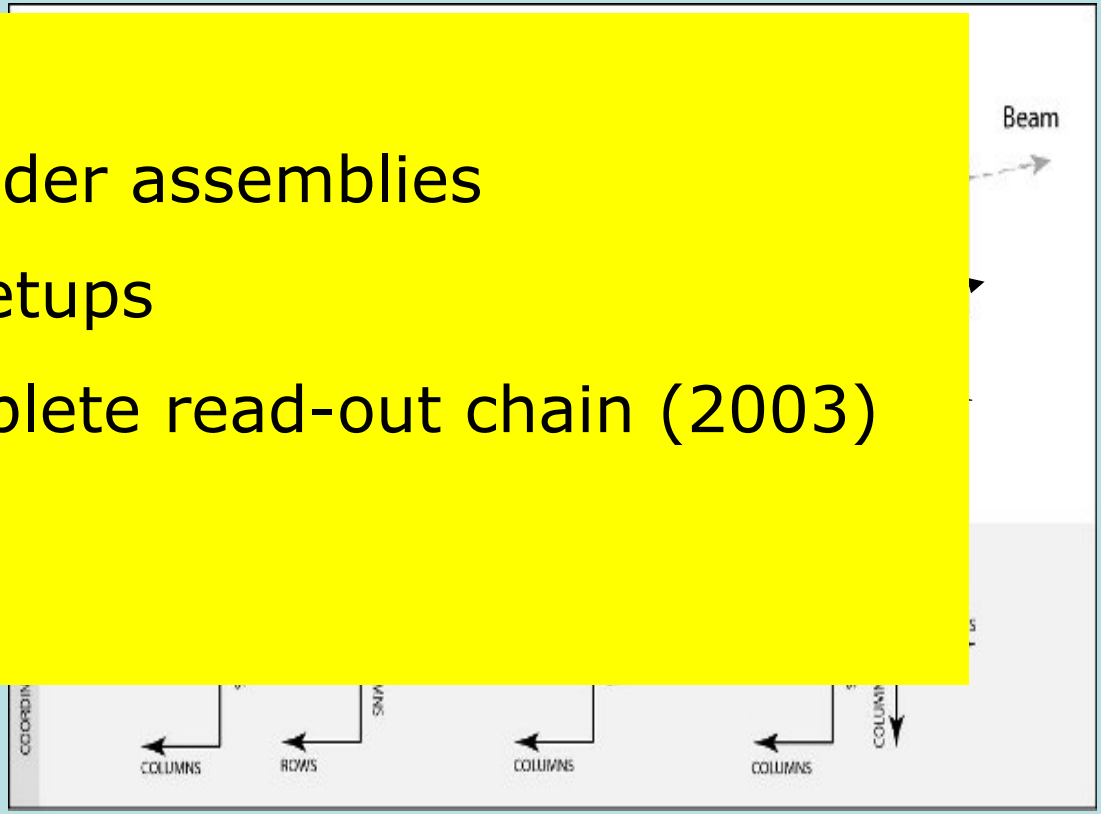
2002 CERN SPS : 350 GeV p/π, 200 and 300 μ sensors tested



Schematics of Proton Setup 2002

No magnetic field !

2003 CERN SPS : 120 GeV p/π , 158 GeV/A Indium ions on target, 300 μ sensors tested



Schematics of Proton Setup 2003

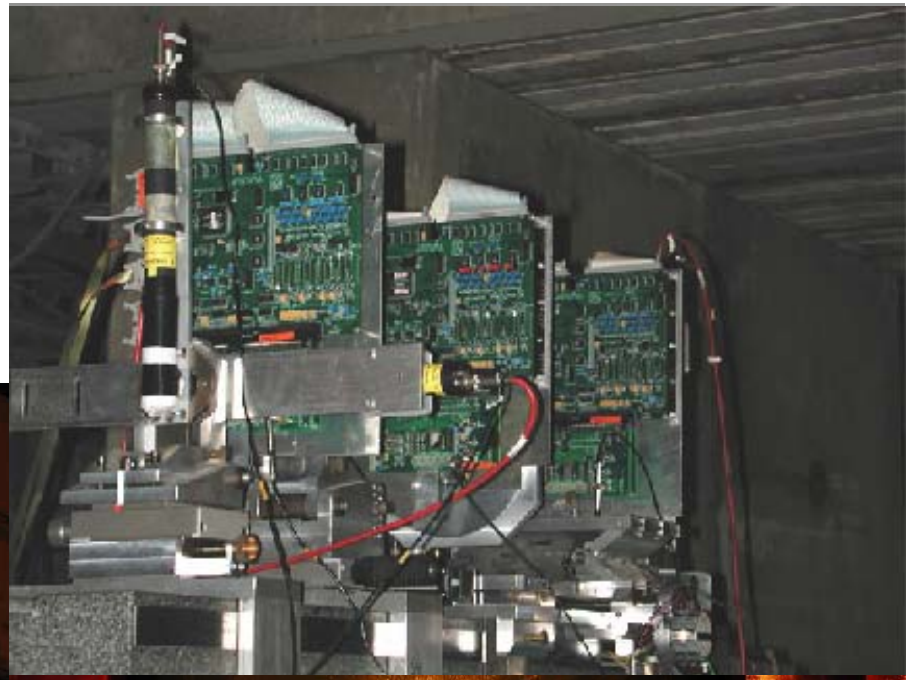
Omitted:

- set ups with ladder assemblies
- ion-on-target setups
- plane with complete read-out chain (2003)

,next slide

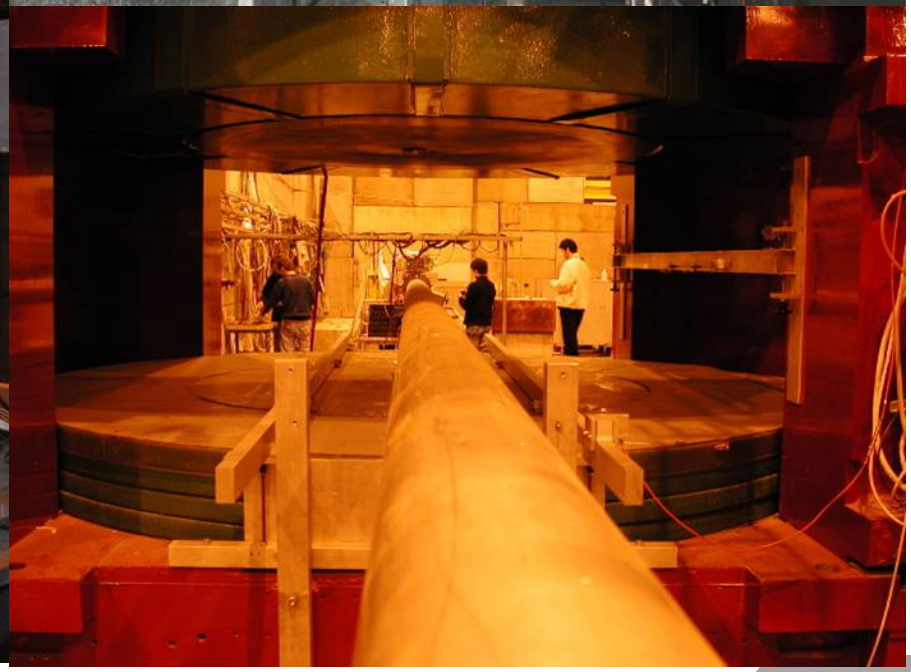
2002/2003 Setups

2002



2003

Complete Readout chain

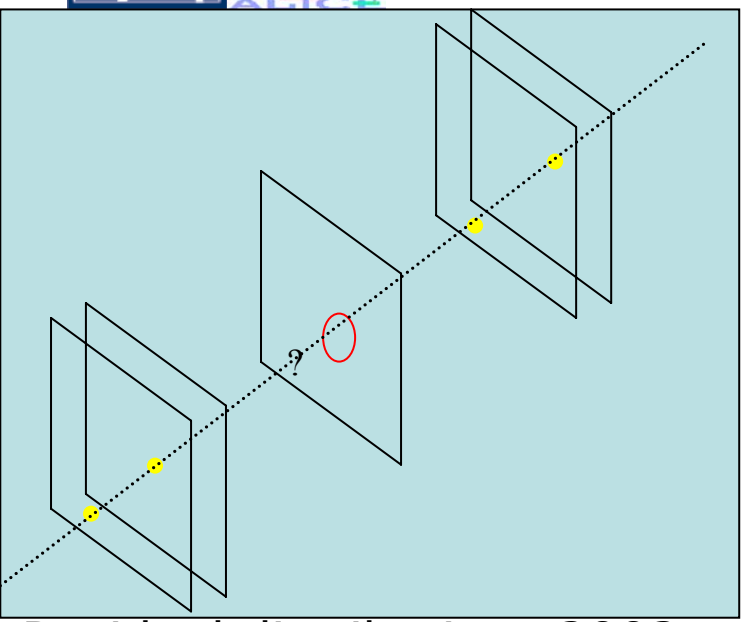


Beam Tests Results 2002/2003: Overview

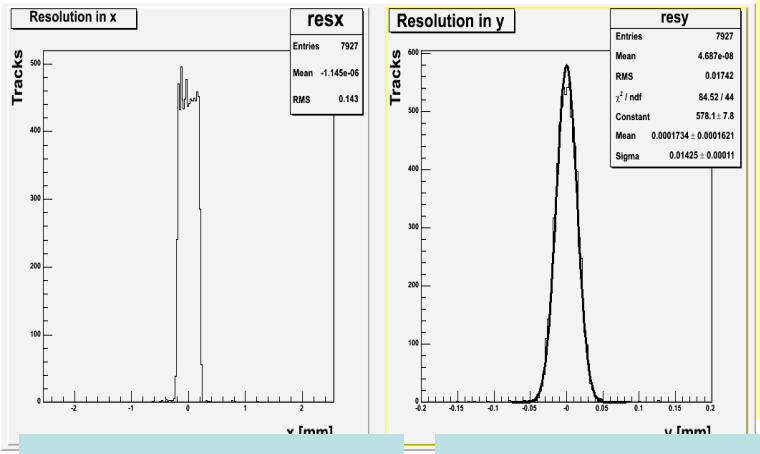
- Beam Test 2002
  - Online:
    - read-out of multi-chip configuration tested
  - Offline:
    - Efficiency: > 99 % at working point.
    - Spatial precision (rφ) at working point:
      $\sigma = (11.1 \pm 0.2)\ \mu m$

- Beam Test 2003
  - Online:
    - full read-out chain (prototypes) tested
    - read-out tested in higher multiplicity environment
  - Offline:
    - efficiencies and spatial precision of 300 μ sensor
    - In-on-Pb target runs analysis under way (Pulvirenti et. al., Pixel 2005).

2002/2003 results: intrinsic precision

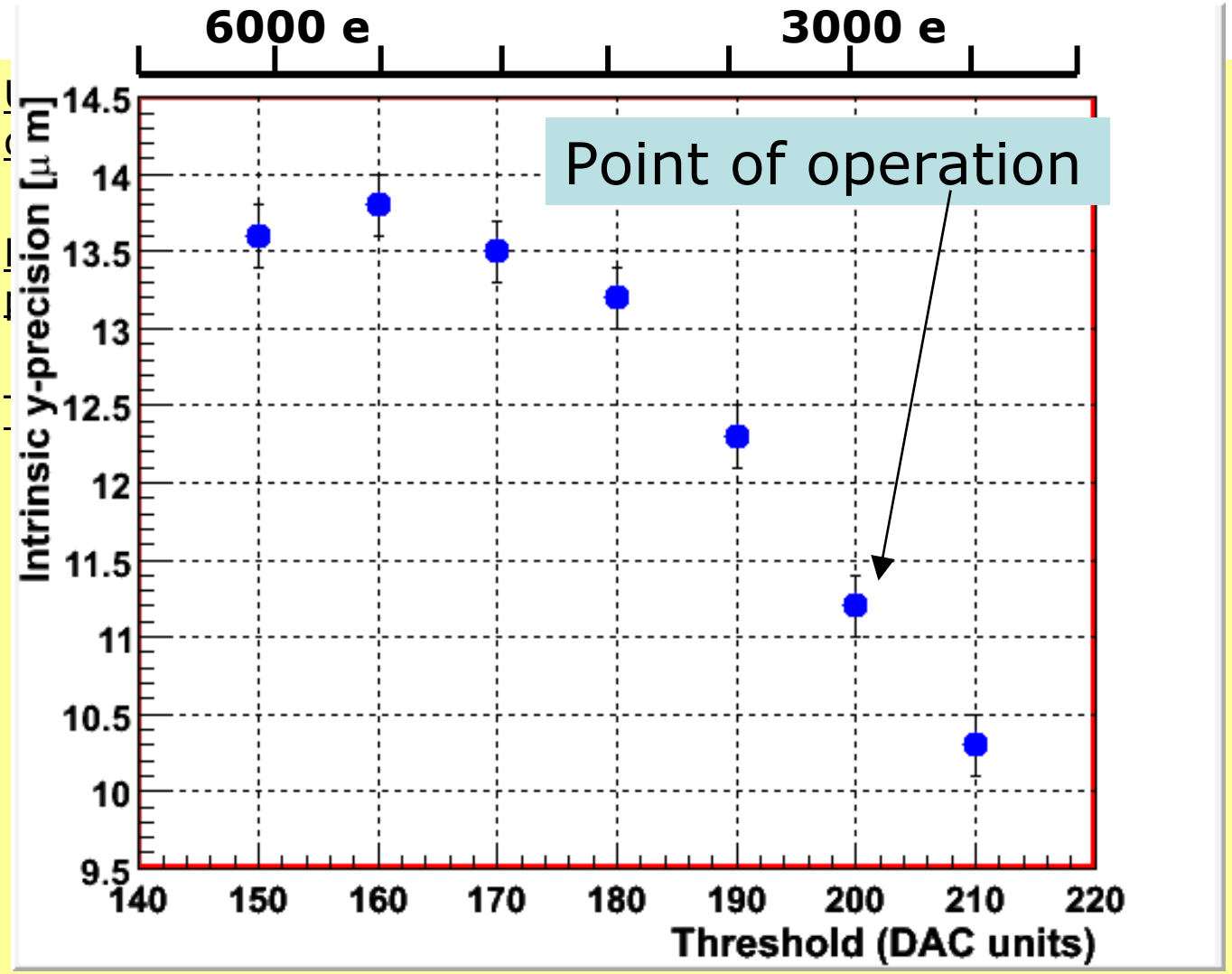


Residual distributions 2003:



large pix dim

small pix dim

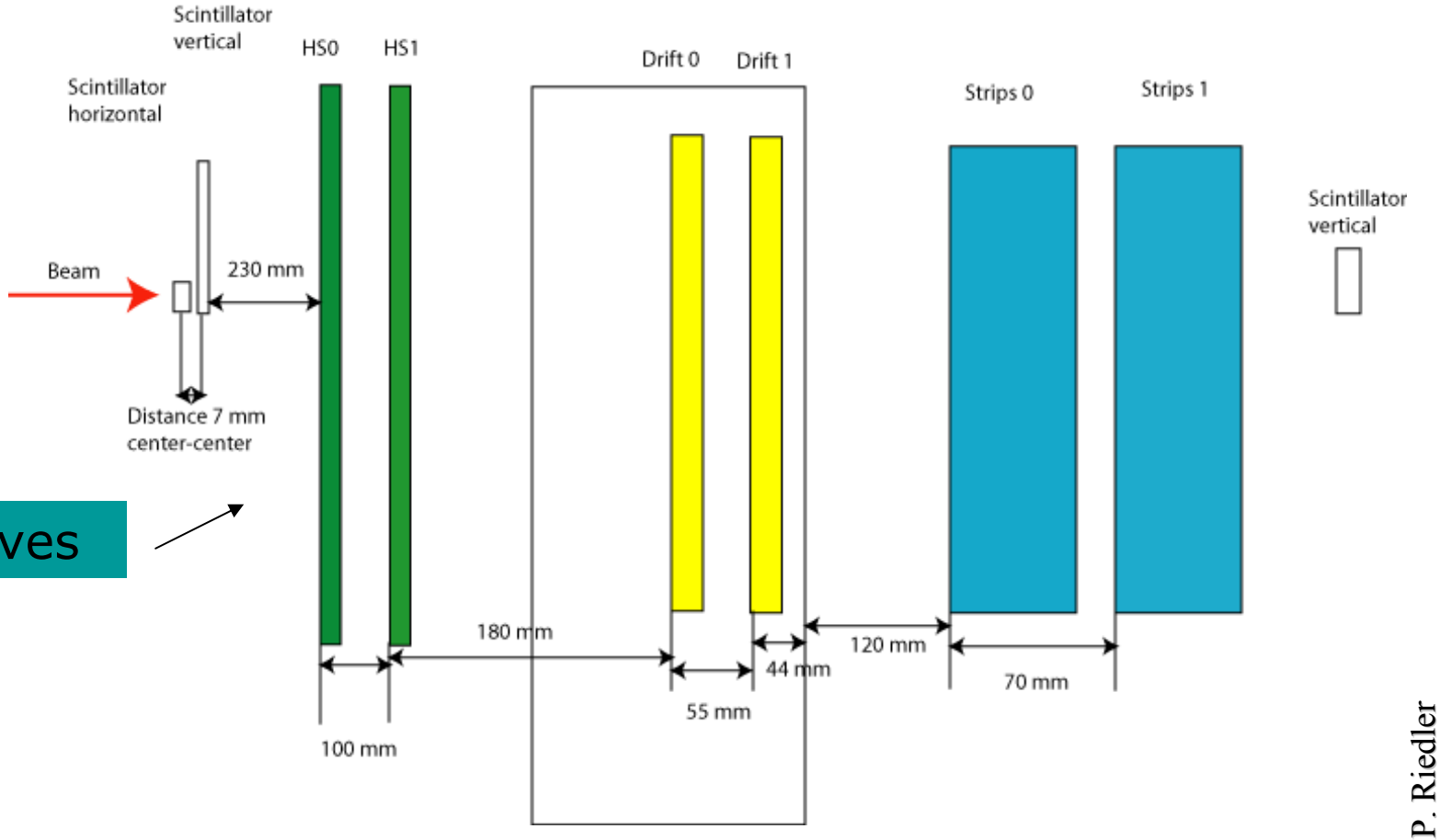


Precision as function of angle,cluster size: not shown

Beam Test: 2004

120 GeV p/π beam

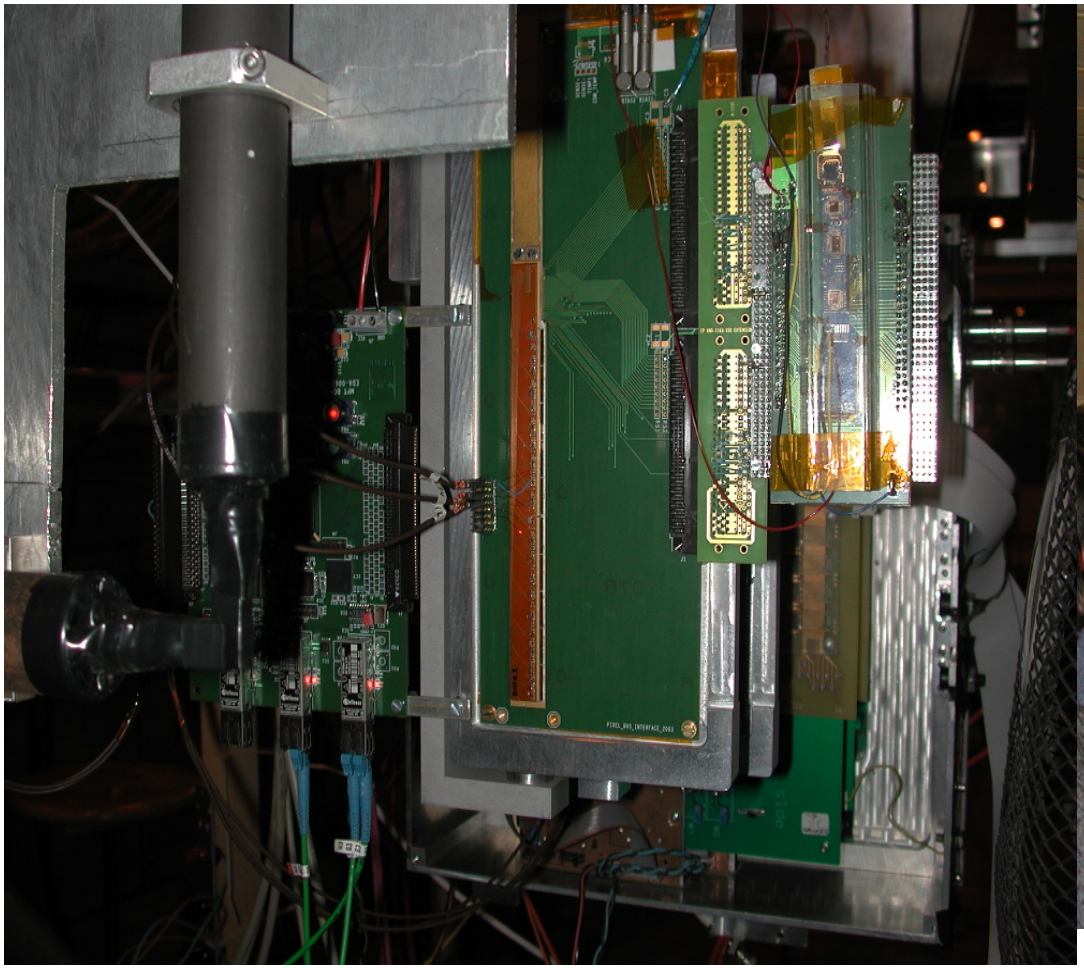
w/o target

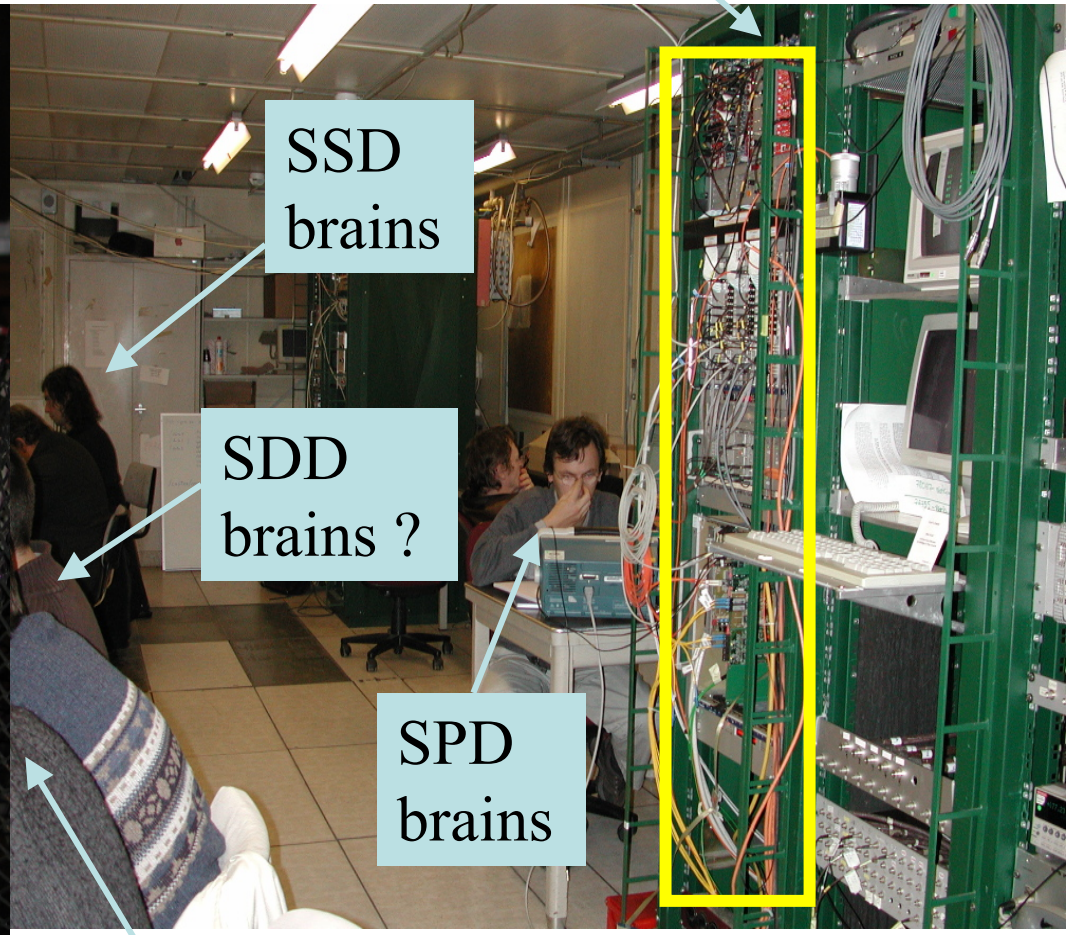


2 full half staves

P. Riedler

Beam Test 2004





Beam Test Results 2004

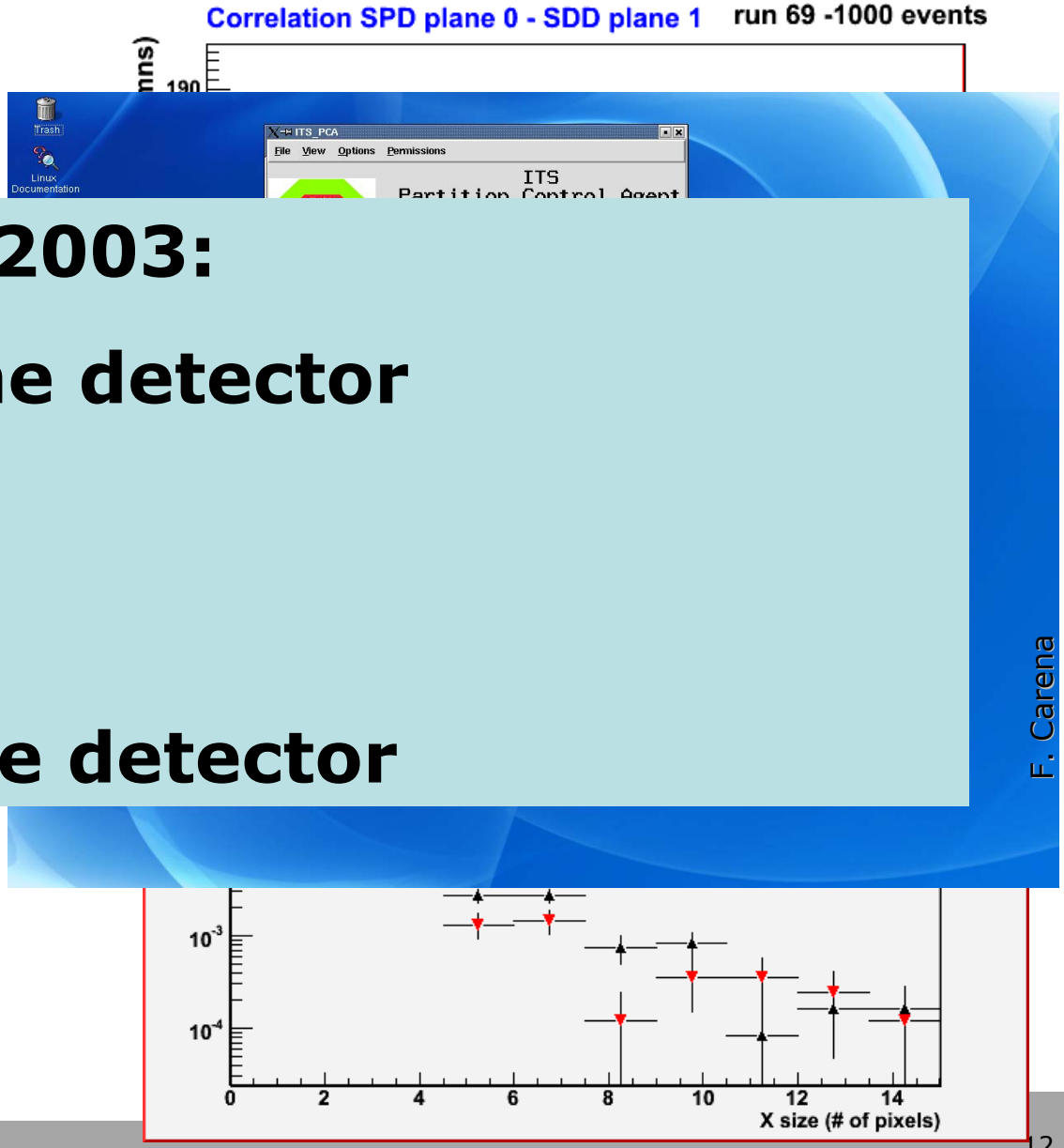
- Online
  - First test of:
    - ALICE Trigger with > 1 subsystem
    - A
  - SPD:
    compo
- Offline
  - Softw
    analys
    during
  - Initia
    tools within AliRoot (so far only applied to simulated data !)
  - Results used to validate use of FLUKA in the ALICE detector simulation

Beam Test 2002/2003:

Learning about the detector

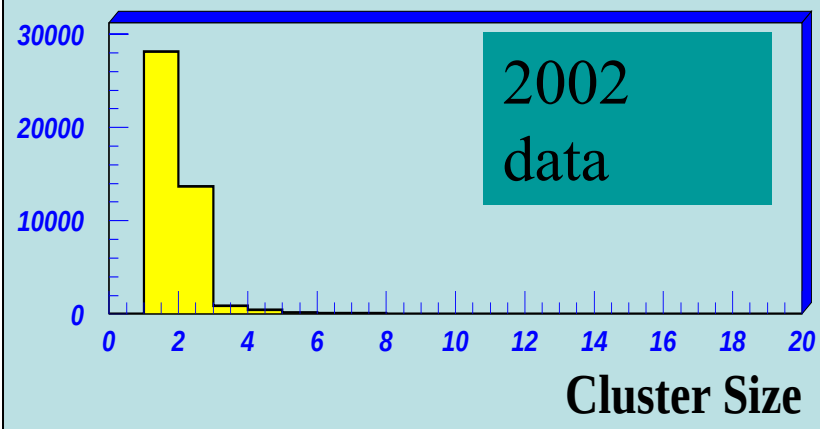
Beam Test 2004:

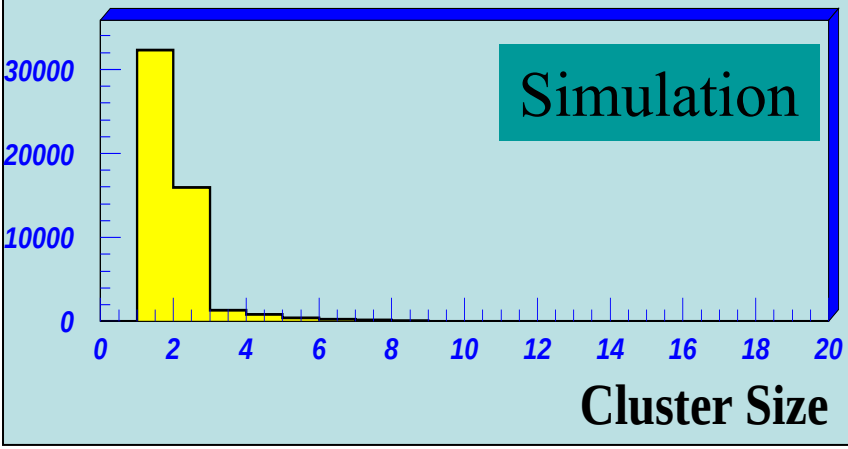
Learning using the detector



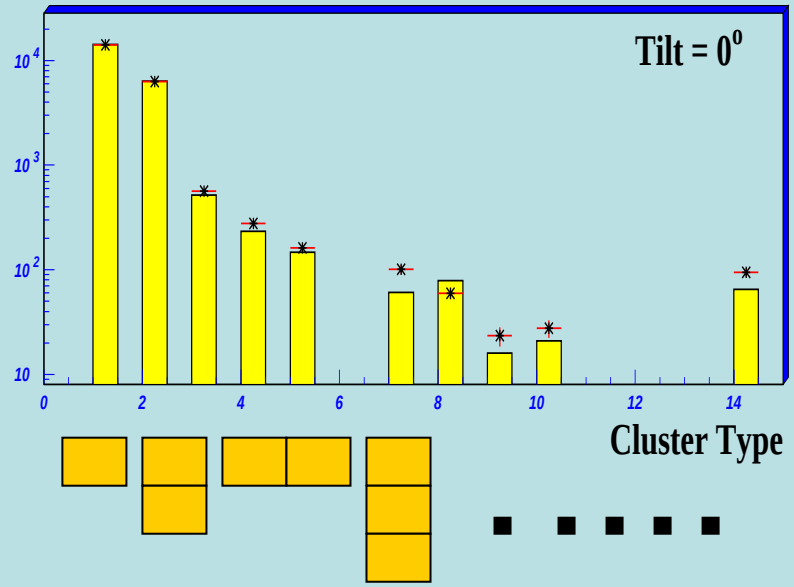
SPD simulation

Cluster Sizes :





Cluster Types :



- Based on GEANT3
- Charge sharing: Gaussian diffusion, charge cloud spread out during the particle's traversal:

$$\sigma_{diff} \propto d_{sensor} / \sqrt{V_{bias}} \approx 5 - 15\ \mu m$$

- tuning of model parameters under way

Conclusions

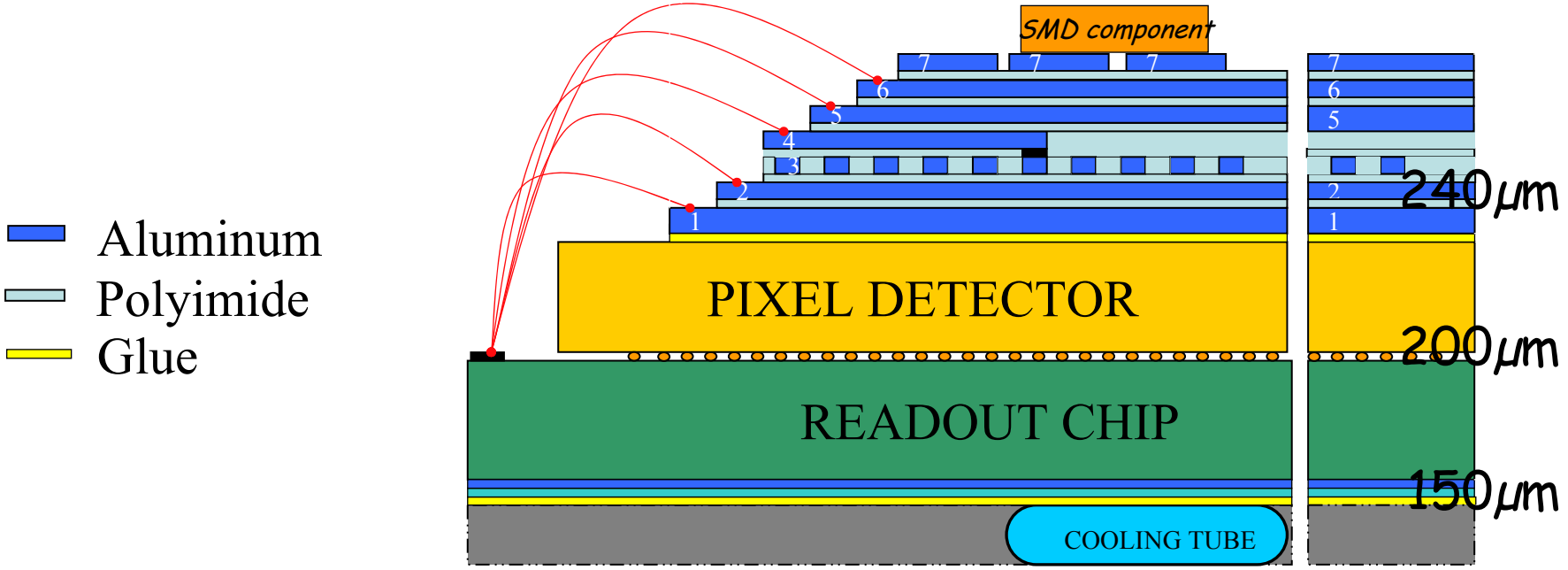
- Beam Tests of the SPD in CERN in 2002 and 2003
  - successfully tested the read-out system of the SPD
  - detector efficiency and intrinsic detector precision determined as function of relevant parameters
- Beam Tests of the ITS at CERN SPS in 2004
  - SPD halfstaves used as tool
  - ALICE DAQ/Trigger system successfully used for >1 subdetector of ALICE for the first time
  - beam test used to validate use of ALICE software framework AliRoot for data analysis and simulation
- Simulation of the Silicon Pixel Detector
  - simulation based on GEANT3, including charge sharing by diffusion qualitatively reproduces beam test data
  - model parameters currently being tuned using beam test data of 2002 and 2003
  - use of other particle tracking packages (FLUKA) validated using beam test data/simulation

MORE DETAILS IN PROCEEDINGS !

BACK-UP SLIDES

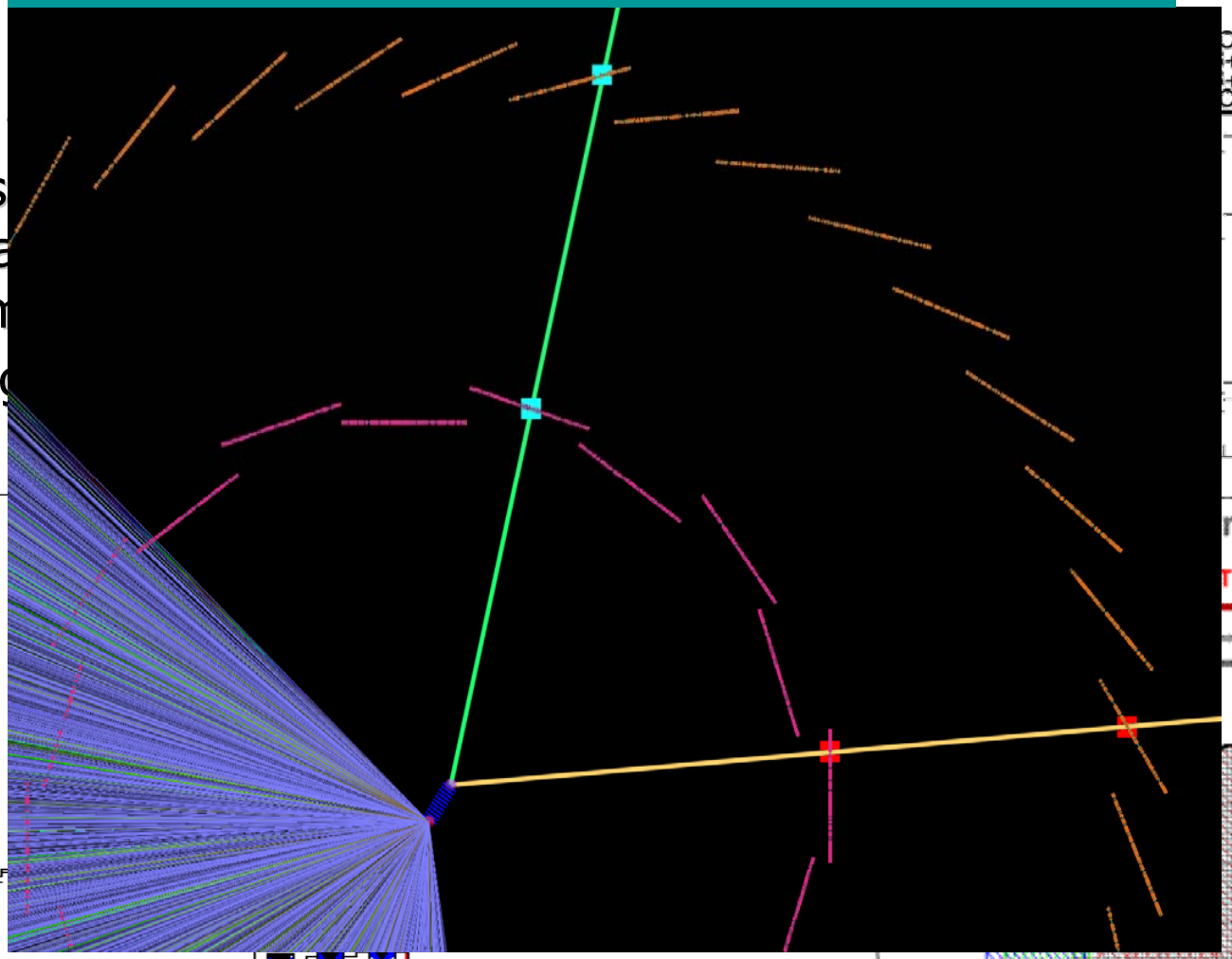
SPD Multilayer Bus

- wire bonds to the readout chips and MCM
- provides data -, control- and power-lines between readout chips and MCM

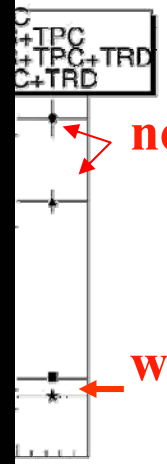


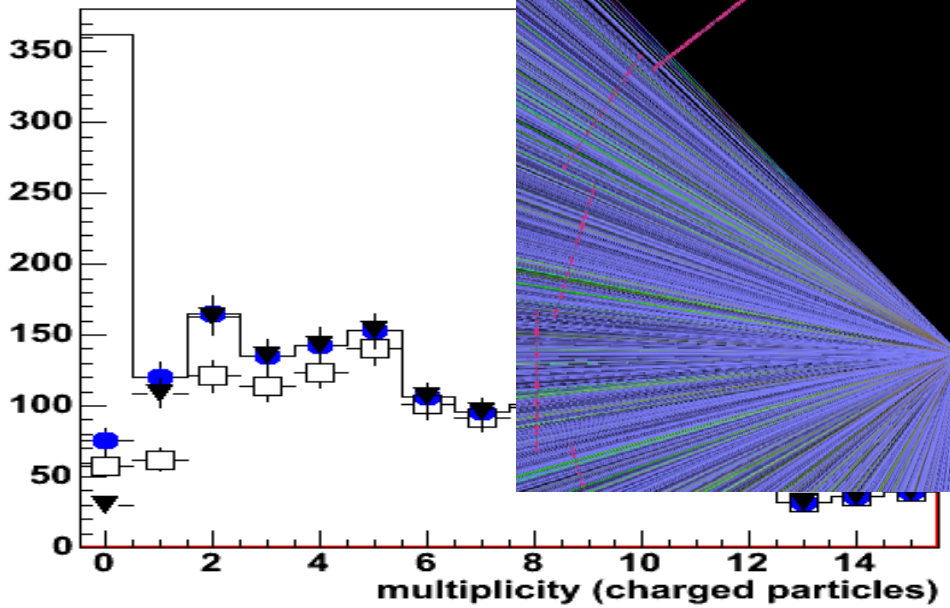
Tasks of the Inner Tracking System

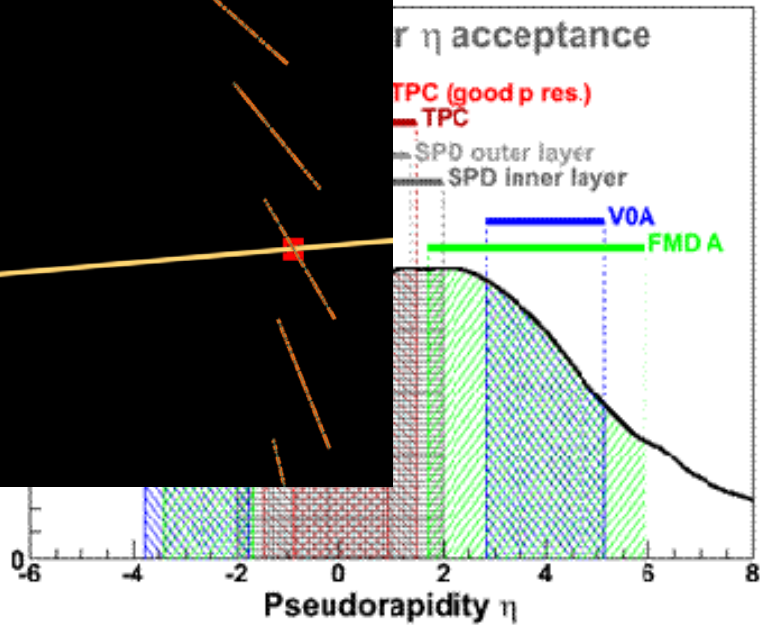
PbPb → D0 → π- π+



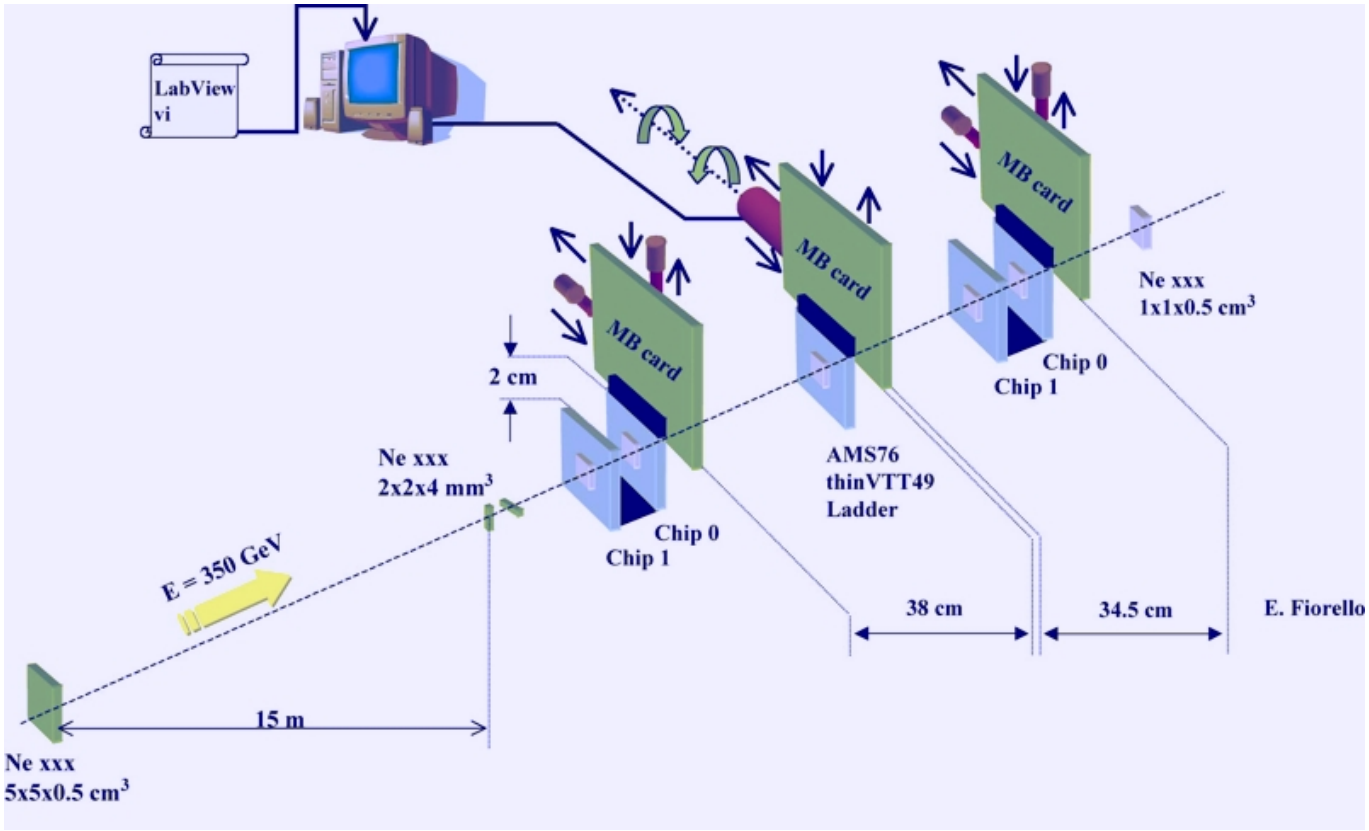
-primary vertexing
-secondary vertices
-low momentum tra
-high pT tracking im
-minimum bias trigg



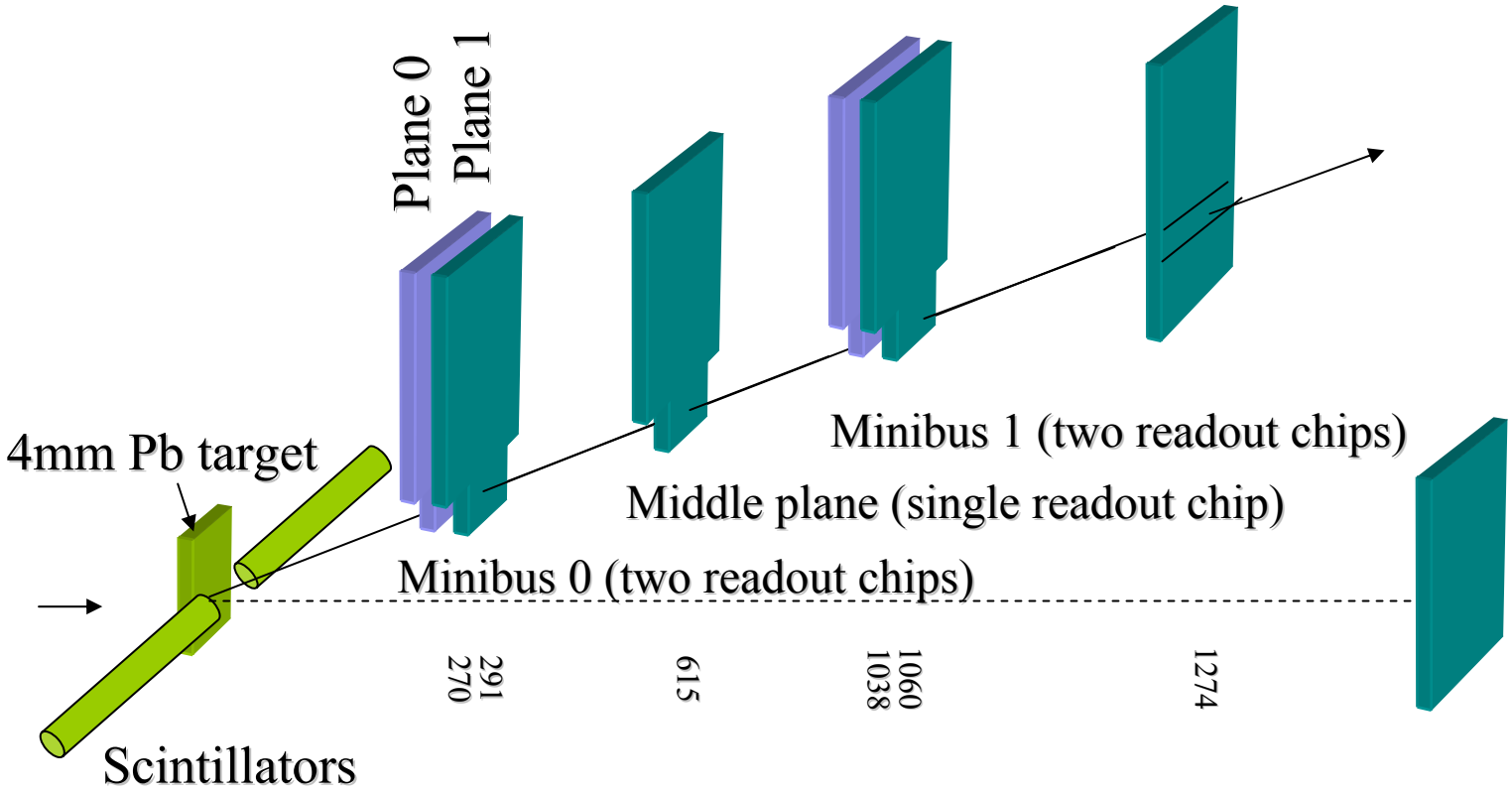




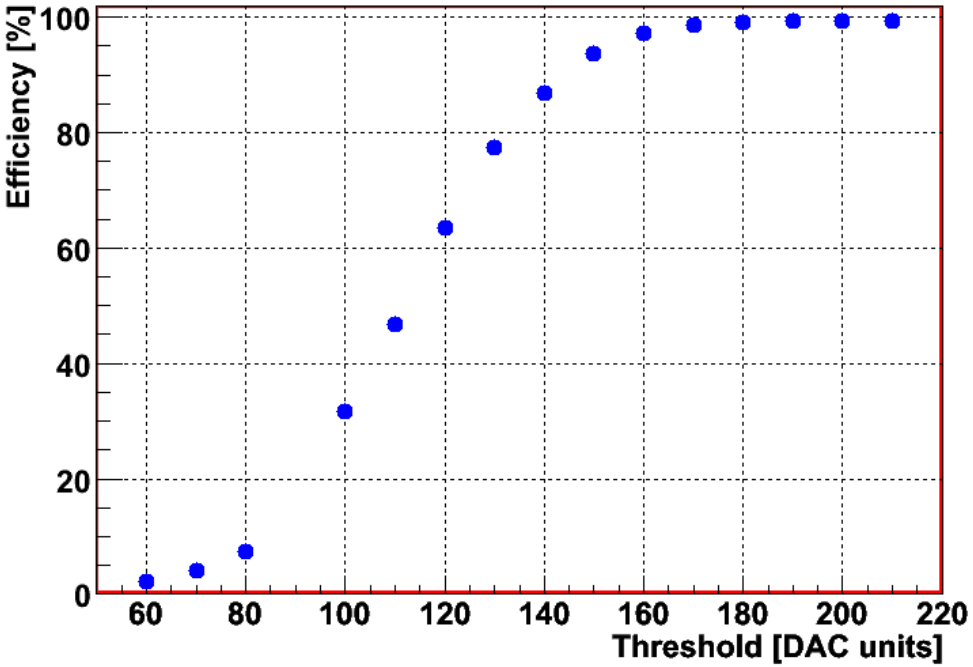
Setup 2002: more detailed view



Setup 2003


Plane 0
Plane 1
4mm Pb target
Minibus 1 (two readout chips)
Middle plane (single readout chip)
Minibus 0 (two readout chips)
261
270
615
1060
1038
1274
Scintillators

2002/2003 results: detector efficiency[1)]



Threshold (e)

INFN Bari

The Detector efficiency

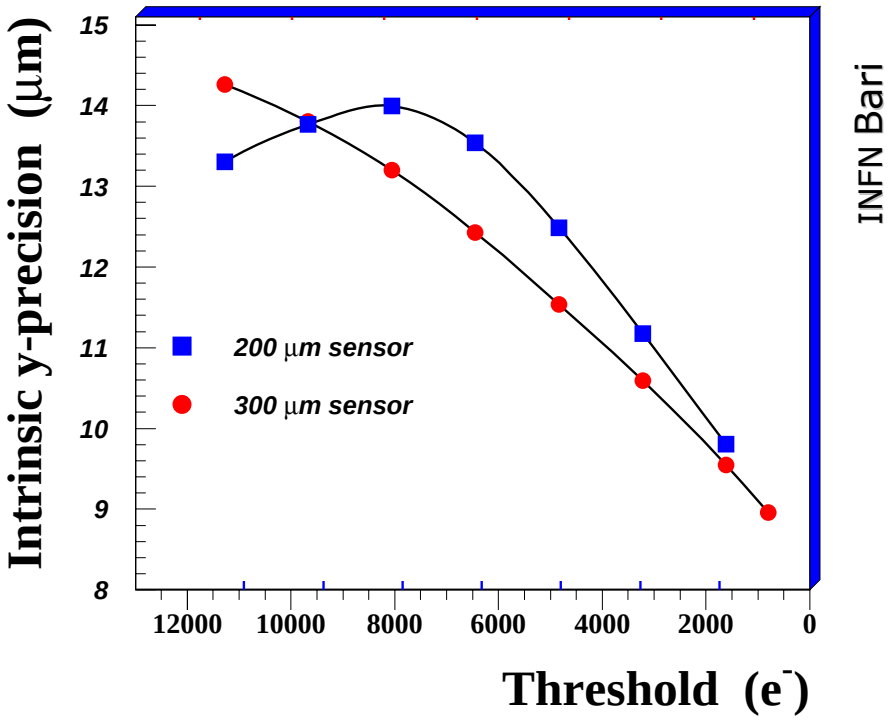
The detector is fully efficient (> 99%) above a threshold setting of DAC 150 (~ 4000 e).

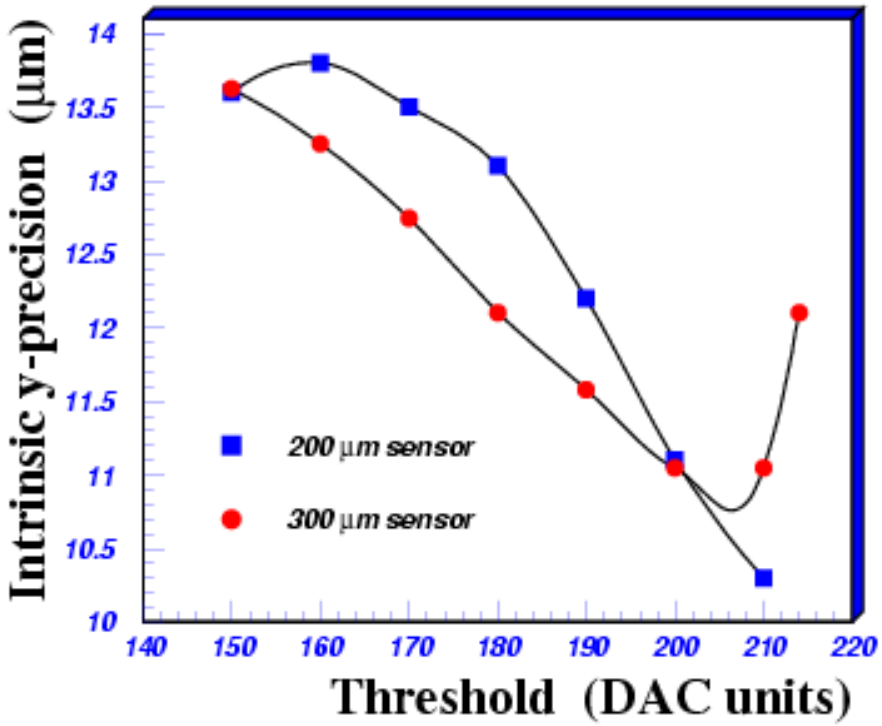
Operational Point:

DAC 200!!

1) Only cluster within < 10 σ(residual) are considered

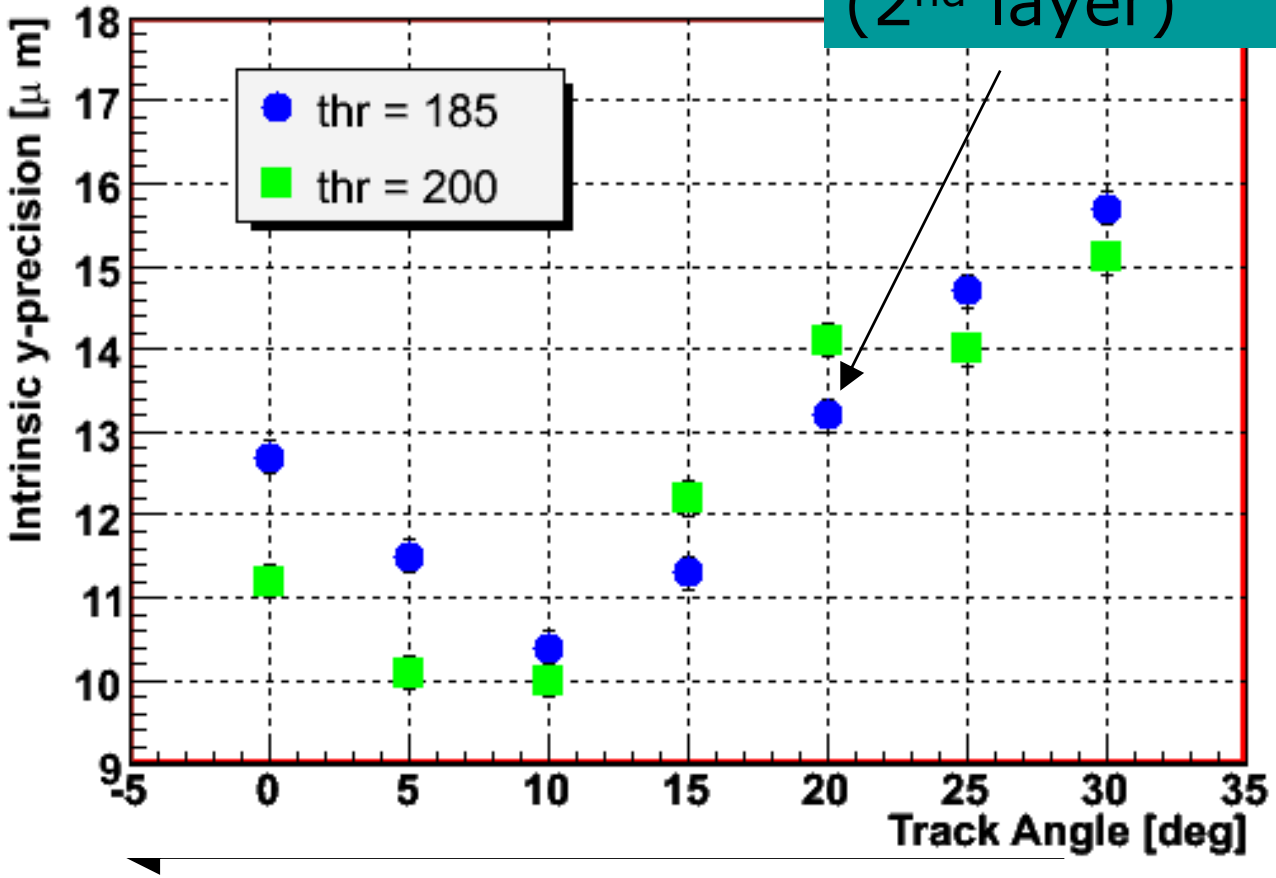
Intrinsic Precision: GEANT simulation and data





Results 2002/2003: Intrinsic Precision

Typical track angle in HI coll (2nd layer)



Threshold (DAC 200 ≈ 3000 e)

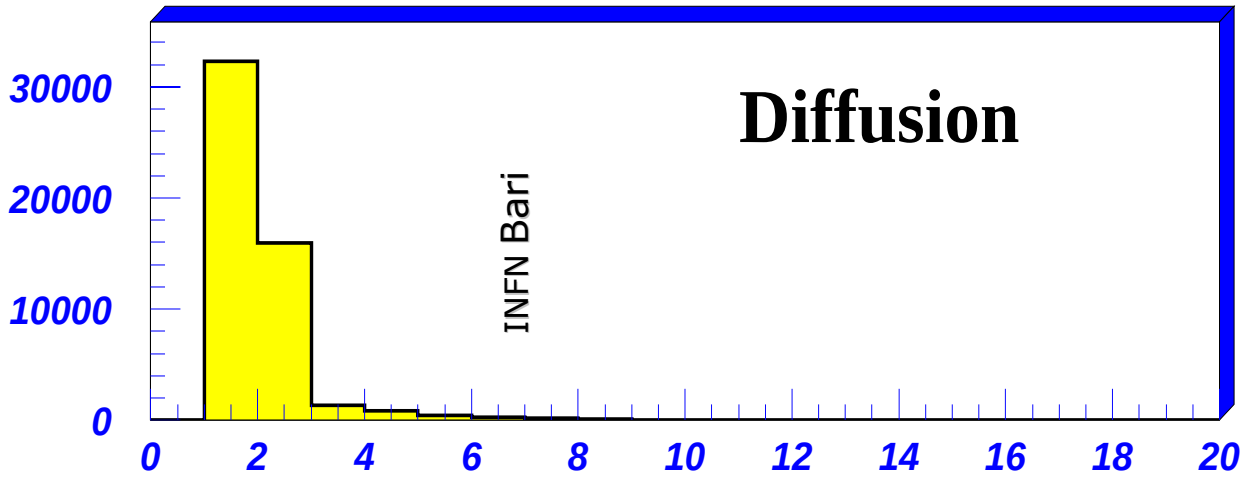
Short pixel dimension

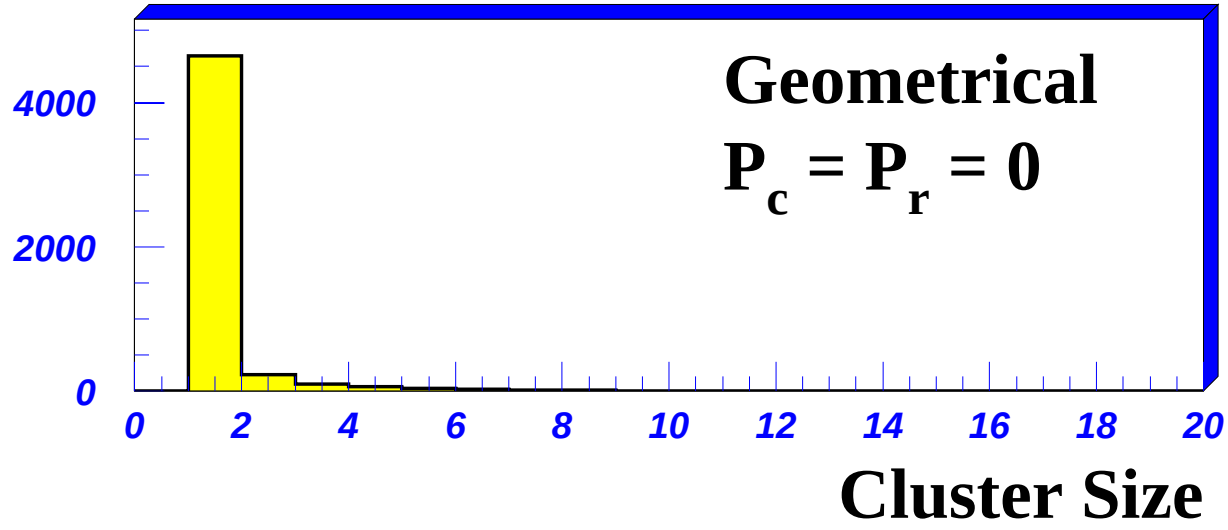
1,2 px clusters in test plane

smaller threshold

larger threshold

Diffusion and no diffusion





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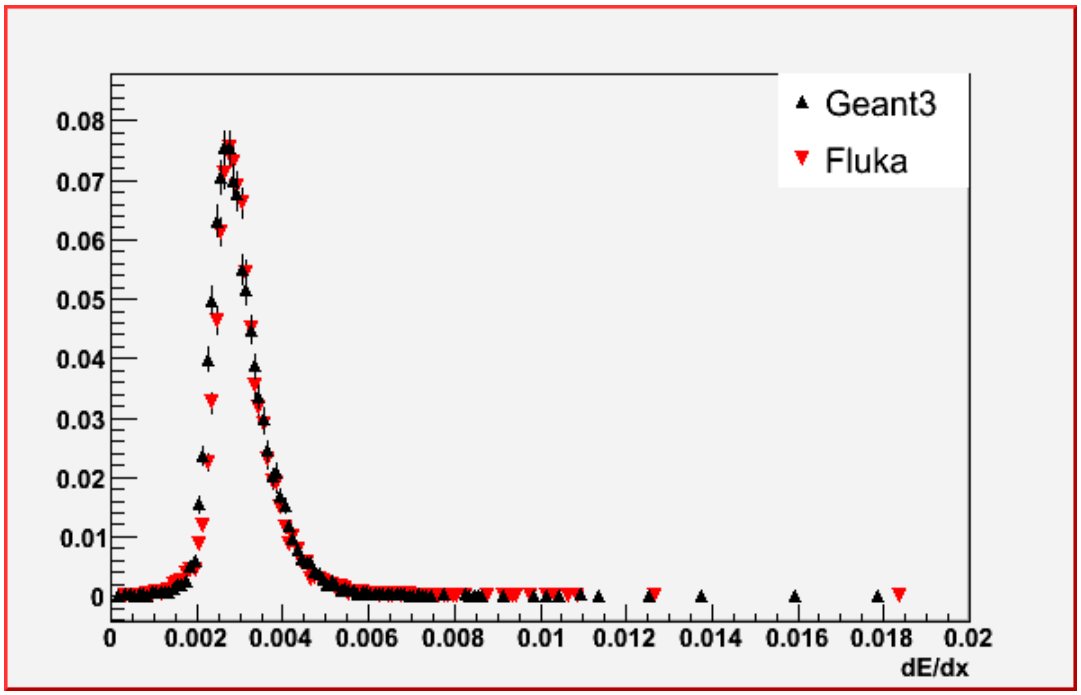
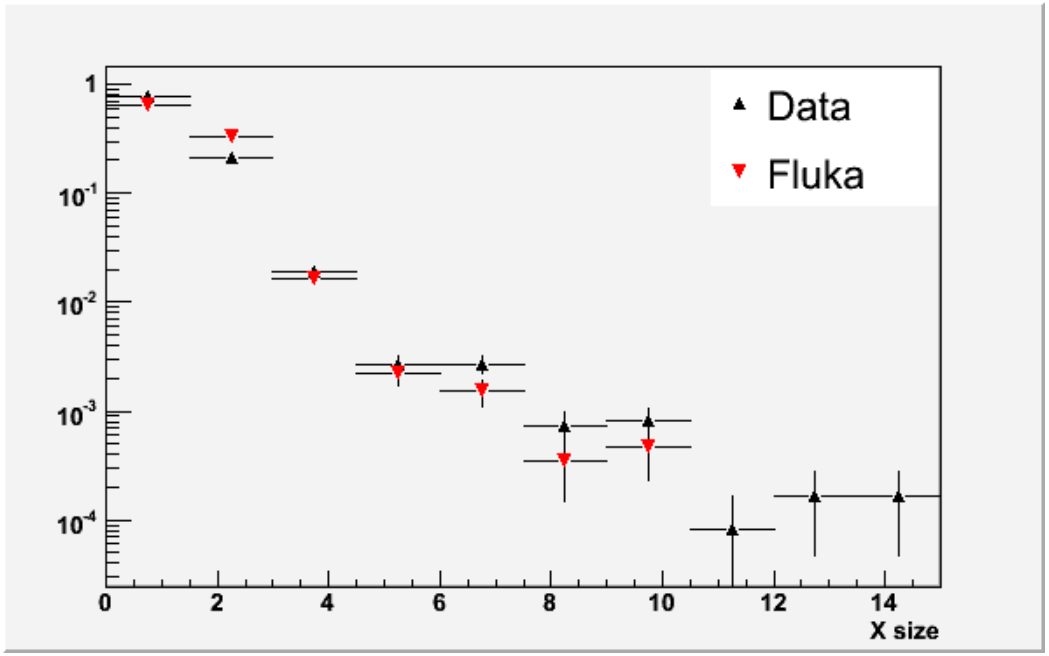
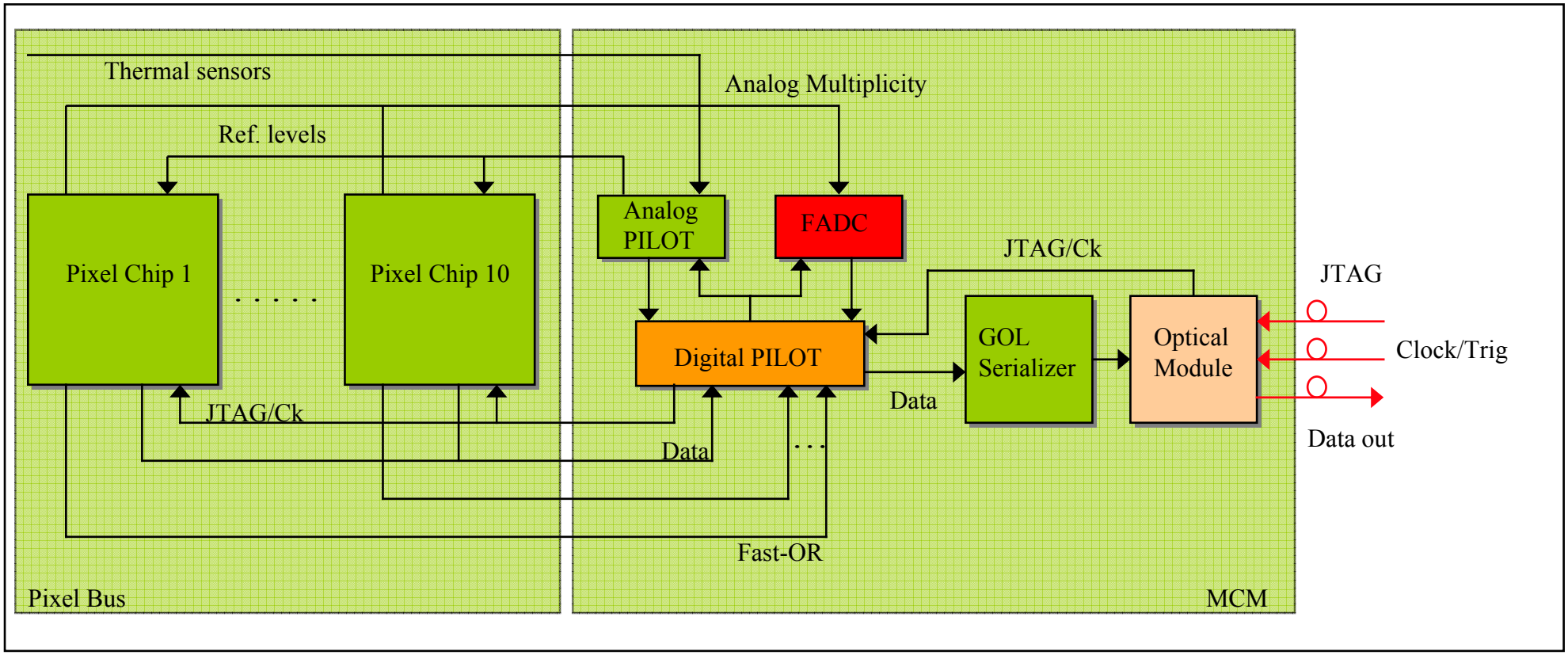
Simulation GEANT/FLUKA/DATA





Multi Chip Module



Radiation Levels

	TID	Fluence 1MeV n eq. [cm^{-2}] @ 10 years
ATLAS Pixels	50 Mrad	1.5×10^{15}
ATLAS Strips	7.9 Mrad	2×10^{14}
CMS Pixels	~24Mrad	~6×10^{14} *
CMS Strips	7.5Mrad	1.6×10^{14}
ALICE Pixel	220krad	3×10^{12}
LHCb VELO	-	1.3×10^{14}/year**

*Set as limit, inner layer reaches this value after ~2 years

**inner part of detector (inhomogeneous irradiation)

P. Riedler