New Si-Vertex Detector for NA61 at SPS/CERN

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(for NA61 Collaboration),
Report at Baldin ISHEPP XXII, JINR, Dubna, September 17, 2014

Outline

1) **Introduction.**
2) **Motivation and challenges of direct open charm measurements at SPS**
3) **Requirements and strategy**
4) **New, high precision Vertex Detector**
5) **Summary**

NA61/SHINE Experiment

NA61(SHINE) at SPS at CERN

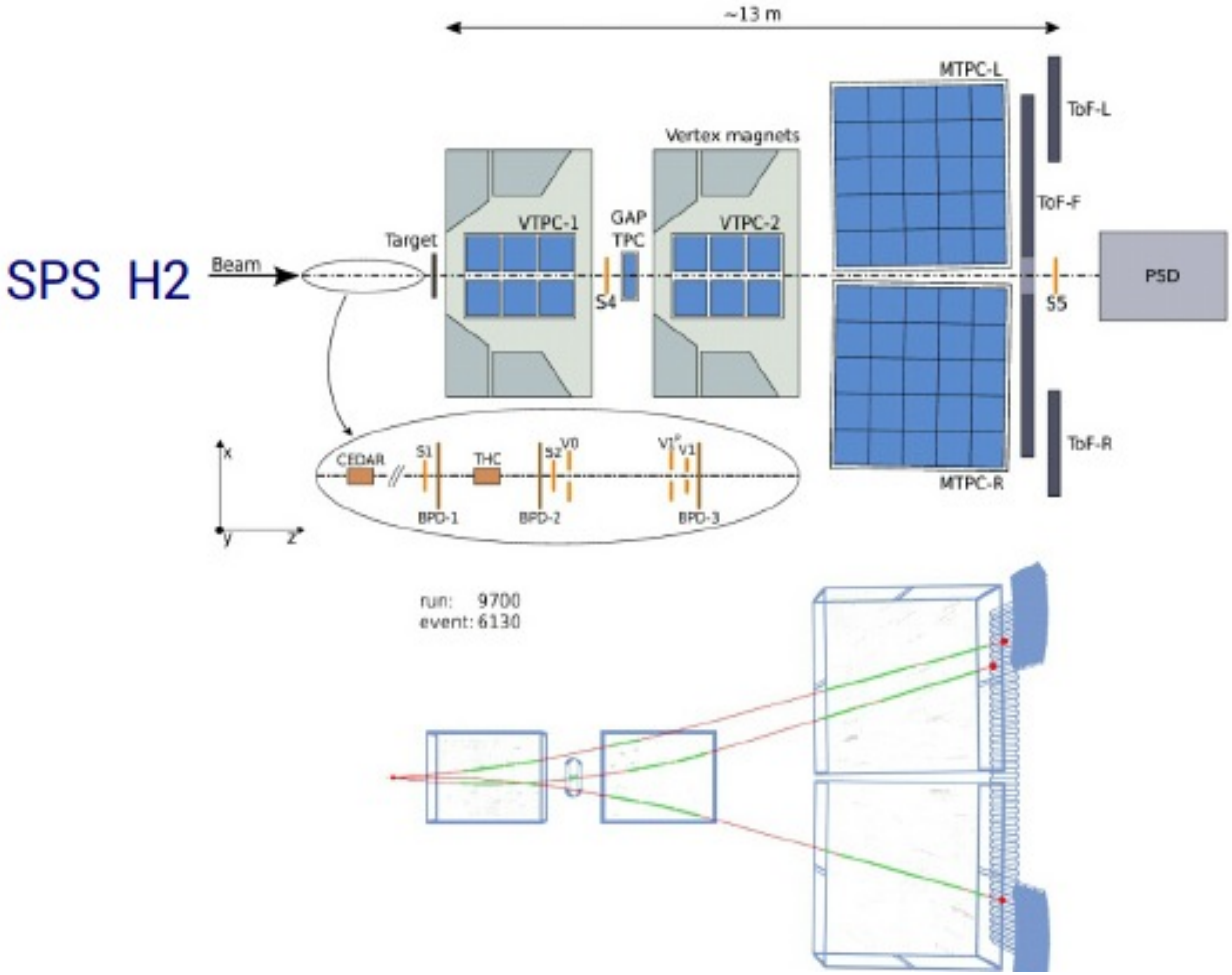
SHINE = **S**PS **H**eavy **I**on and **N**eutrino **E**xperiment

Goals:

1) study the properties of **the onset of deconfinement** and **search for the critical point of strongly interacting matter** which is pursued by investigating p+p, p+Pb and nucleus-nucleus collisions

2) **precise hadron production measurements** for improving calculations of the initial neutrino beam flux in the long-baseline neutrino oscillation experiments as well as for more reliable simulations of cosmic-ray air showers.

NA61(SHINE) installation at CERN/SPS

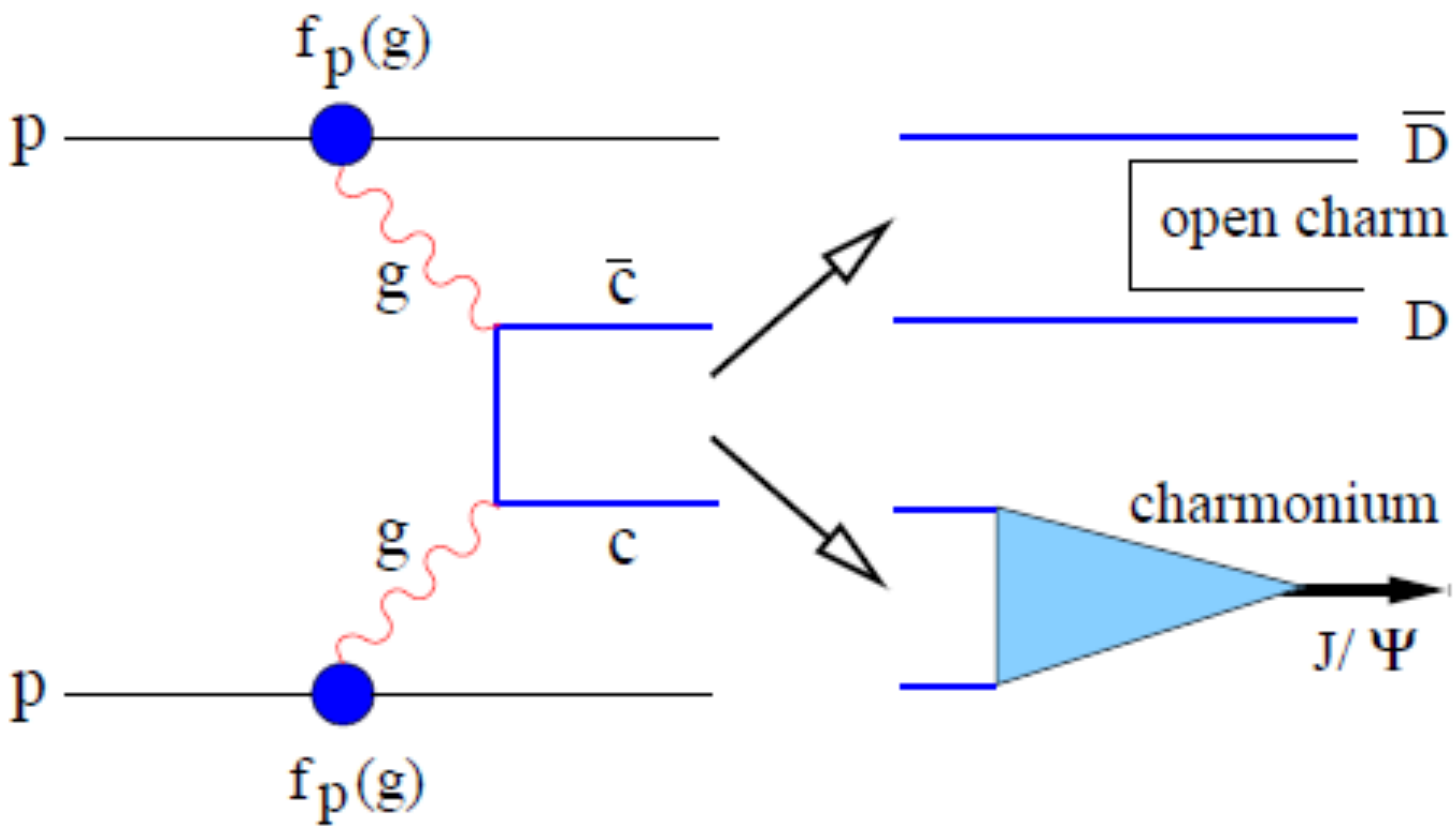


- A large acceptance hadron spectrometer
- Beam particles measured in set of counters and MWPC detectors
- Charged tracks measured in set of 5 **TPCs** → measurement of ***q***, ***p*** and identification via dE/dx
- 3 ToF walls: identification via time of flight measurement
- **Projectile Spectator Detector** counts the non-interacting nucleons

JINST **9** P06005(2014)

Motivation for open charm

-- a tool to study the formation of a deconfined medium formed in high energy AA collisions capable to test the color screening effects on binding of charm quarks to color neutral **J/ψ** production [1]



<-- about 90%

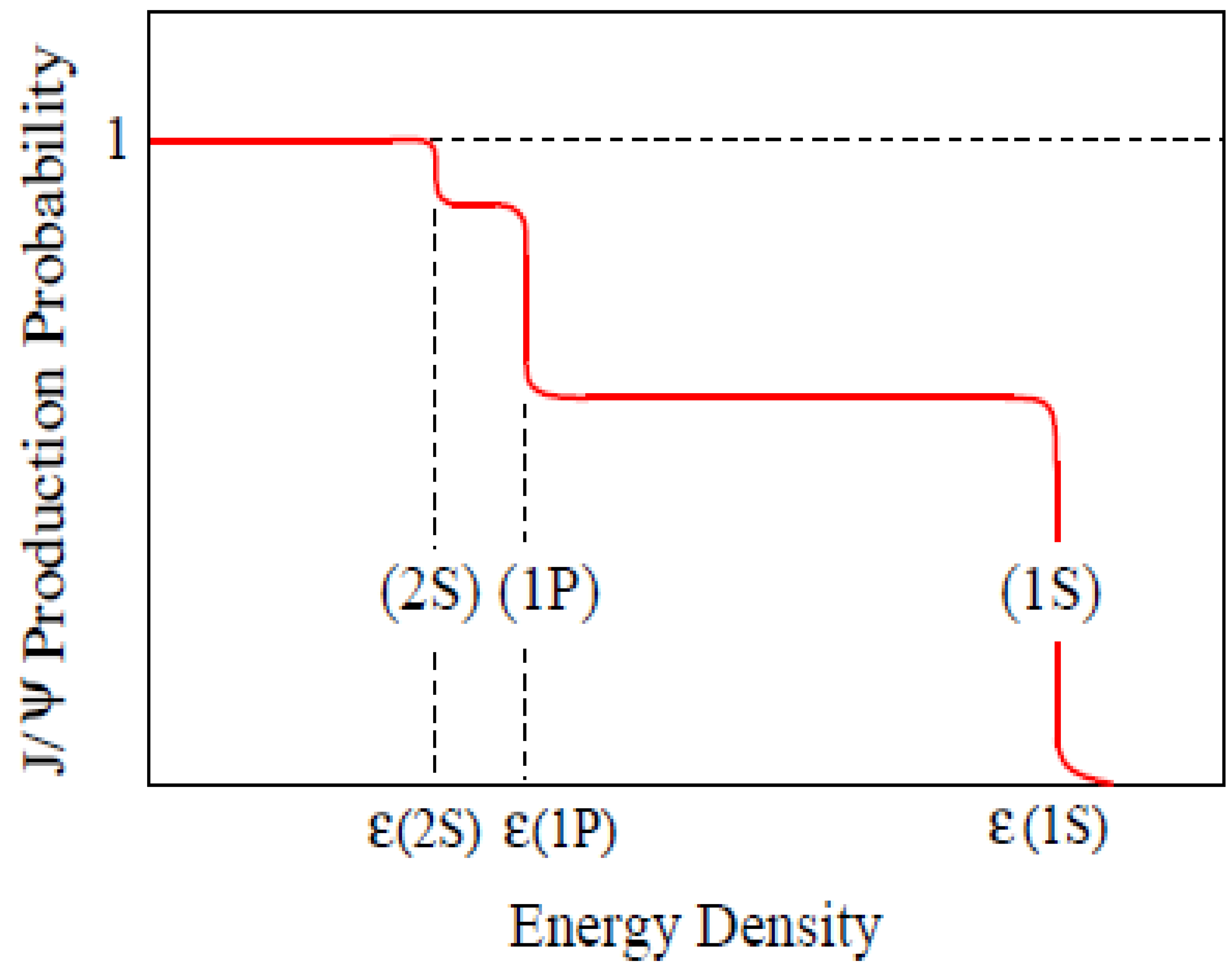
<-- about 10%
for all charmonia

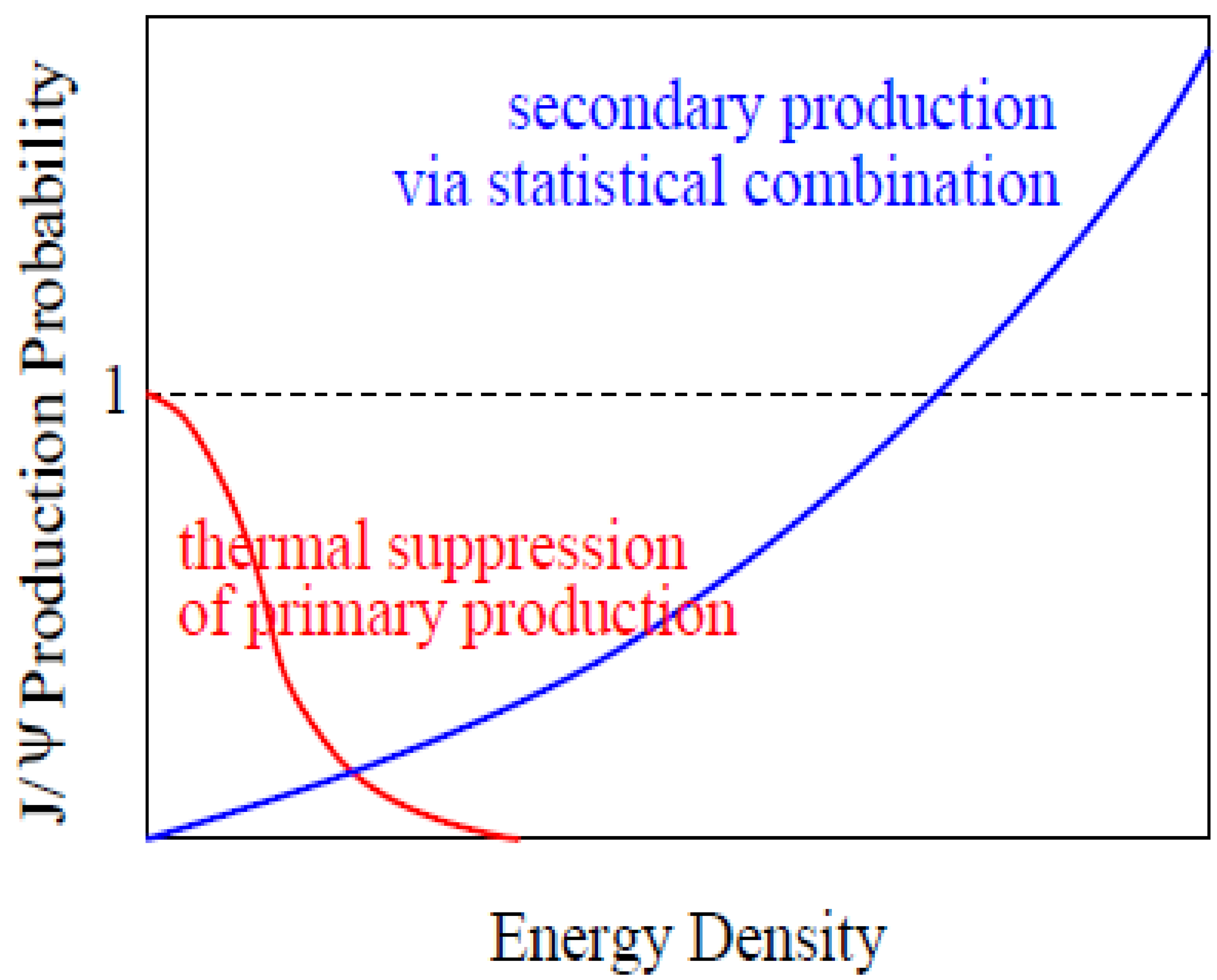
Fig.1 Schematic view of J/ψ production **in pp collisions** (see [2])

AA collisions --?

[1] **T. Matsui and H. Satz**, Phys. Lett. B 178 (1986) 416.
[2] **Helmut Satz,** Calibrating the In-Medium Behavior of Quarkonia, arXiv: 1303.3493, 12 April 2013

Color screening in a quark-gluon plasma in AA collisions:
suppression or enhancement of J/ψ ? [1,2]





[1] Helmut Satz, Calibrating the In-Medium Behavior of Quarkonia, arXiv: 1303.3493, 12 April 2013

[2] Statistical enhancement of J/ψ? -- see **P. Braun-Munzinger and J. Stachel,** Nucl. Phys. A690 (2001) 119.

The crucial observable [1]

"…**the rate of (J/ψ)/open charm,** can thus in good approximation be taken as the rate of (J/ψ)/D for a specific D-meson state" [1] .

This will provide a possibility of:

1. Model independent analysis of a deconfined medium in AA collsions
2. Discrimination of initial and final state effects in AA collsions

…..so far there were no open charm measurements at SPS energies…

[1] **Helmut Satz,** Calibrating the In-Medium Behavior of Quarkonia, arXiv: 1303.3493, 12 April 2013

Measurements strategy

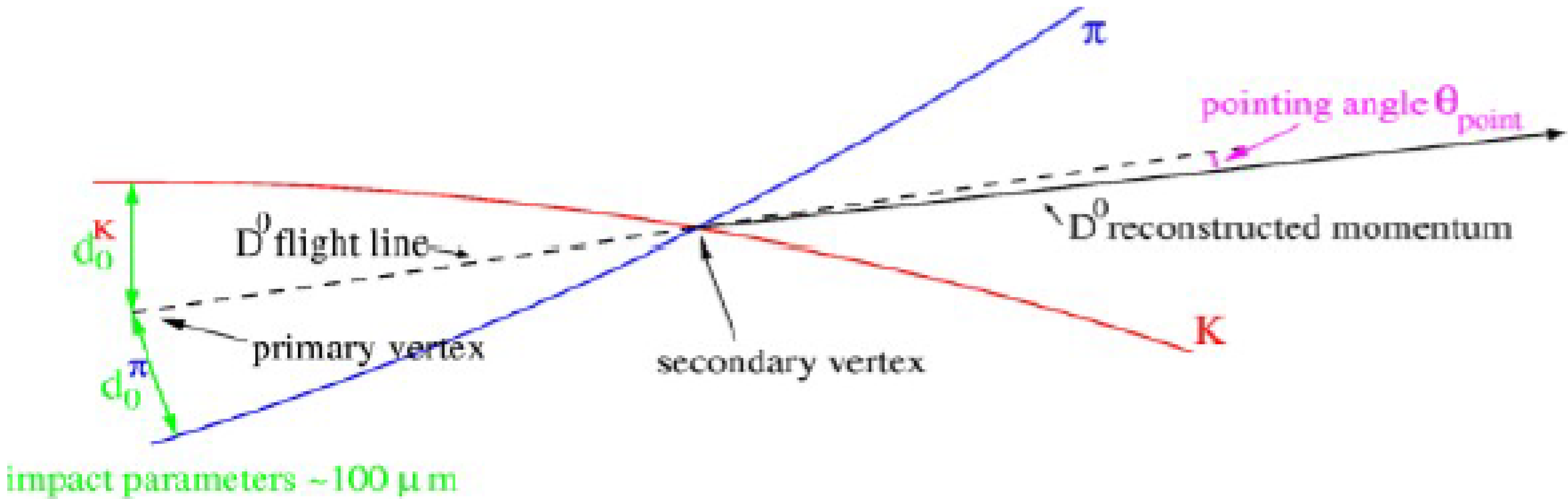


Figure from the report by Yasir Ali at SQM 2013

Challenges

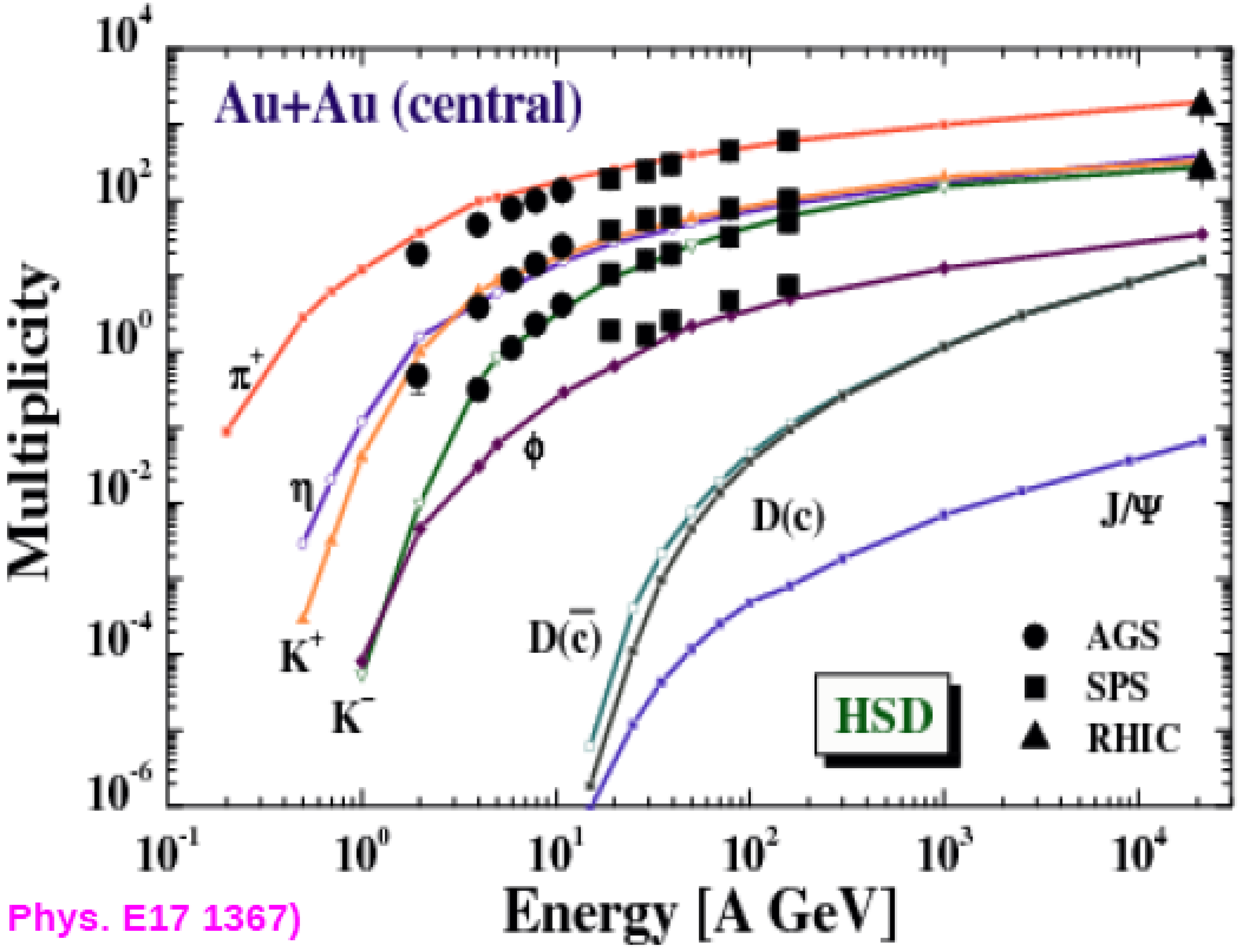
Reconstruction from hadronic decay channels

- Short life-time

Meson	Decay Channel	Cτ	Branching Ratio
D^0	$D^0 \rightarrow K^- + \pi^+$	122.9μm	(3.91±0.05)%
D^0	$D^0 \rightarrow K^- + \pi^+ + \pi^+ + \pi^-$	122.9μm	(8.14±0.20)%
D^+	$D^+ \rightarrow K^- + \pi^+ + \pi^+$	311.8μm	(9.2±0.25)%
D^+_s	$D^+_s \rightarrow K^+ + K^- \pi^+$	149.9μm	(5.50±0.28)%
D^{*+}	$D^{*+} \rightarrow D^0 + \pi^+$	----------	(61.9±2.9)%

Challenges for open charm measurements:

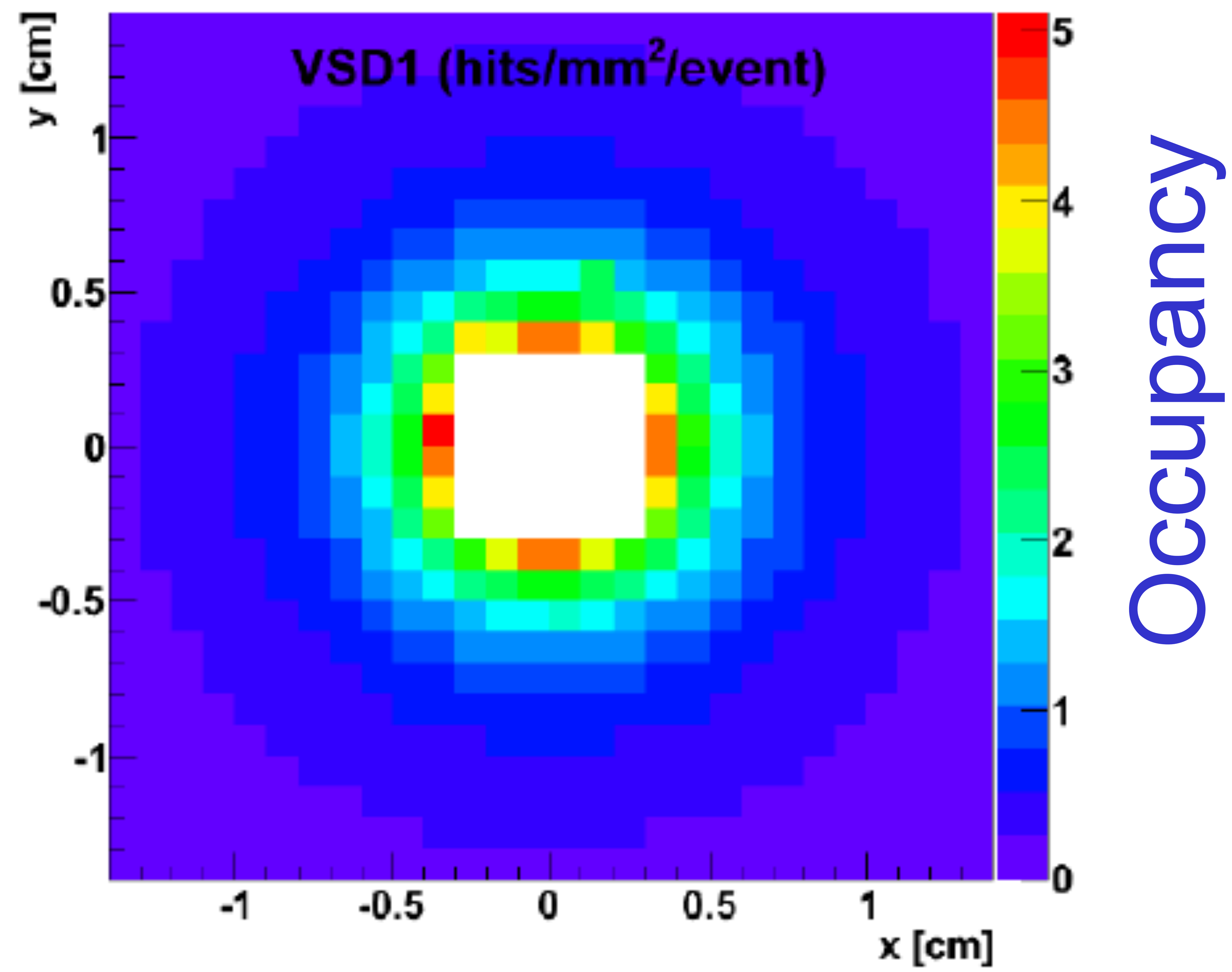
Low yields



(Int. J. Mod. Phys. E17 1367)

Results of feasibility studies [1-3]

Simulations for central Pb-Pb
using GEANT
and event generators

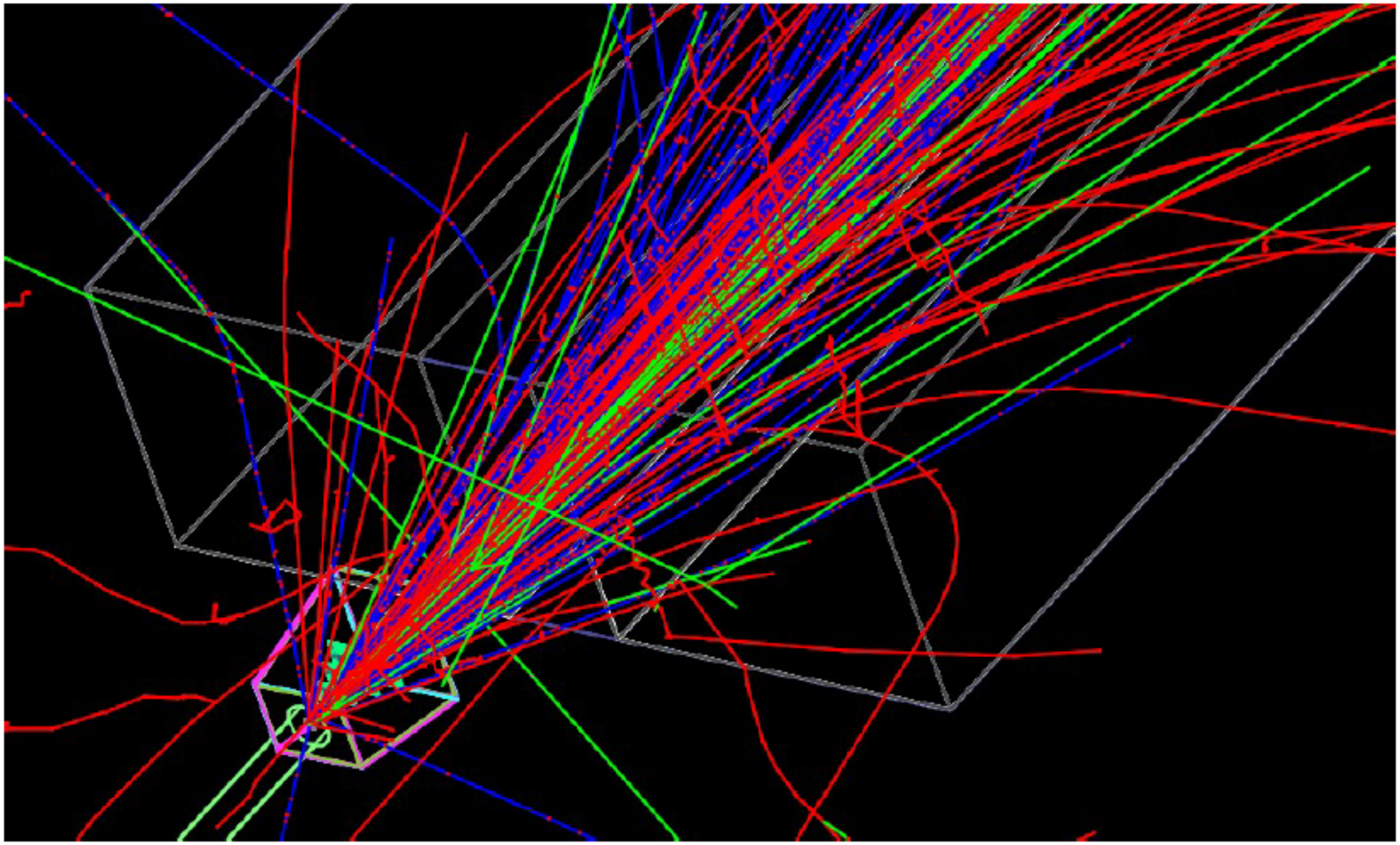


AMPT : (Phys.Rev.C72:064901, 2005)
HSD : (Int. J. Mod. Phys. E17 1367)
PYTHIA: (T. Sjostrand etal., Comput. Phys. Commun. 135, 238 (2001))

[1] **Yasir Ali and Pawel Staszel** for the NA61/SHINE collaboration, in Proceedings of 14th International Conference on Strangeness in Quark Matter (SQM2013), Journal of Physics: Conference Series **509** 012083(2014).
[2] **Yasir Ali, Pawel Staszel,** EPJ Web of Conferences, **71**, 00004 (2014).
[3] **Yasir Ali, Pawel Staszel**, Acta Physica Polonica B Proceedings Supplement **6**, No 4,1081 (2013).

Simulations

AMPT Event: Pb+Pb at 158 AGeV



→ VTPCs filled with Ar-CO_2 mixture, location and dimensions as in NA61/SHINE experimental setup.

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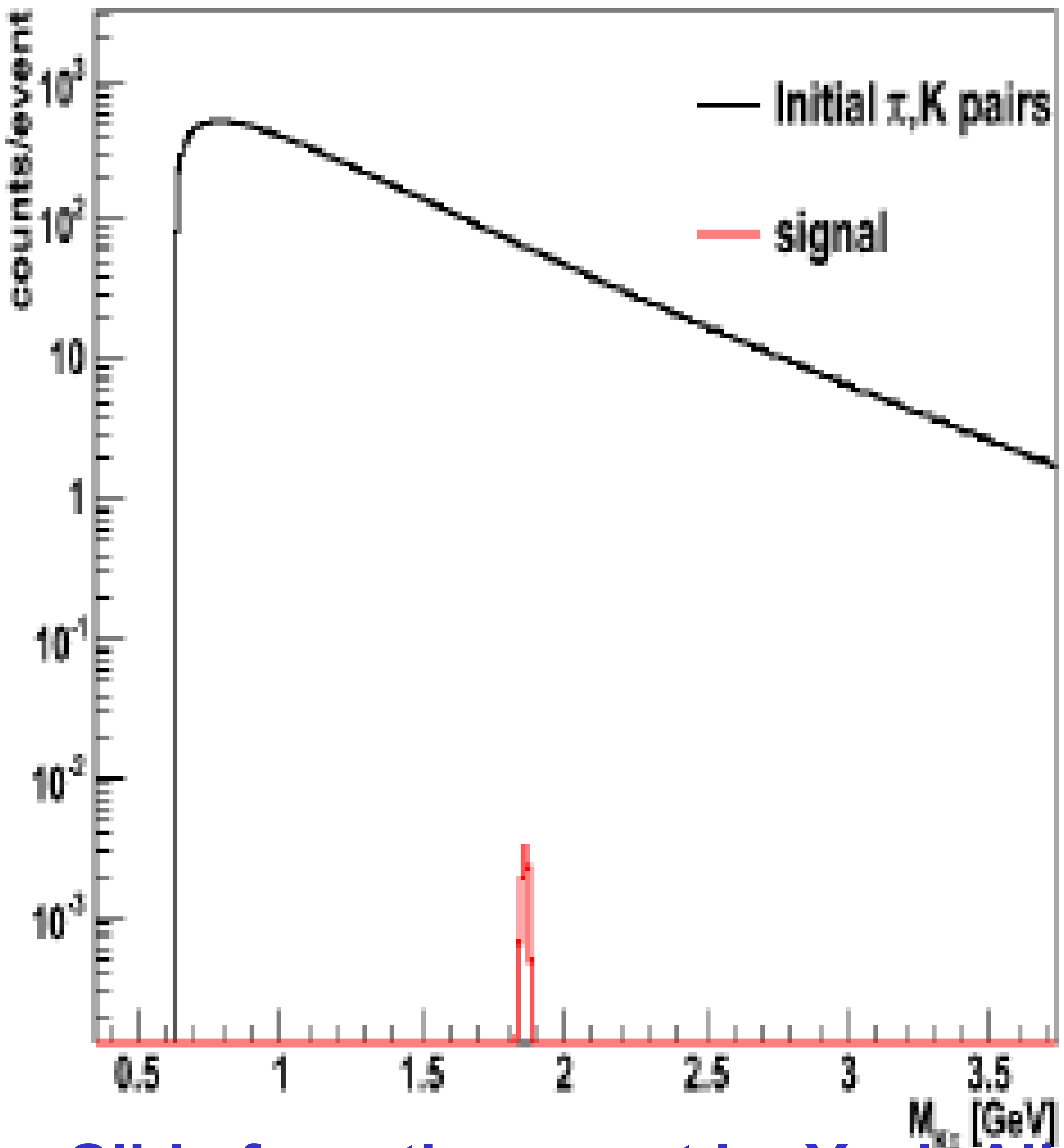
→ Uniform magnetic field: 1.5 T in VTPC-1 and 1.1 T in VTPC-2 (one slide)

Slide from the report by Yasir Ali at SQM 2013

Background supression strategy

→ Combinatorial background is very large → need to apply background suppression cuts.
→ Optimized to assure good signal Acceptance.



Single particle cuts:

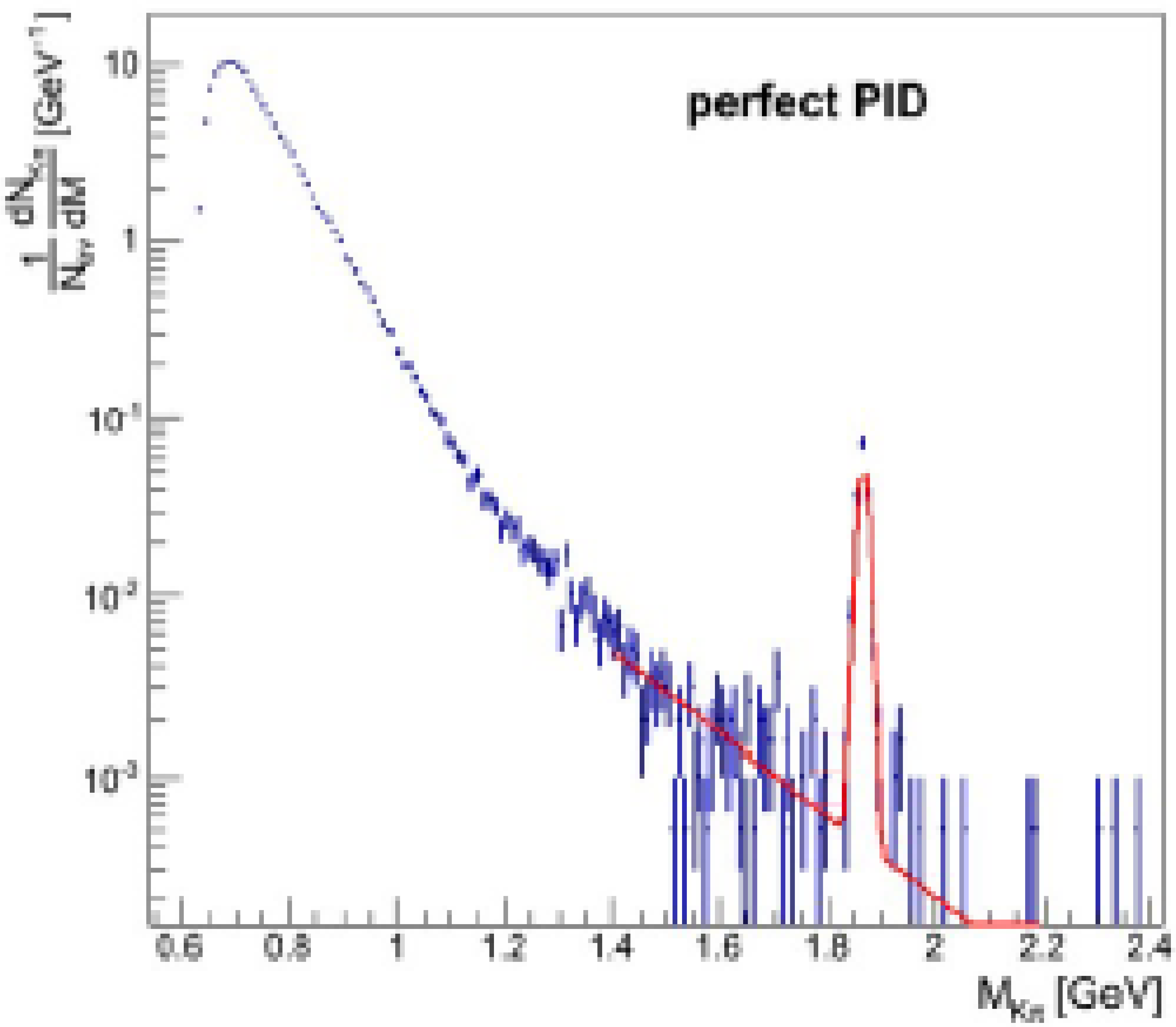
1. cut on **pT** (> 0.4)
2. cut (track impact parameter **d** (>40μm)

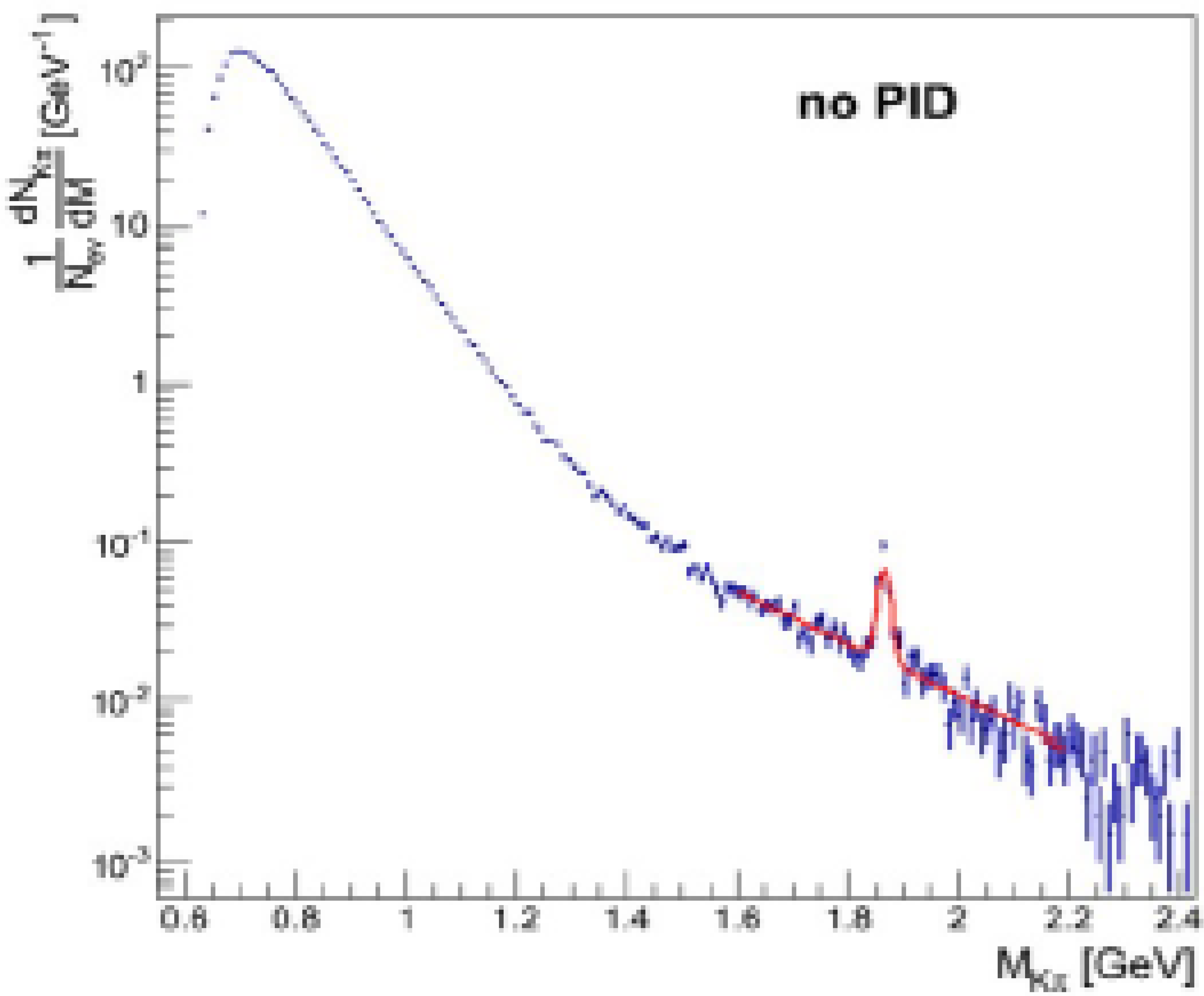
Two particle cuts:

3. Track pair vertex cut $\boldsymbol{V_z}$ (> 500μm)
4. Parent impact parameter cut **D** (< 22μm)

Slide from the report by Yasir Ali at SQM 2013

Reconstructed yield for $D^0 \rightarrow K^+ \pi^-$, 200k 0-10% cent. Pb+Pb at 158 AGeV



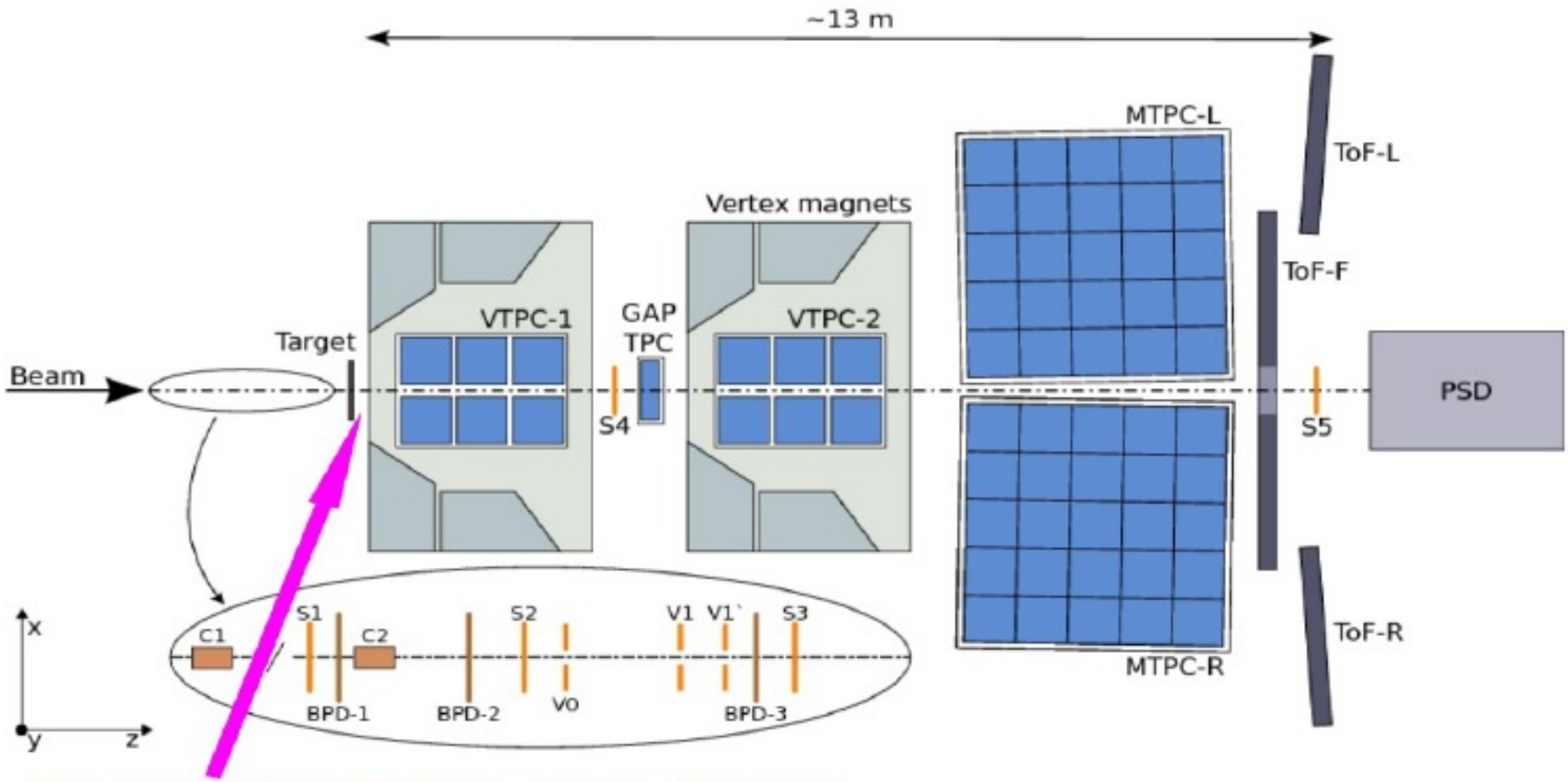


- → S/B = 66
- → SNR (@50M) = 276
- → 77800 detected D^0+D^0bar mesons in 50M central Pb+Pb

- → S/B = 2
- → SNR (@50M) = 249
- → 77800 detected D^0+D^0bar mesons in 50M central Pb+Pb

Slide from the report by Yasir Ali at SQM 2013

New Vertex Detector for NA61



Position of the future vertex detector

General requirements to new VD

- Fast detector to separate 2000 events/s ~100 μs
- Significant improvement of tracking charged particles in the target region ~ 5 μm and of secondary vertex resolution – 50 μm
- Good radiation tolerance
- Very low material budget ~few 0.1% Xo

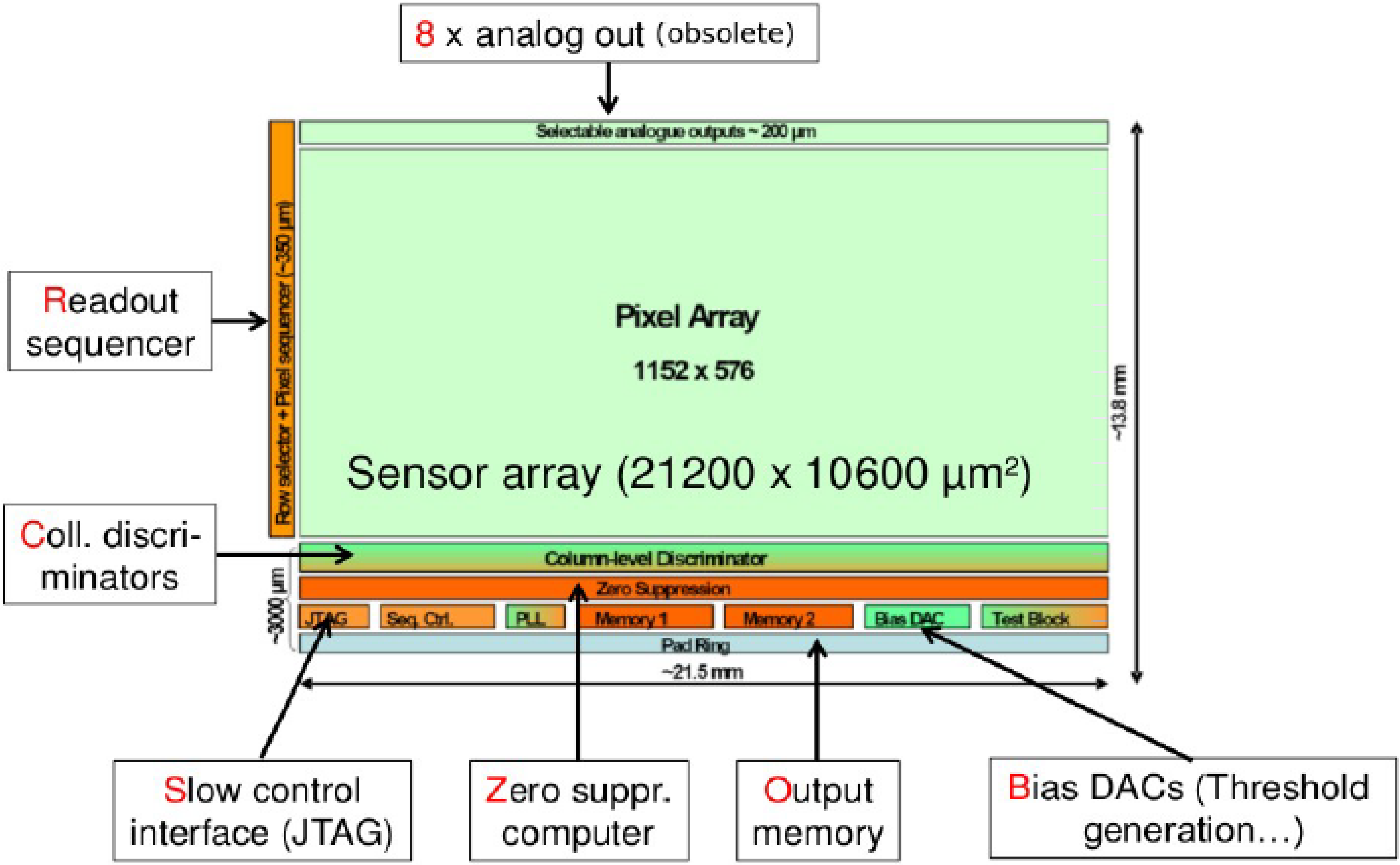
Requirements & sensors

	NA61	Hybrid	CCD	MIMOSA
Resolution	< 5 μm	30 μm	< 5 μm	< 3.5 μm
Mat. Budg.	Few 0.1 X_o	~1% X_o	~0.1% X_o	~0.05% X_o
Rad. Tol (1)	$3x10^{10}$ neq/cm^2	>10^{14} neq/cm^2	<10^9 neq/cm^2	>10^{13} neq/cm^2
Rad. Tol (2)	~1 krad	~10 Mrad	~1Mrad	~300 krad
Time resolution	~100 μs	~20 μs	~100 μs	~115.2 μs

Rad/tolerance: (1) – for non-ionising and (2) – ionising particles

From the report by Yasir Ali at SQM 2013

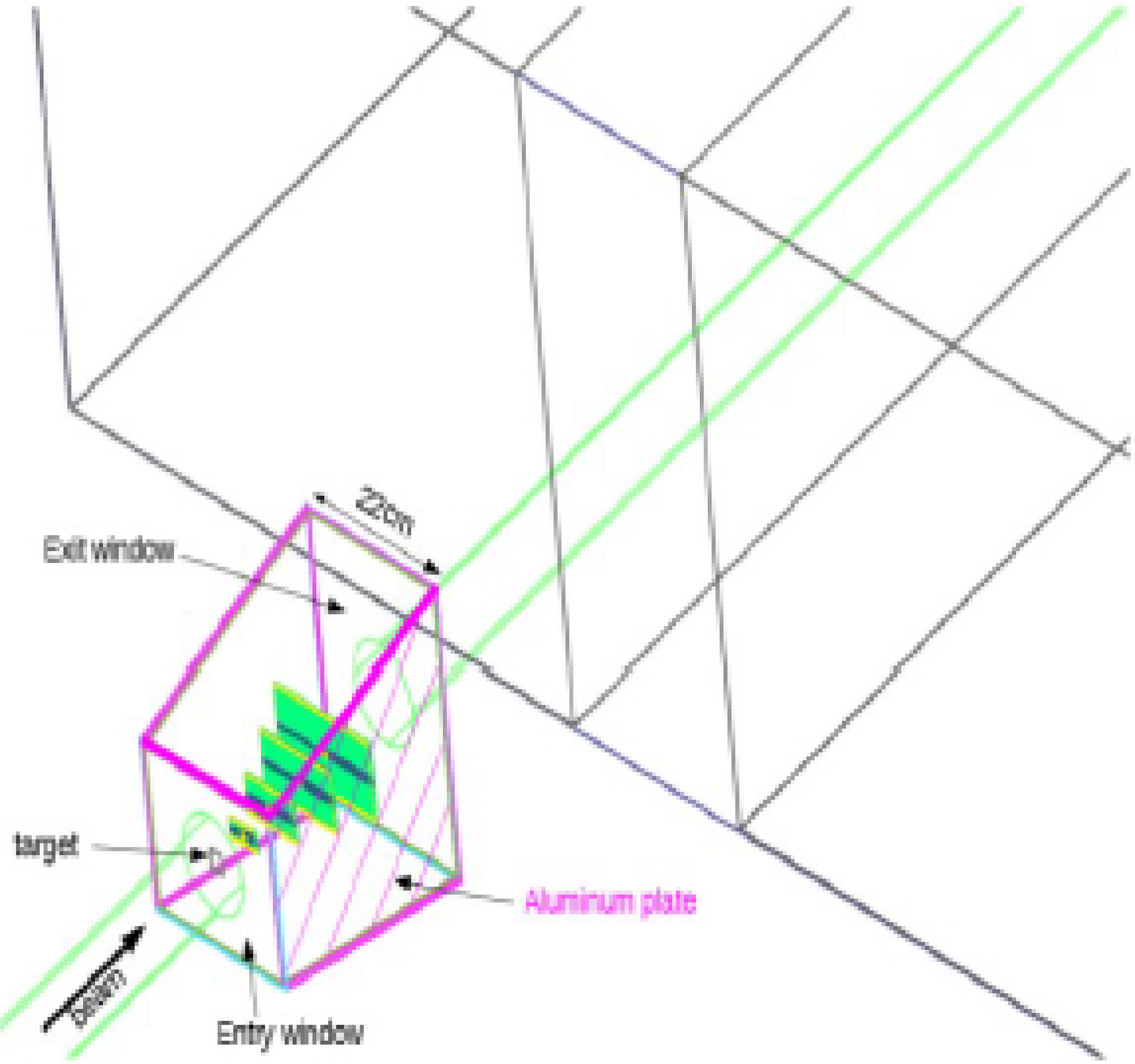
Block diagram of MIMOSA-26



Development Strategy

- Minimize the multiple scattering in the sensitive region to ~ 0.3% X (including MIMOSA-26 sensor and services)
- Use available technology [1] by ALICE at the LHC of support/cooling/precise positioning of sensors to ensure the optimal performance of high coordinate resolution of MIMOSA-26 chip

[1] The ALICE Collaboration, Technical Design Report for the Upgrade of the ALICE Inner Tracking System ALICE-TDR-017, CERN-LHCC-2013-024, 08.11.2013,(2013).



VDS1 : 5 cm
VDS2: 10 cm
VDS3: 15 cm
VDS4: 20 cm

VD in GEANT4

MIMOSA-26 sensors

→ Carbon fiber support

→ Water cooling tubes

Vessel:

→ Rectangular top/bottom plates

→ Trapezoidal left/right plates

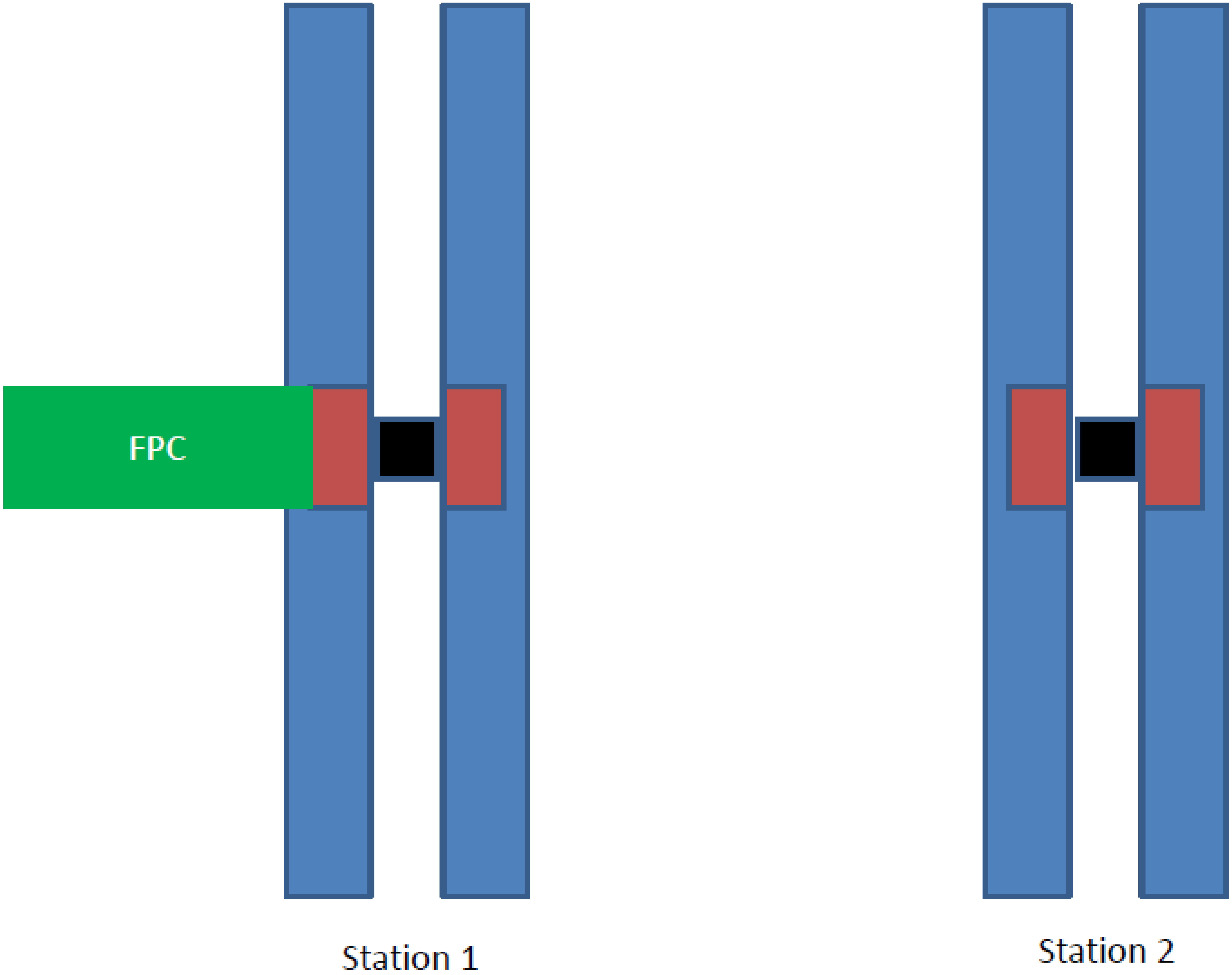
→ same length of carbon ladder

→ similar distance between top/bottom plates and VDS1-VDS4

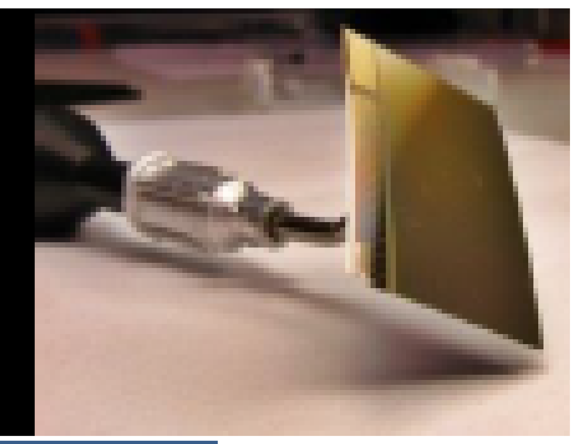
→ flat micro cables variation in length +/- 2cm

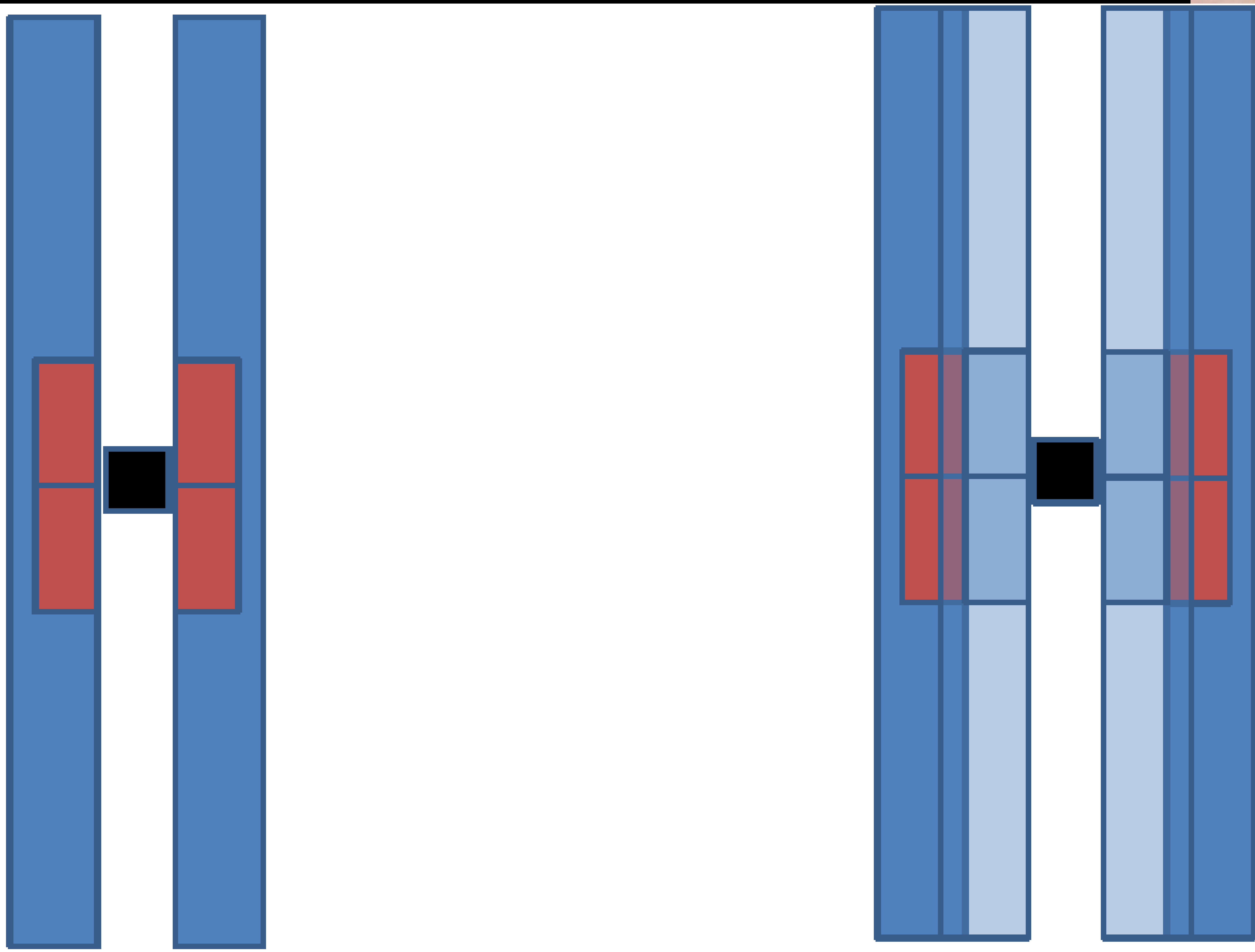
Slide from the report by Yasir Ali at SQM 2013

Proposed geometry of station 1 and 2



Proposed geometry of station 3 and 4





Station 3 Station 4

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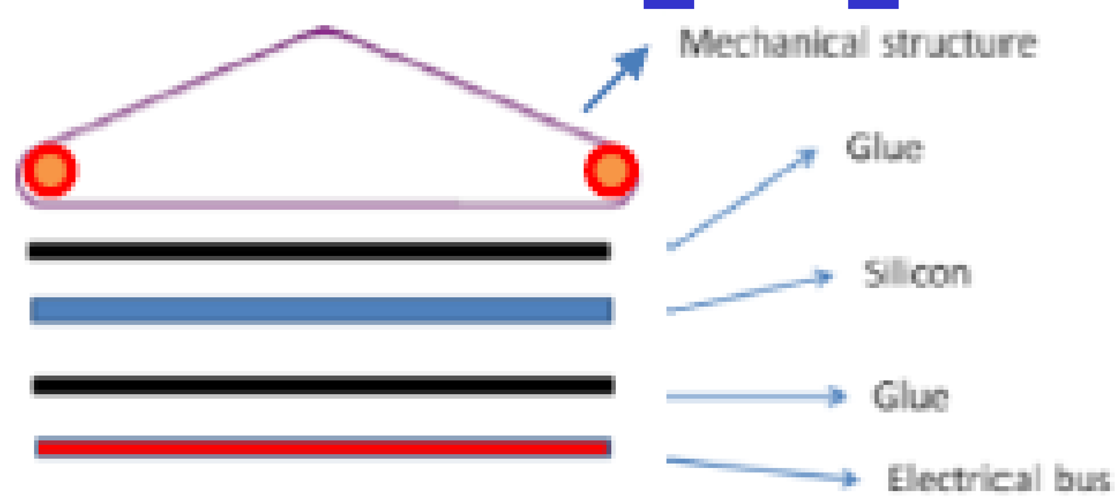
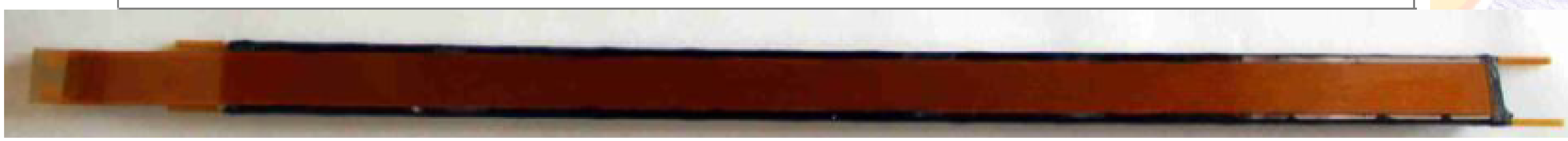
Ultra-light mechanical and cooling CF structure [1] to support MIMOSA-26



Ladder prototype equipped with

dummy components

Material	Surface (%)	Tickness (μm)	X_0 (%)	X/X_0 (%)	Contribution to the total X/X_0 (%)
CFRP filament	53	190	25	0.04	15.4
Polyimide Tubes	19	70	28.6	0.005	1.8
Water	19	1450	36.1	0.06	22.7
Glue (CFRP - silicon)	25	100	44.4	0.006	2.2
Silicon	100	50	9.36	0.054	20.5
Glue (silicon - bus)	100	100	44.4	0.022	8.6
Electrical bus	100	-	-	0.075	28.8
Total				≈ 0.26	



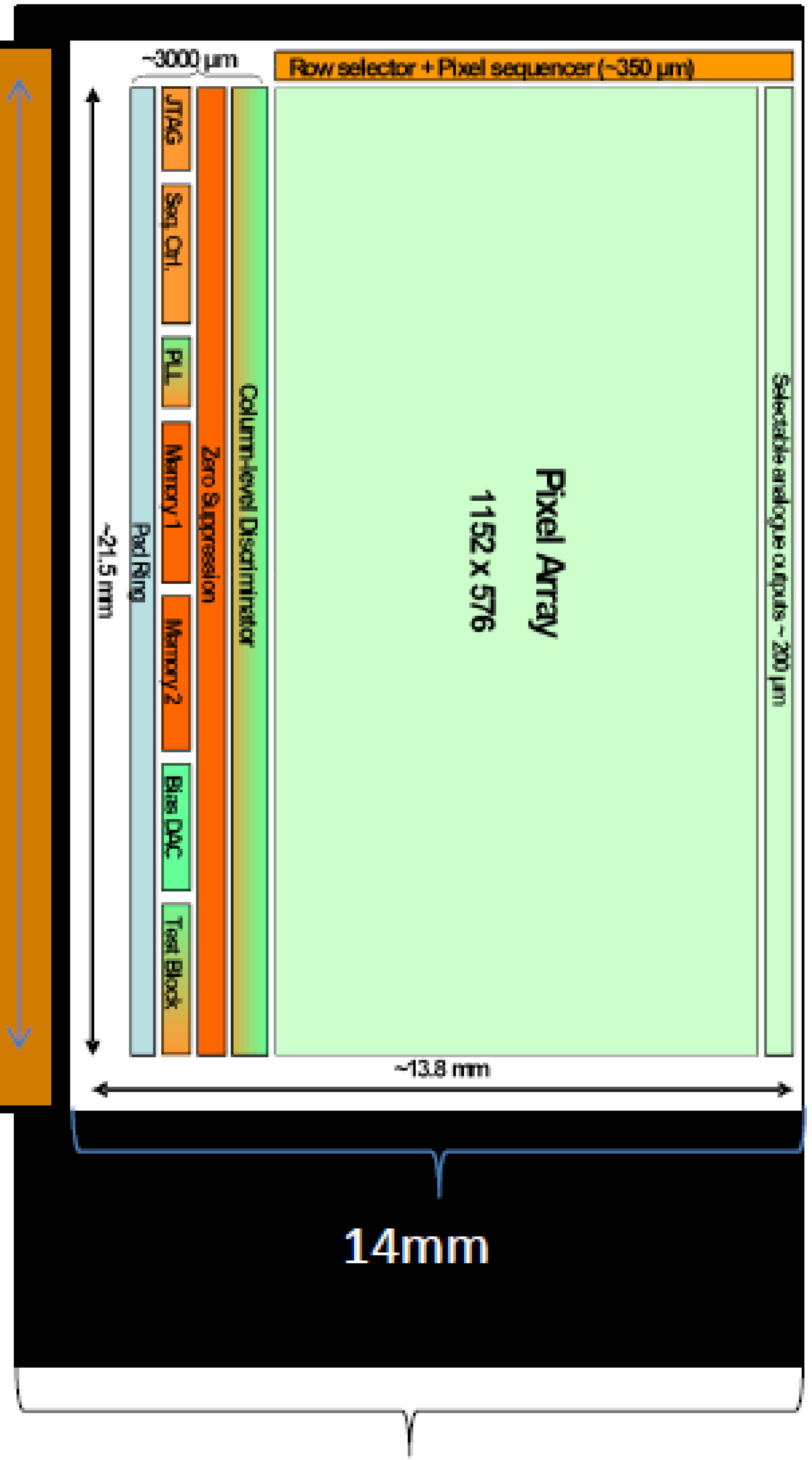
[1] The ALICE Collaboration, ALICE-TDR-017, CERN-LHCC-2013-024, 08.11.2013,(2013).

Tests in progress: FPC (Flexible Printed Circuit) cable + MIMOSA-26 chip

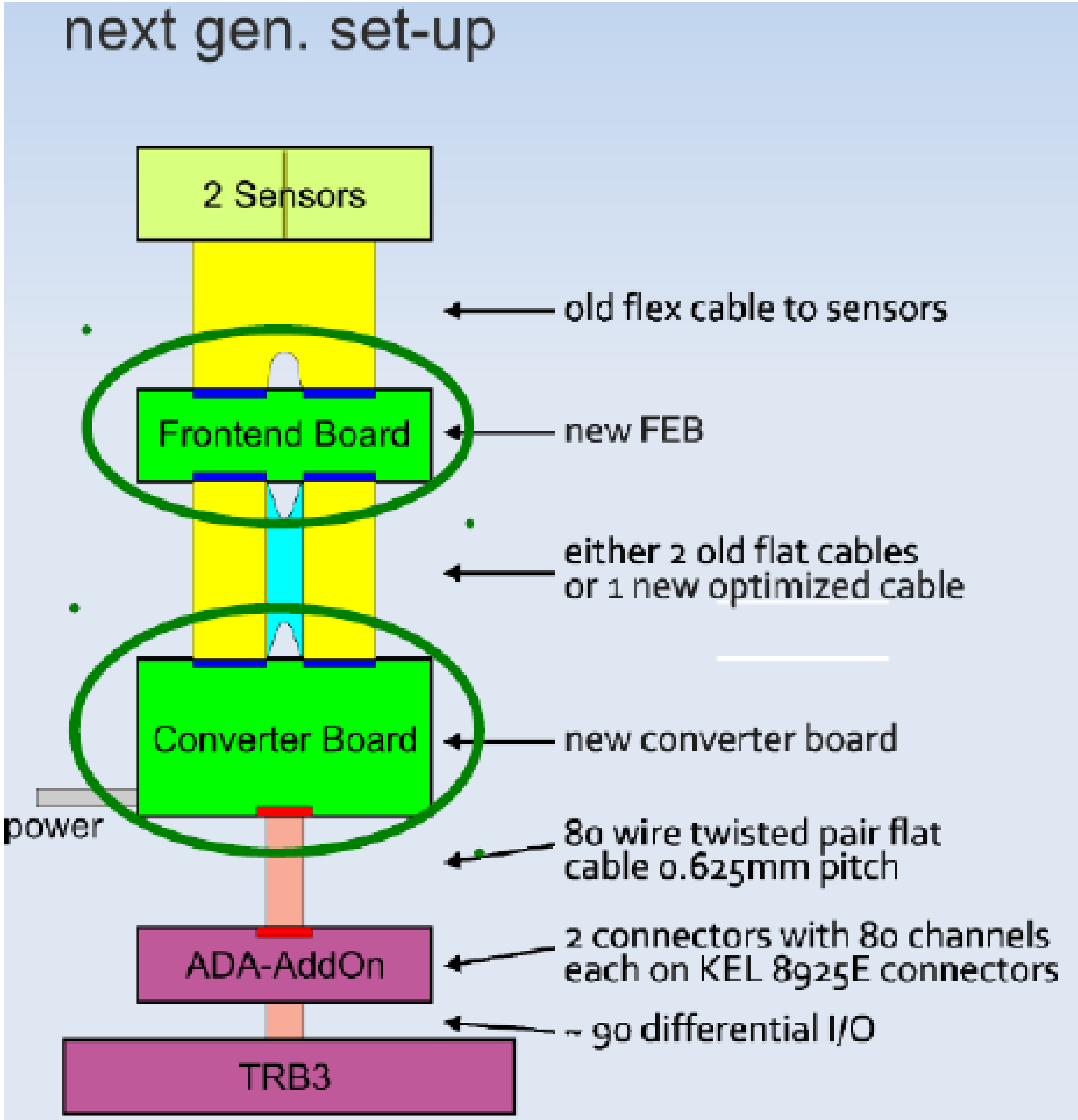
Ladder not wider than sensor
⇒ No landing space for cable
⇒ Cable integration not possible

Cable... width ( ) = 2 sensors in reality

Ladder flexible
⇒ Wire bonding works with ultra-sound
⇒ Sound might be absorbed
⇒ Feasibility of bonding needs to be demonstrated



Tests in progress: readout scheme

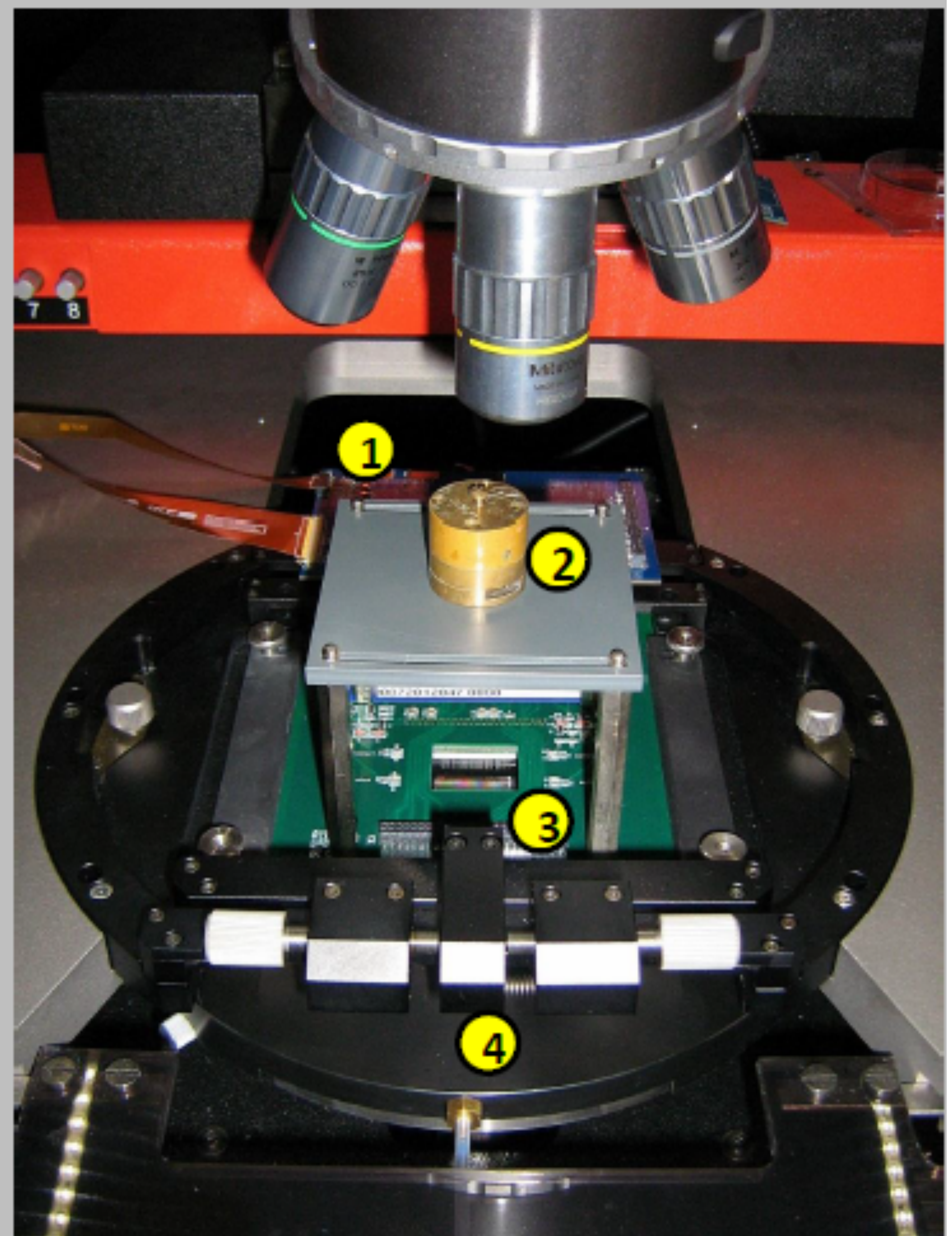


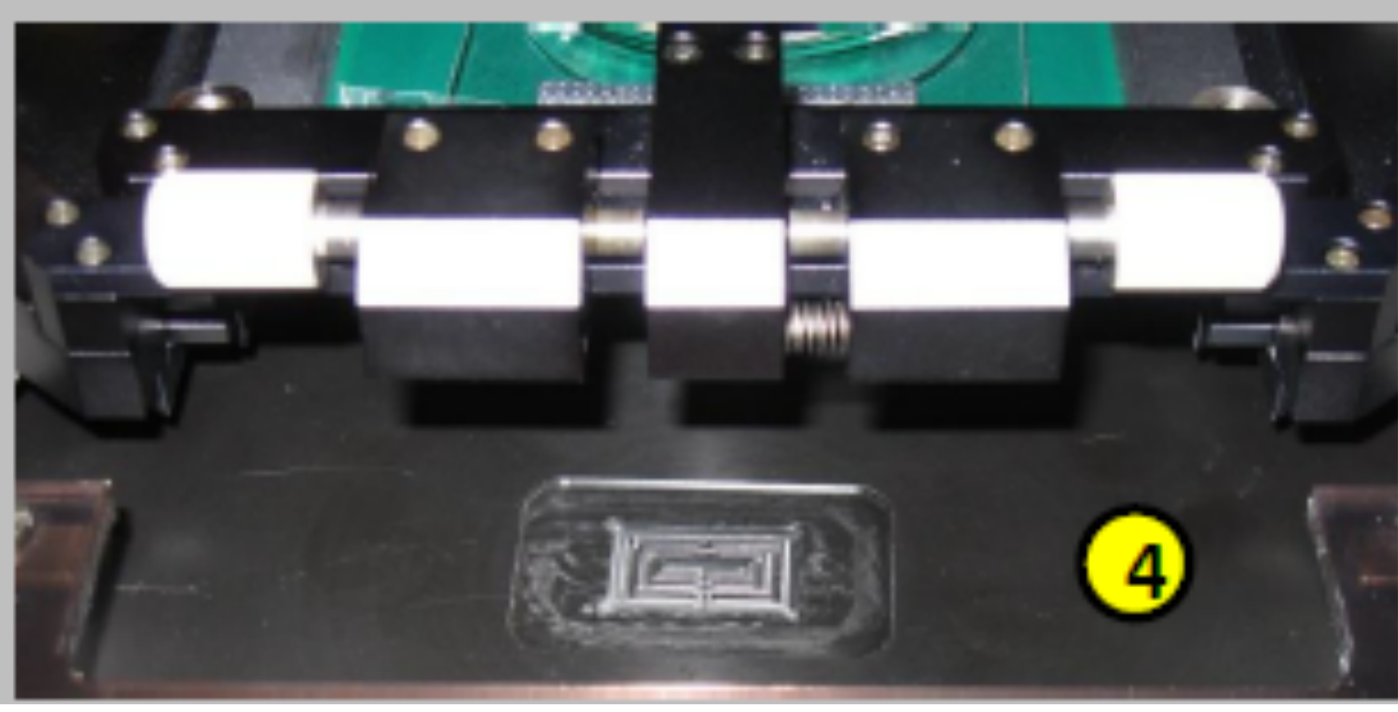
Sensor tests at IKF

Probe tests of 50 µm thin MIMOSA-26 sensors

- Located in a dedicate cleanroom (ISO-6) at IKF.
- Suss MicroTec PA-200 probe station is employed.
- Probe station is located inside a light and electromagnetic tight box.

1. Adapter board
2. Radioactive source
3. Probe card head, HTT-Dresden (65 tungsten needles, minimum pitch of 100 µm)
4. Chuck adapter with multi-channel underpressure holding





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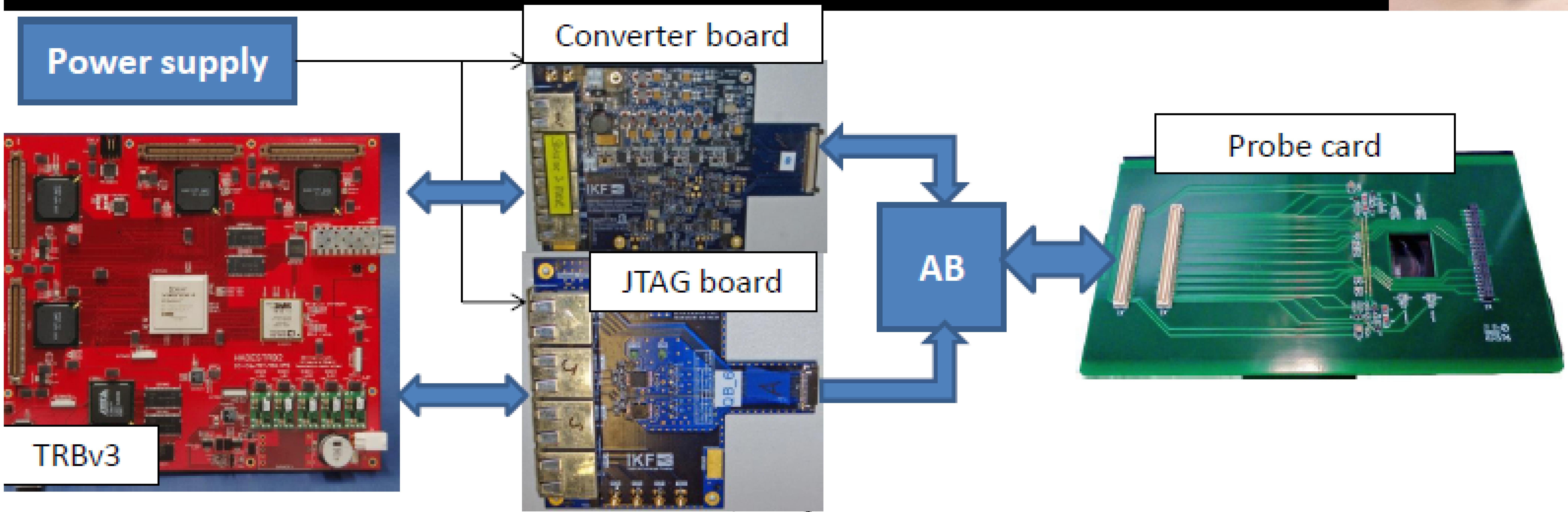
Slide from Michal Koziel talk at *24th CBM Collaboration Meeting, 8-12.09.2014, Krakow, Poland.*

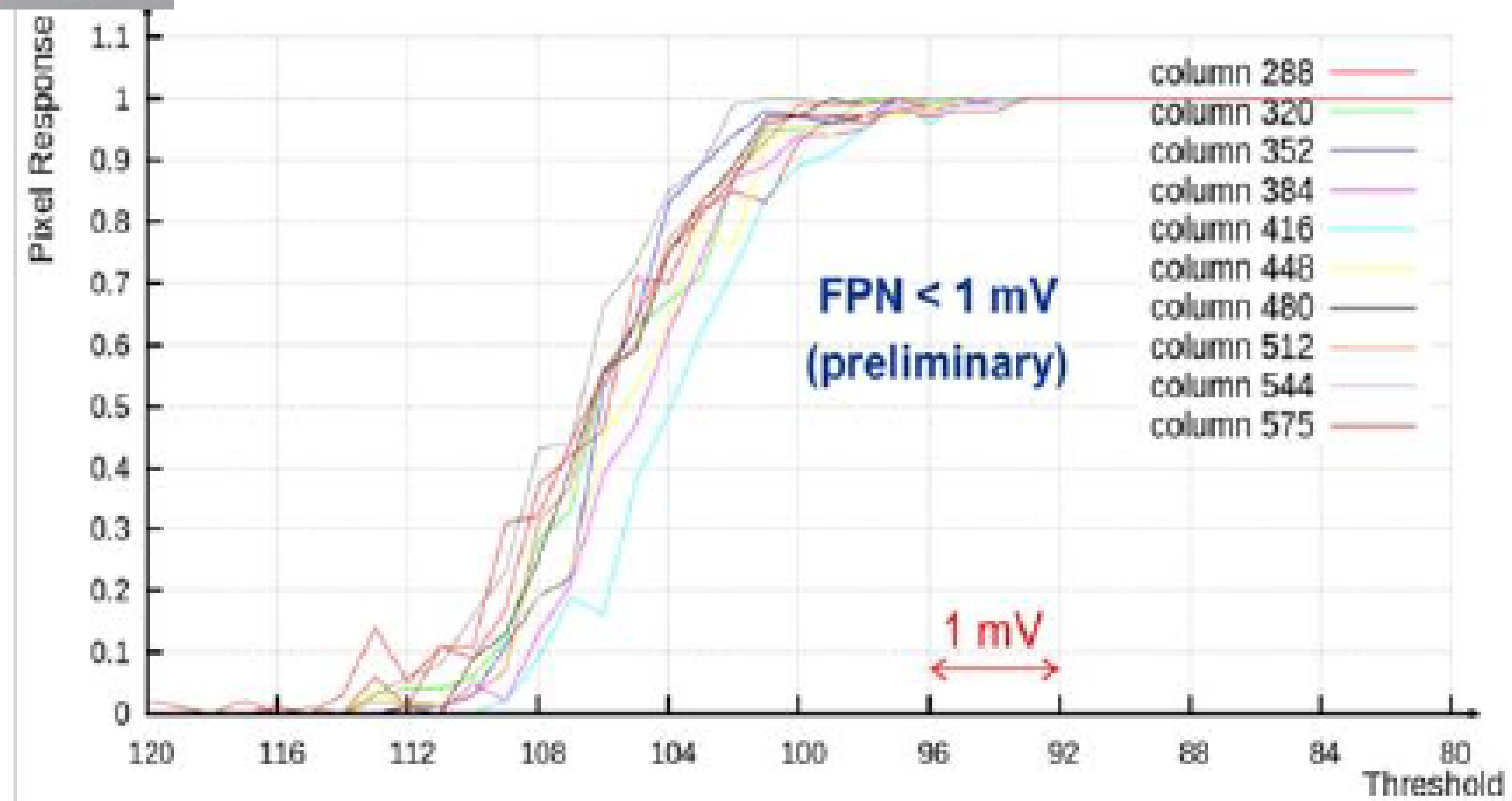
Sensor tests at IKF, cntd…

Probe tests of 50 µm thin MIMOSA-26 sensors



Tests planned:

- „Smoke test" ***DONE***
- Sensor behaviour and response to JTAG signal ***DONE***
- Check of programming registers ***DONE***
- Dead pixels (tests with pulsing light or radioactive source) ***DATA TAKEN/NOT ANALYSED***
- Hot pixels ***DATA TAKEN/NOT ANALYSED***
- S-curves (noise information) **IN PROGRESS**



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Probe tests of 50 µm thin CMOS sensors can be done with standard probe cards !

Slide from Michal Koziel talk at 24th CBM Collaboration Meeting, 8-12.09.2014, Krakow, Poland.

Summary

- Challenges in open charm measurements in nuclear collisions in NA61 experiment at SPS energies could be met by new high precision, radiation hard Vertex Detector
- General design of VD is well understood
- The first batch of 50μm thin MIMOSA-26 chips was successfully tested at IKF Frankfurt
- Work is in progress

Thank you!

ETH, Zurich, Switzerland
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Institute for Particle and Nuclear Studies, KEK, Tsukuba, Japan
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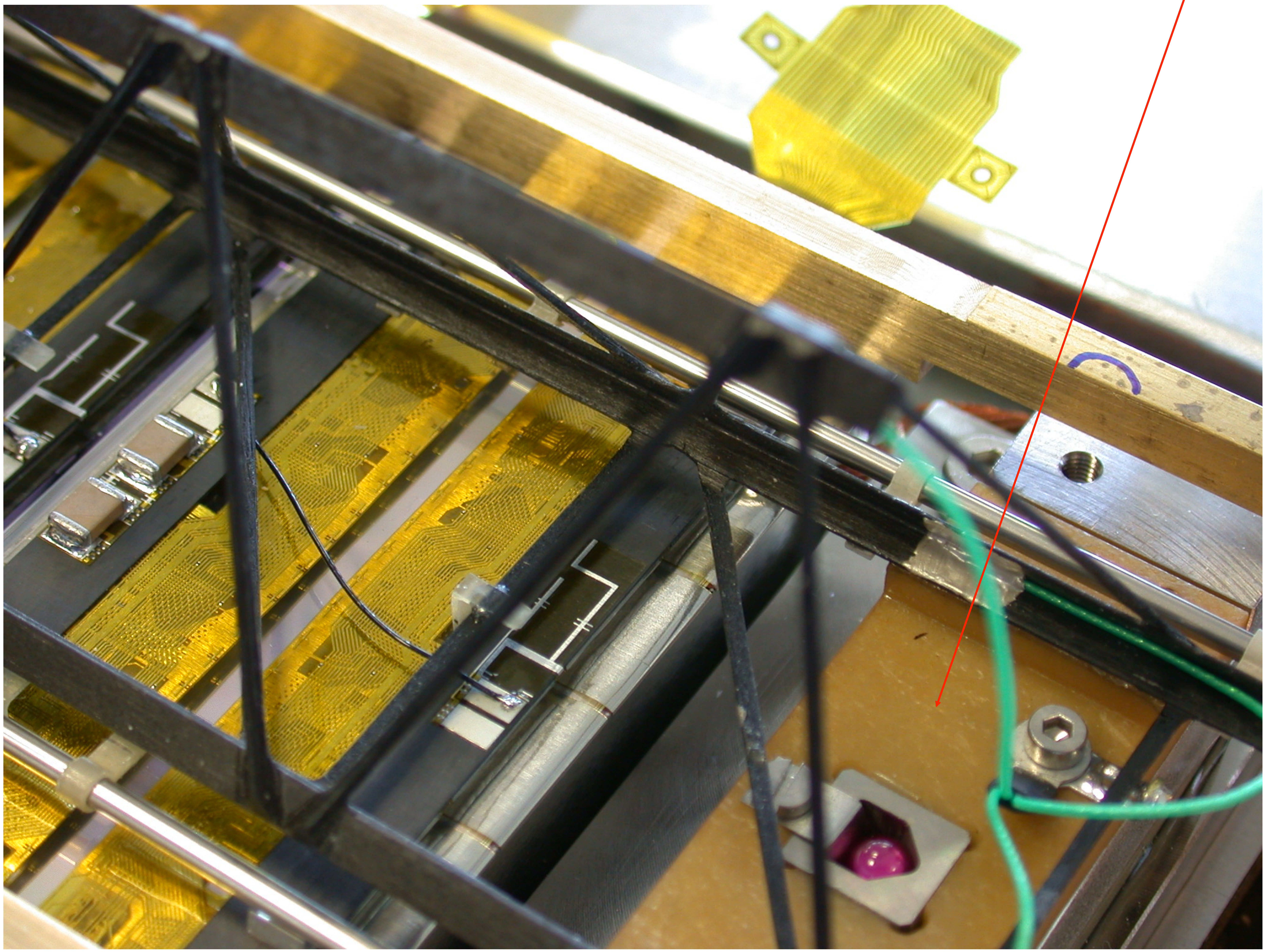
Back-up

CURRENT ALICE/ITS END-LADDER FIXATION:



Abstract

Measurements with the NA61/SHINE experiment [1] at the CERN SPS of hadrons containing charm quarks could be important in investigations of the initial stage of nucleus-nucleus collision at relativistic energies. The 1st feasibility studies [2], [3],[4] of direct open charm measurements in central Pb-Pb collisions at SPS energies has proved the possibility of such an experiment and established the requirements for the design of the new Vertex Detector (VD) for the NA61 installation. This new, high precision VD should be capable of providing an accuracy of particle tracking to the vertex on the level of a few microns. The VD is also required to have extremely low material budget (of the order of 0.3 % Xo), a high radiation tolerance and rather high speed. These requirements are to be met using coordinate sensitive Si-sensor chips in CMOS technology. In this report we present the general design of a new VD for NA61/SHINE. Some practical solutions to meet the requirements for this VD are proposed and demonstrated based on the experience obtained and proven earlier [5].

References

[1] N.Abragall et al. (NA61 Collaboration), JINST **9** P06005(2014).

[2] Yasir Ali and Pawel Staszel for the NA61/SHINE collaboration, in Proceedings of 14th International Conference on Strangeness in Quark Matter (SQM2013), Journal of Physics: Conference Series **509** 012083(2014).

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[5] The ALICE Collaboration, Technical Design Report for the Upgrade of the ALICE Inner Tracking System ALICE-TDR-017, CERN-LHCC-2013-024, 08.11.2013,(2013).