Future Vertex Detector For Open Charm Measurements with NA61/SHINE Experiment at CERN-SPS

Yasir Ali

Supervisor: Dr hab. Pawel Staszel

II Symposium on applied nuclear physics and innovative technologies

September 24th - 27th, 2014, Jagiellonian University, Kraków Poland

INTERNATIONAL PHD PROJECTS IN APPLIED NUCLEAR PHYSICS AND INNOVATIVE TECHNOLOGIES

This project is supported by the Foundation for Polish Science – MPD program, co-financed by the European Union within the European Regional Development Fund

Contents

- →Introduction of project
- → Physics motivation
- → NA61/SHINE detector overview
- → Feasibility study (results)
- → Realistic simulation
- → Vertex detector studies and Read out tests
- → Summary

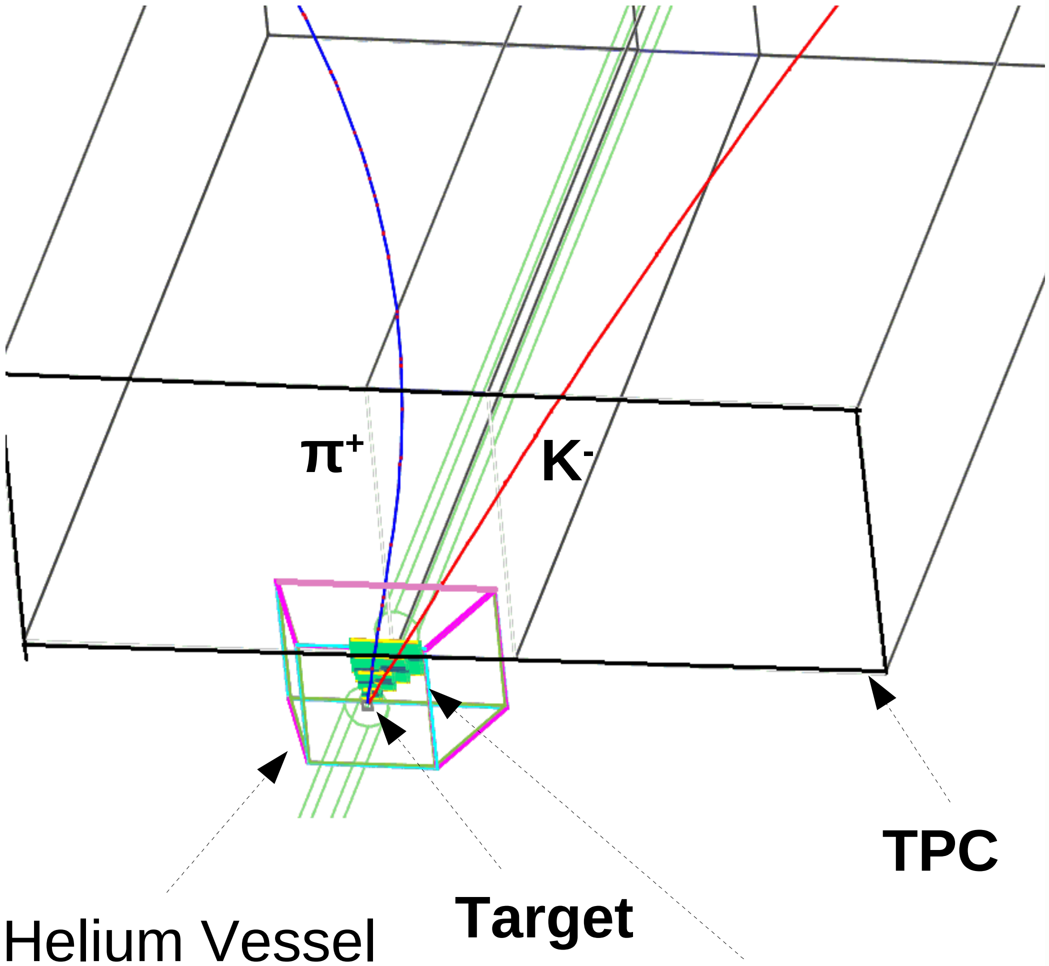
Introduction of Project:

- → A feasibility study of (open charm) measurements with two body decay ($D^0 \rightarrow K^- \pi^+$ BR=3.91%) channel in central Pb+Pb collisions and Ar+Ar collisions at the CERN SPS energies will be presented.
- → The study is done for 158 AGeV and 40 AGeV.
- → The NA61/SHINE requires upgrade with a new vertex detector (based on MIMOSA-26 silicon based sensors) that will allow precise track and vertex reconstruction at the target proximity.
- → Results are based on the predicted yields of open charms
- → Realistic simulation is developed (Digitization, Track Extrapolation). Efficiency and fakes calculation of track reconstruction is also on going.
- → Read out tests of MIMOSA-26 sensors are on going.

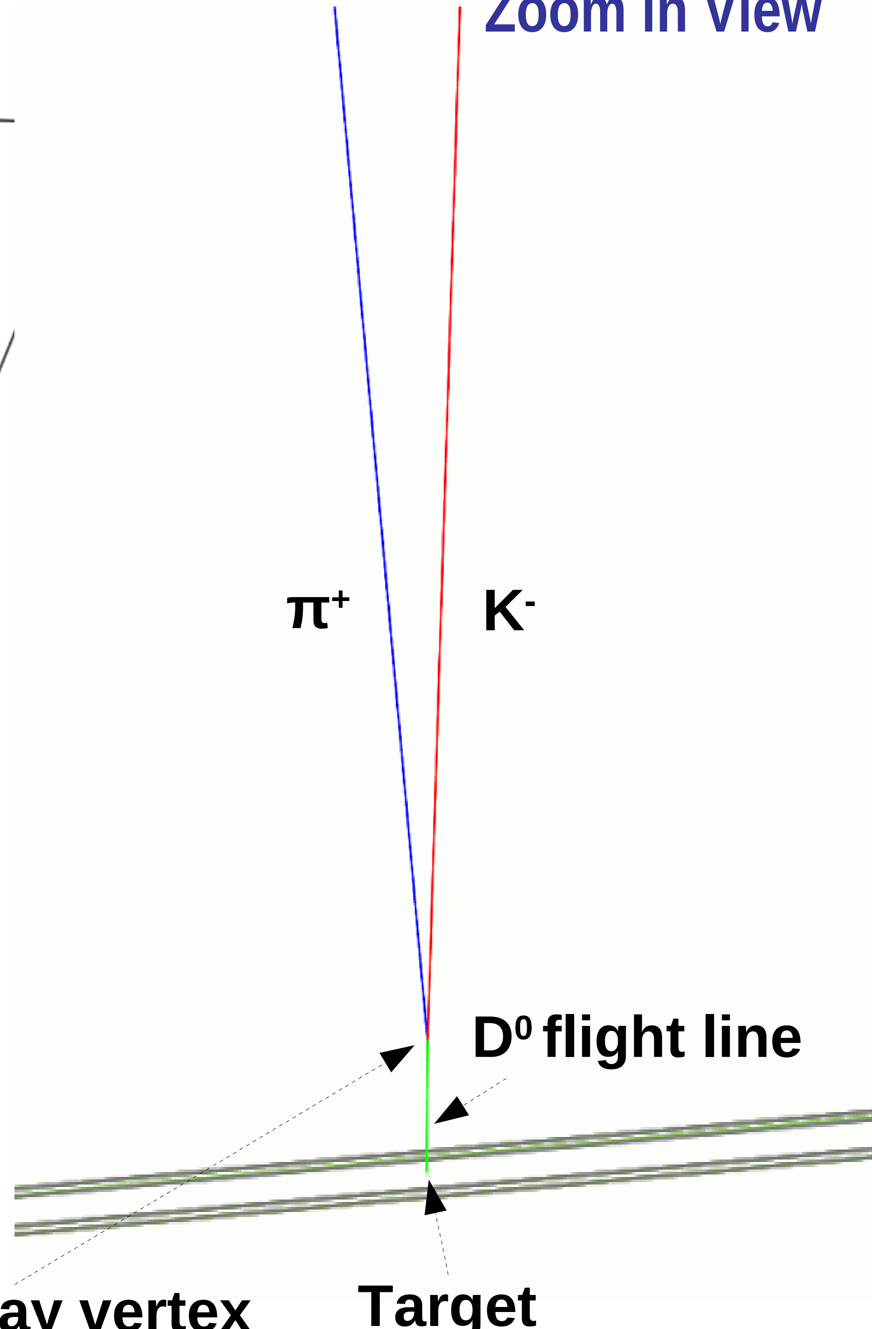
Open Charm decay channels

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)%

D^0 Decay



Zoom in View



Physics motivation

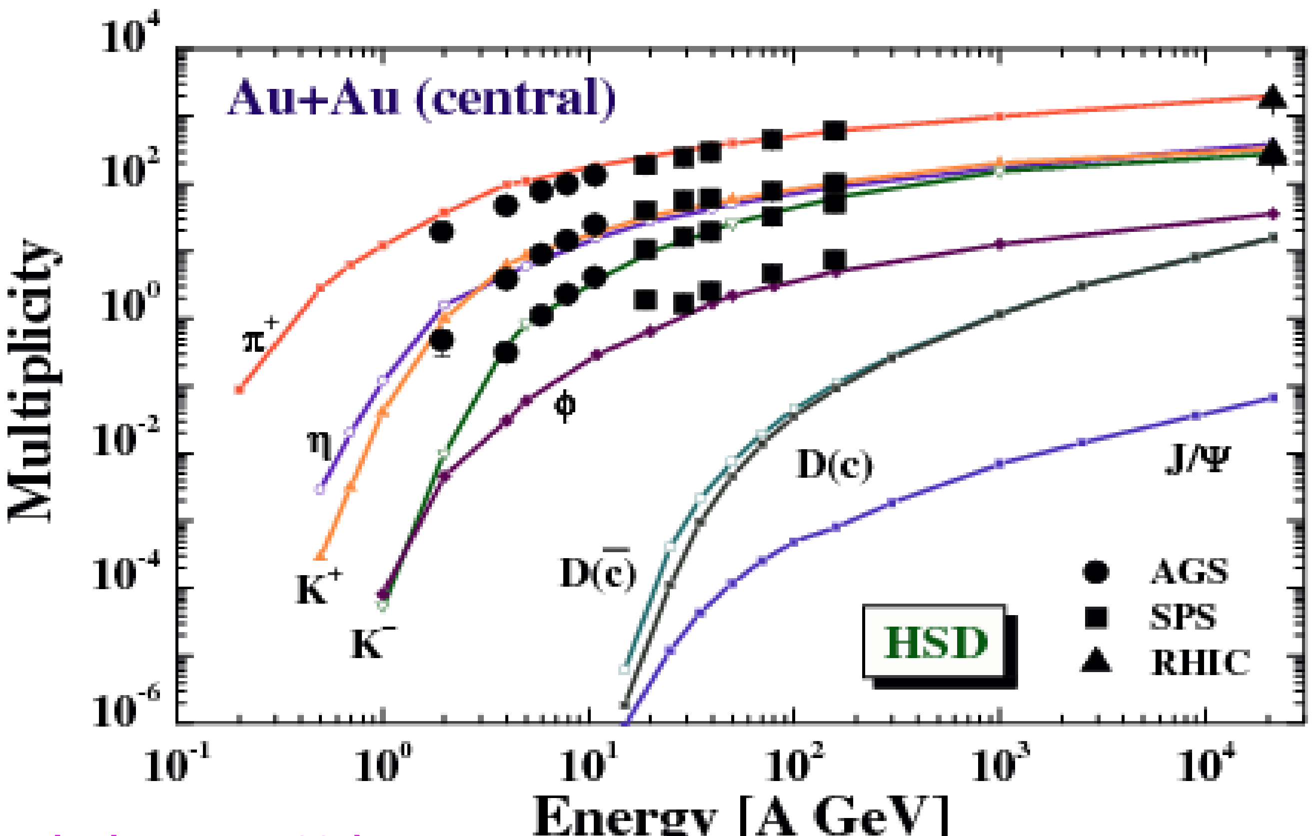
→ So far no direct open charm measurements at SPS energies

→ Experimental initiatives which measure charmonia states at SPS energies (Town Meeting "Relativistic Heavy-Ion Collisions" Fleuret and Usai)

→ Simultaneous measurements of charmonia and open charm

1. are needed to construct charm observables that are model independent.
2. will allow to disentangle between initial and final state effects

(Satz. Rep. Prog. Phys. 63 1511 2000)



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

Physics motivation cnt.

→ Measurement of J/ψ at top SPS energy (NA50,NA60) was performed

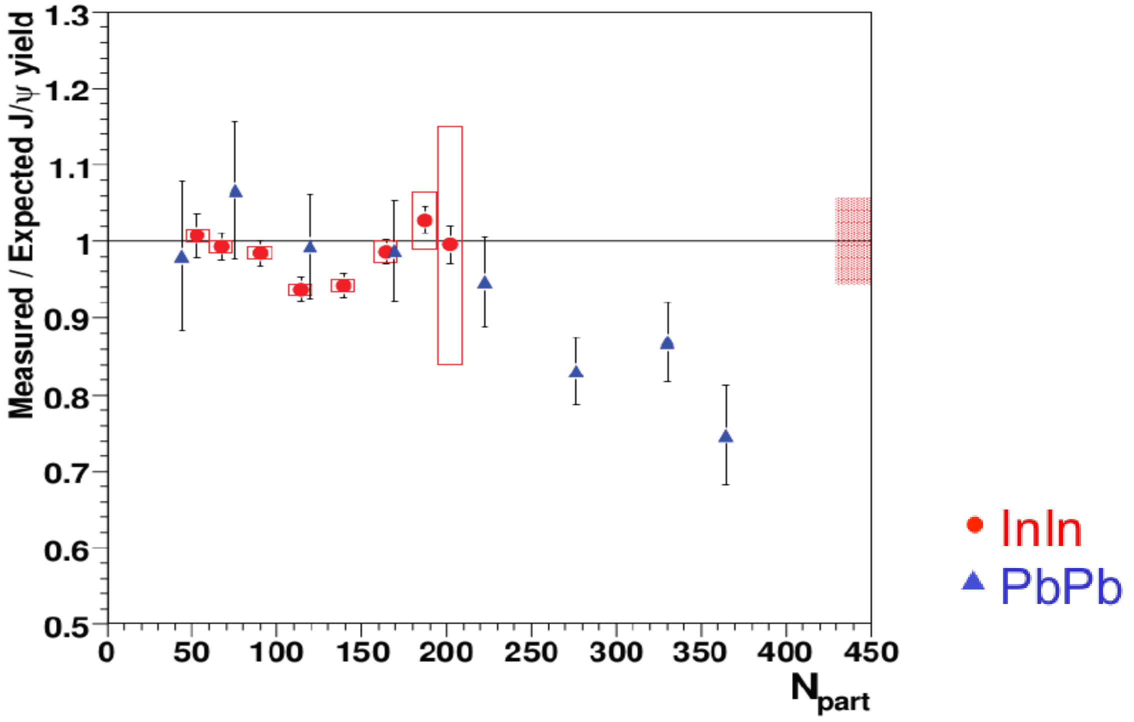
→ Anomalous suppression of J/ψ for central A+A collisions (N_{part}>200).

→ Attributed to QGP formation but other scenarios can not be ruled out.

→ Measurement of charm production in open charm channel is requested

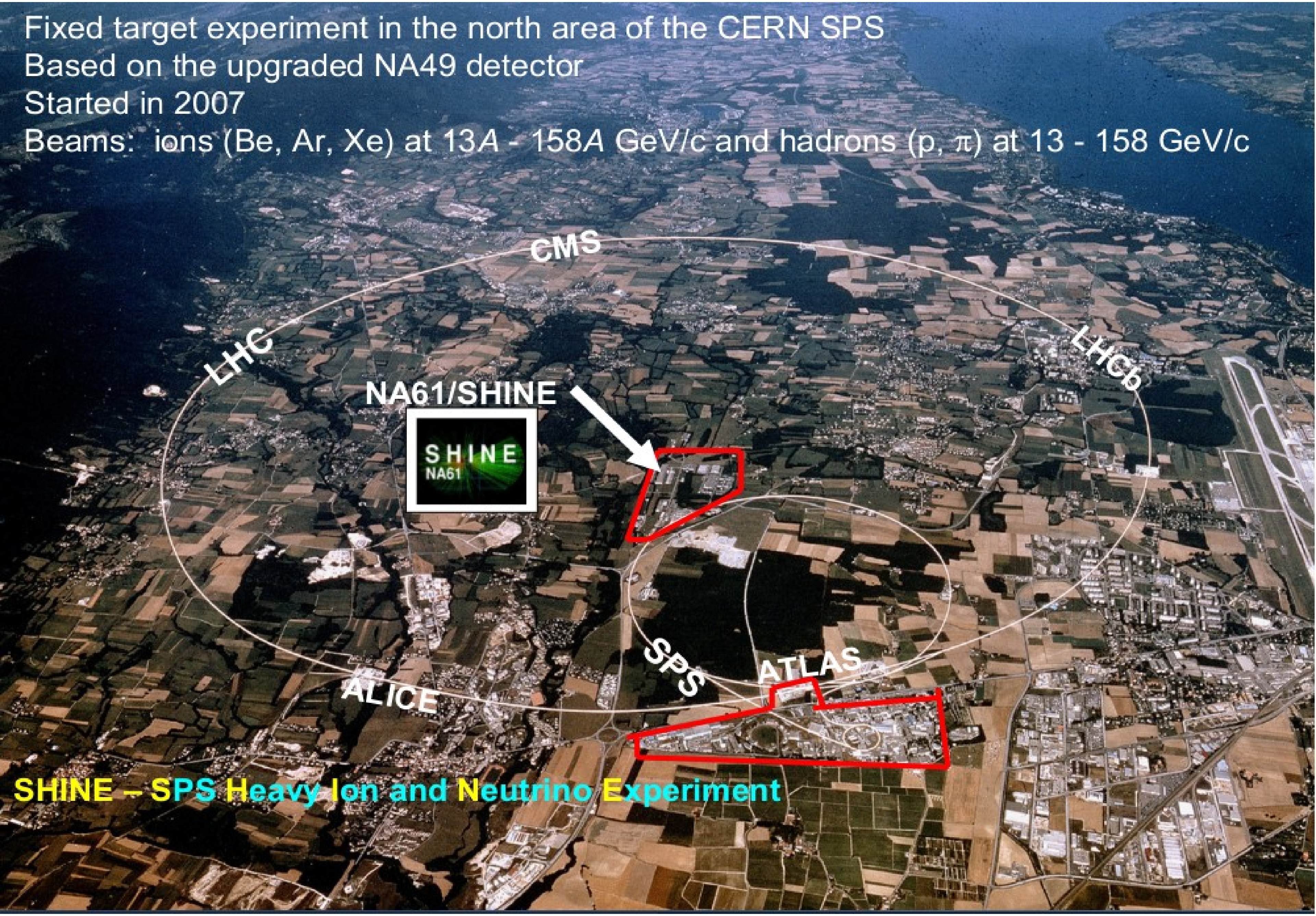
(Phys. Lett. B 178 416 1986)

→ If anomalous behavior of charm production is present in the open charm channel we will be able to characterize this effect versus centrality and energy.

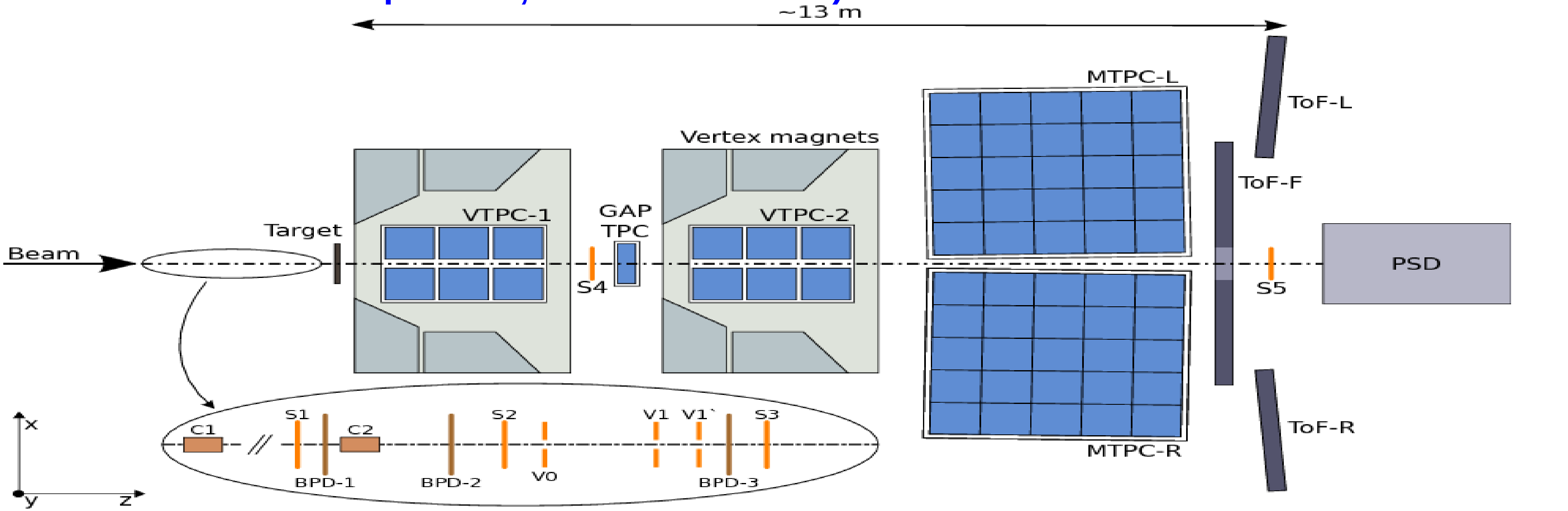


(arXiv 0907. 3682 v2 [nucl-ex] 2009)

Fixed target experiment in the north area of the CERN SPS
Based on the upgraded NA49 detector
Started in 2007
Beams: ions (Be, Ar, Xe) at 13A - 158A GeV/c and hadrons (p, π) at 13 - 158 GeV/c



NA61/SHINE detector – Schematic layout (horizontal cut in the beam plane, not to scale)



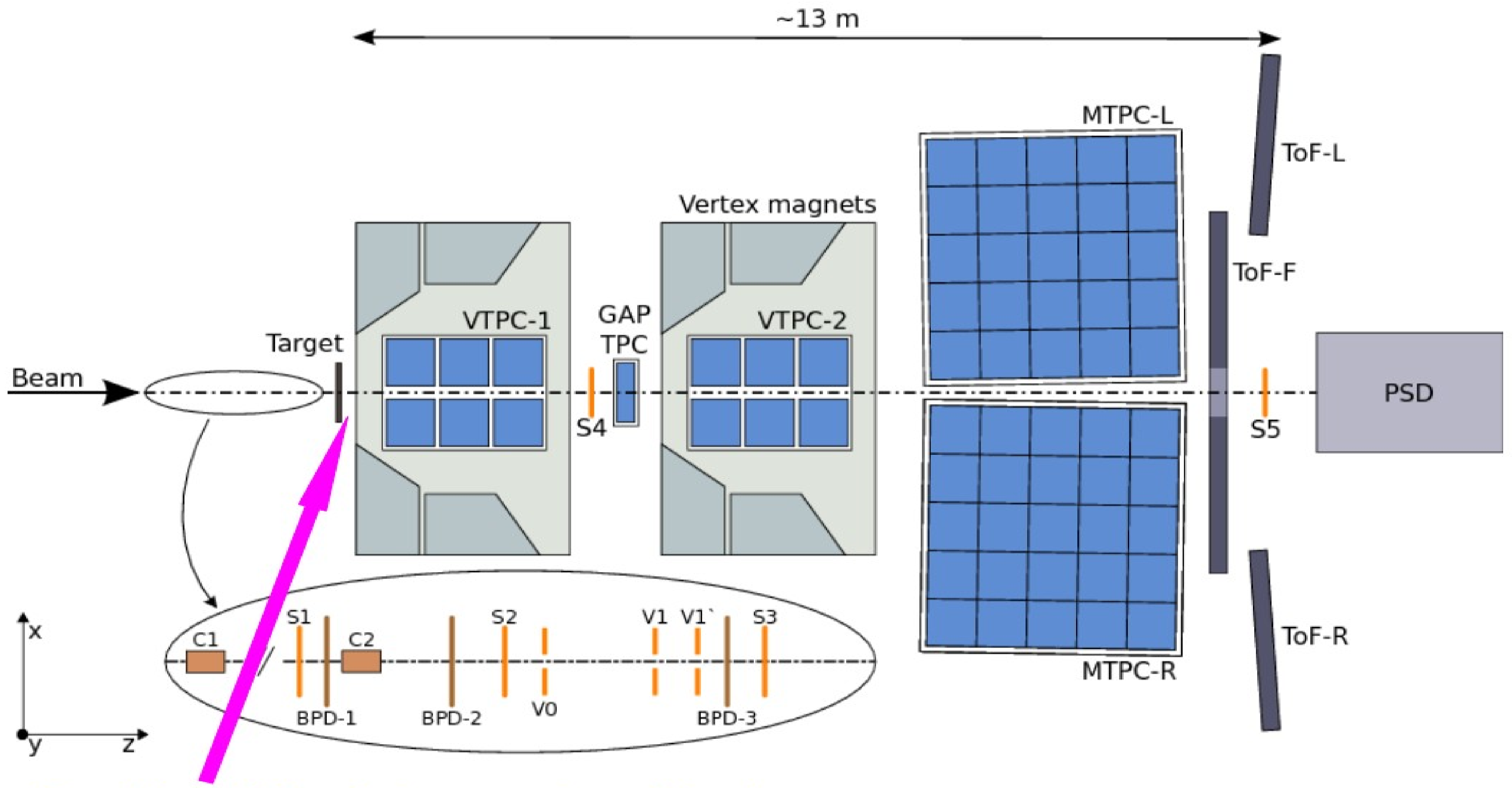
Beam detectors and triggering → A set of upstream scintillator and Cherenkov counters and beam position detectors provides timing reference, charge and position measurements

Time of Flight Walls → mainly used for Hadron identification

Time Projection Chambers → four large volume TPC's serve as tracking detectors

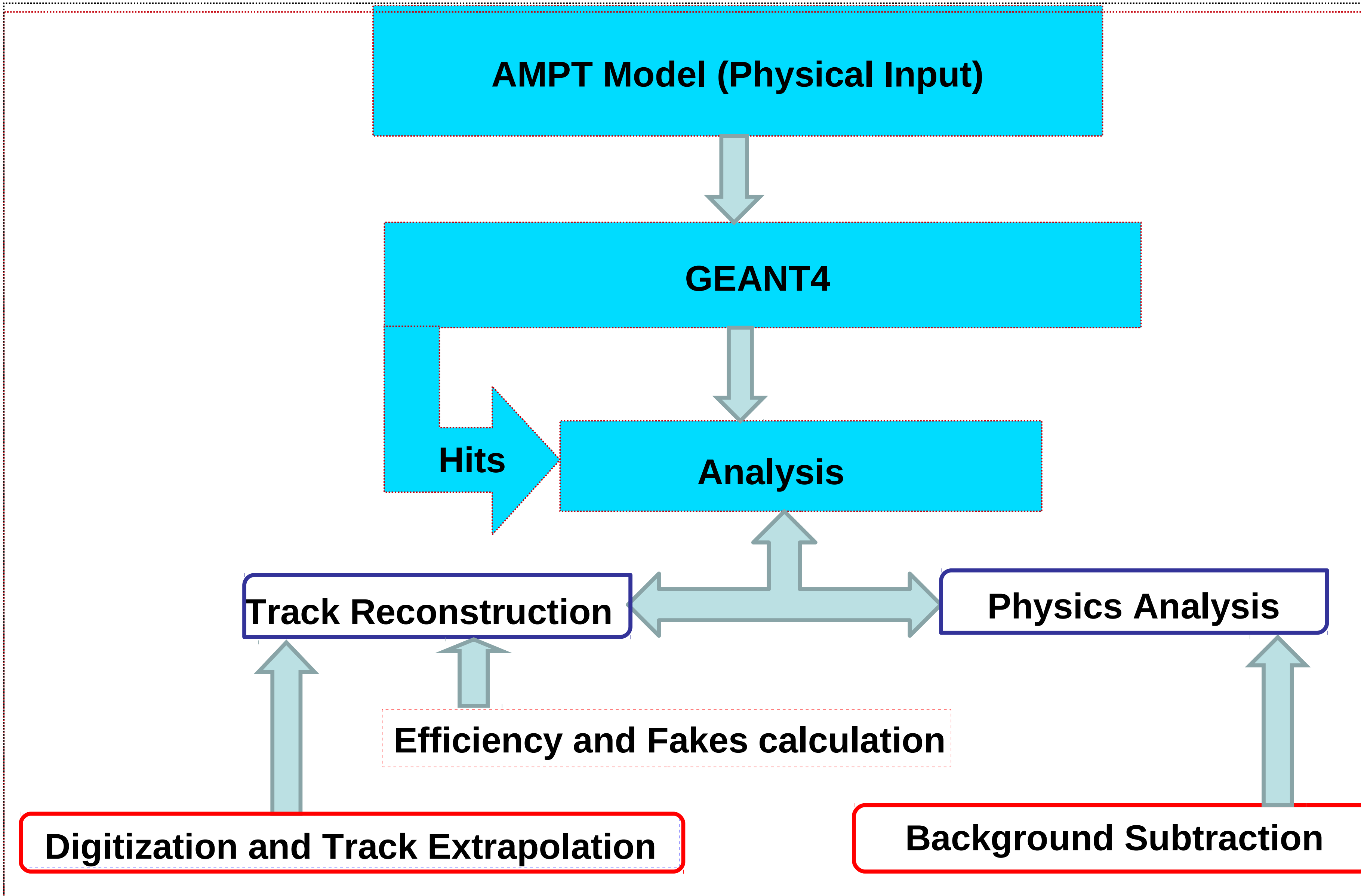
Projectile Spectator Detector(PSD) → A Calorimeter which is positioned downstream of the time of flight detectors measure energy of projectile fragments.

NA61/SHINE detector – Schematic layout (horizontal cut in the beam plane, not to scale)



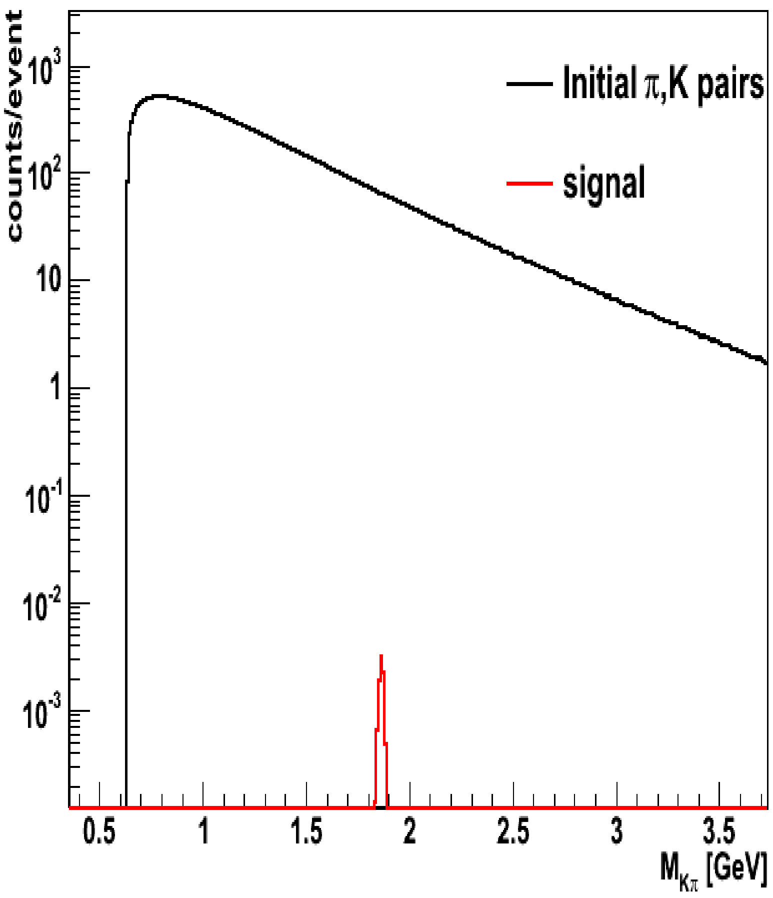
Position of the future vertex detector

Overview of *Simulation Framework*



Background Suppression strategy

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



Single particle cuts:

1. Cut on ($p_T > 0.4$ GeV/c)
2. Cut (track impact parameter (d > 40 μm)

Two particle cuts:

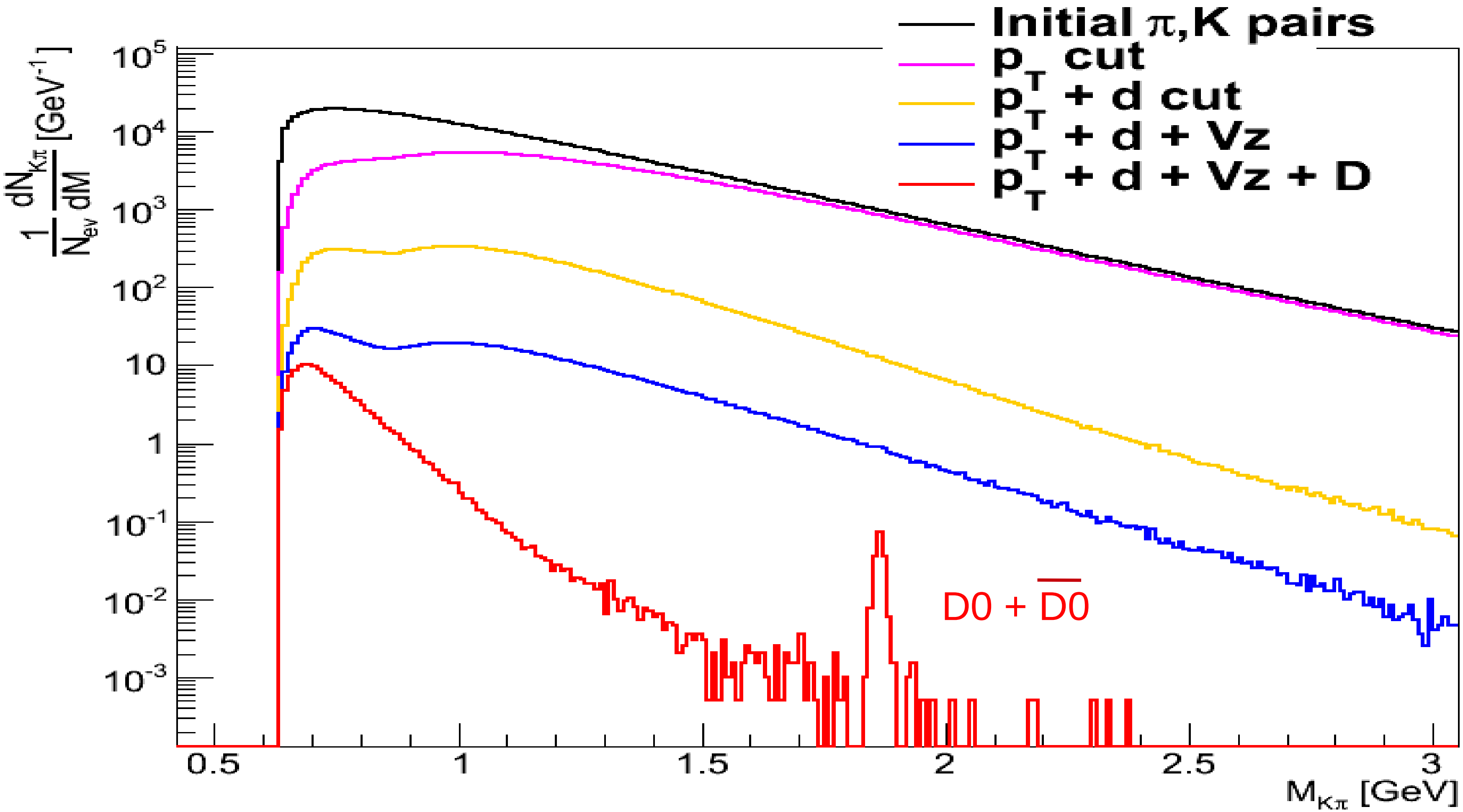
3. Track pair vertex cut ($V_z > 500$ μm)
4. Parent impact parameter cut (D < 22 μm)

.

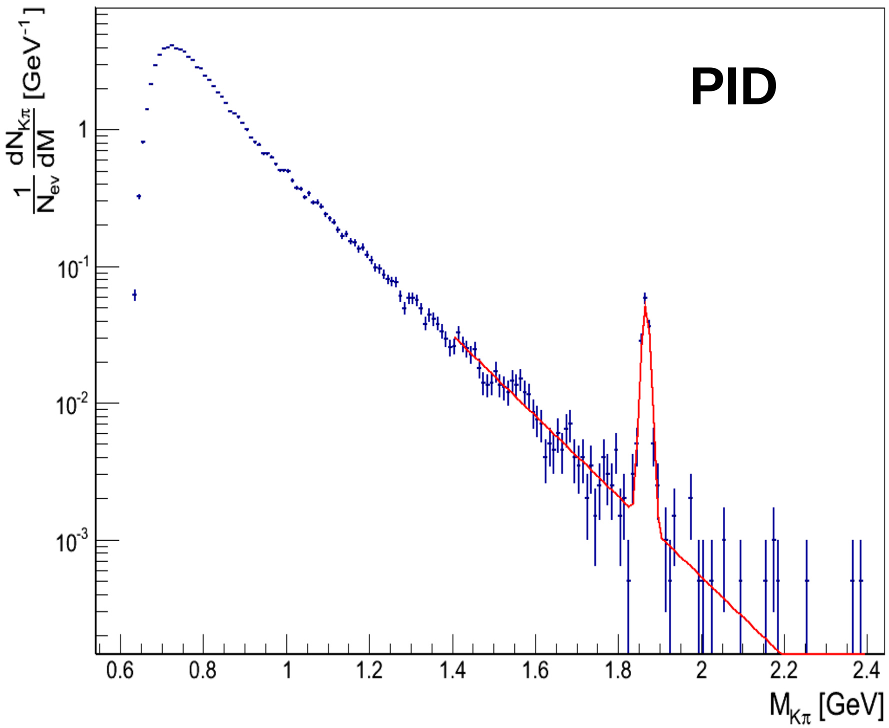
Summary of Cuts

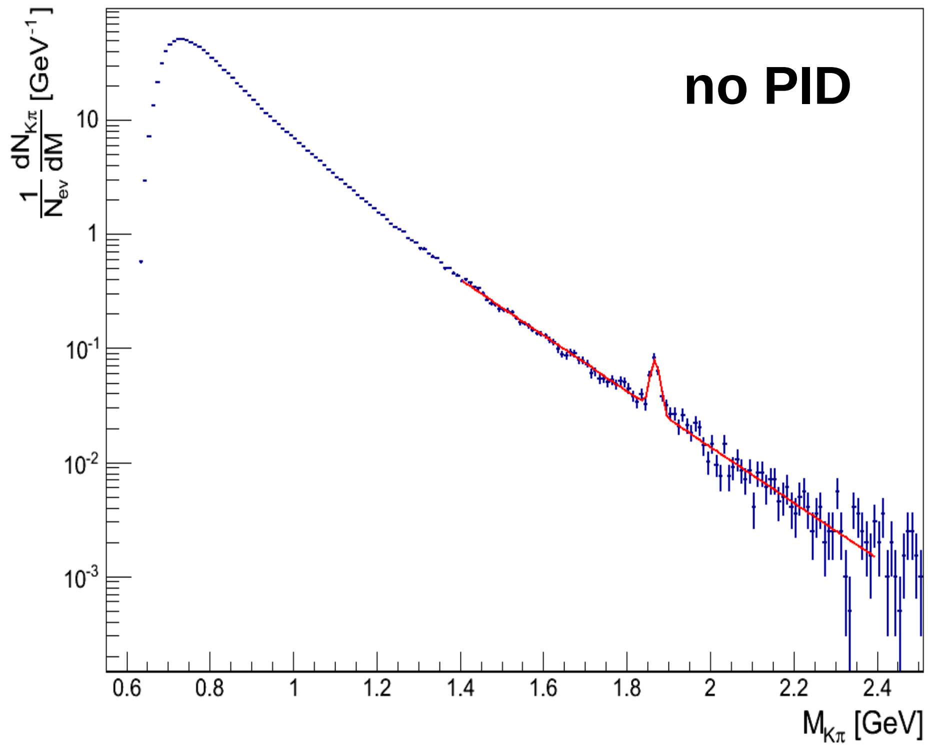
Reduction of Background ≈ 10^6

Reduction of Signal ≈ 1.8



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

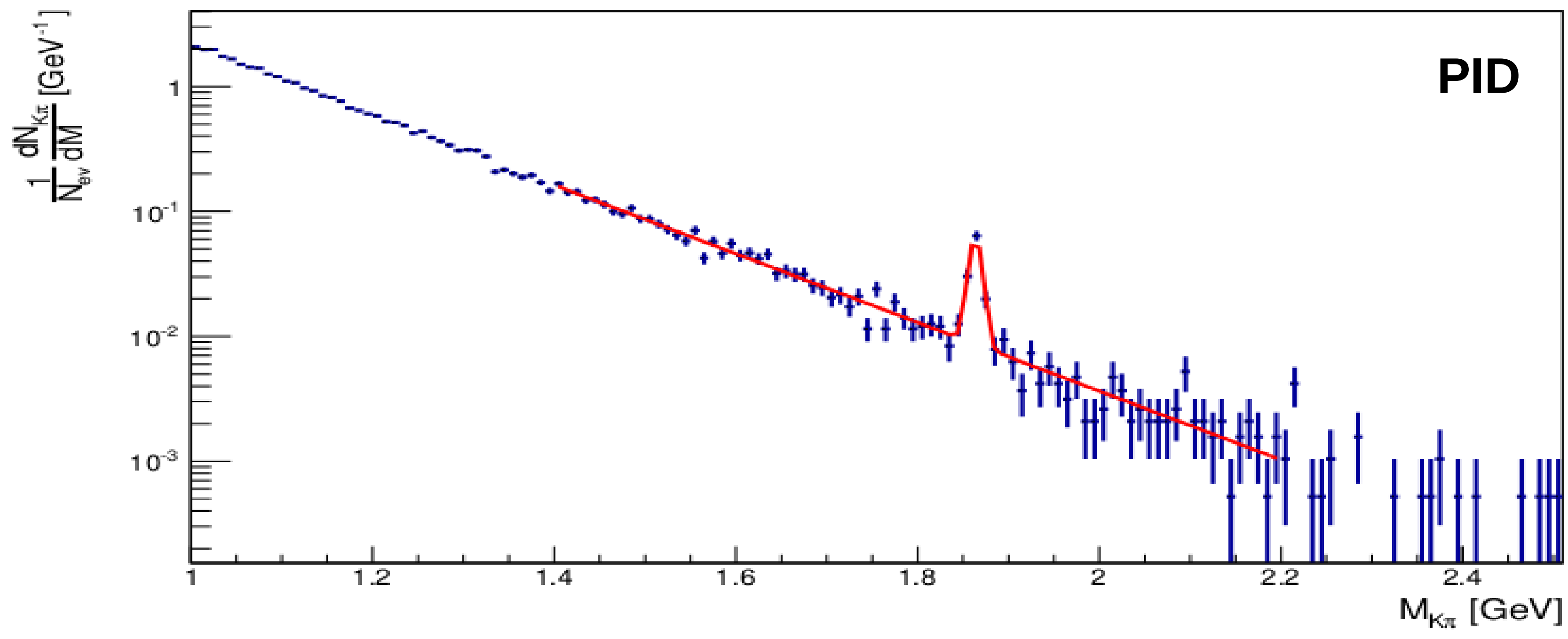




- → **S/B = 17**
- → **SNR(@50M) = 246**
- → **64300 detected $D^0+\overline{D^0}$ mesons in 50M central Pb+Pb (PID)**

- → **S/B = 1**
- → **SNR(@50M) = 197**
- → **64300 detected $D^0+\overline{D^0}$ mesons in 50M central Pb+Pb (no PID)**

Reconstructed yield for $D^0 \rightarrow K^- \pi^+$, 200k 0-10% cent. Pb+Pb at 40 AGeV



- → **S/B = 1.0**
- → **SNR(@50M) = 11.3**
- → **2000 detected $D^0+\overline{D^0}$ mesons in 50M central Pb+Pb (PID)**

- → **S/B = 0.07**
- → **SNR(@50M) = 2.1**
- → **2000 detected $D^0+\overline{D^0}$ mesons in 50M central Pb+Pb (no PID)**

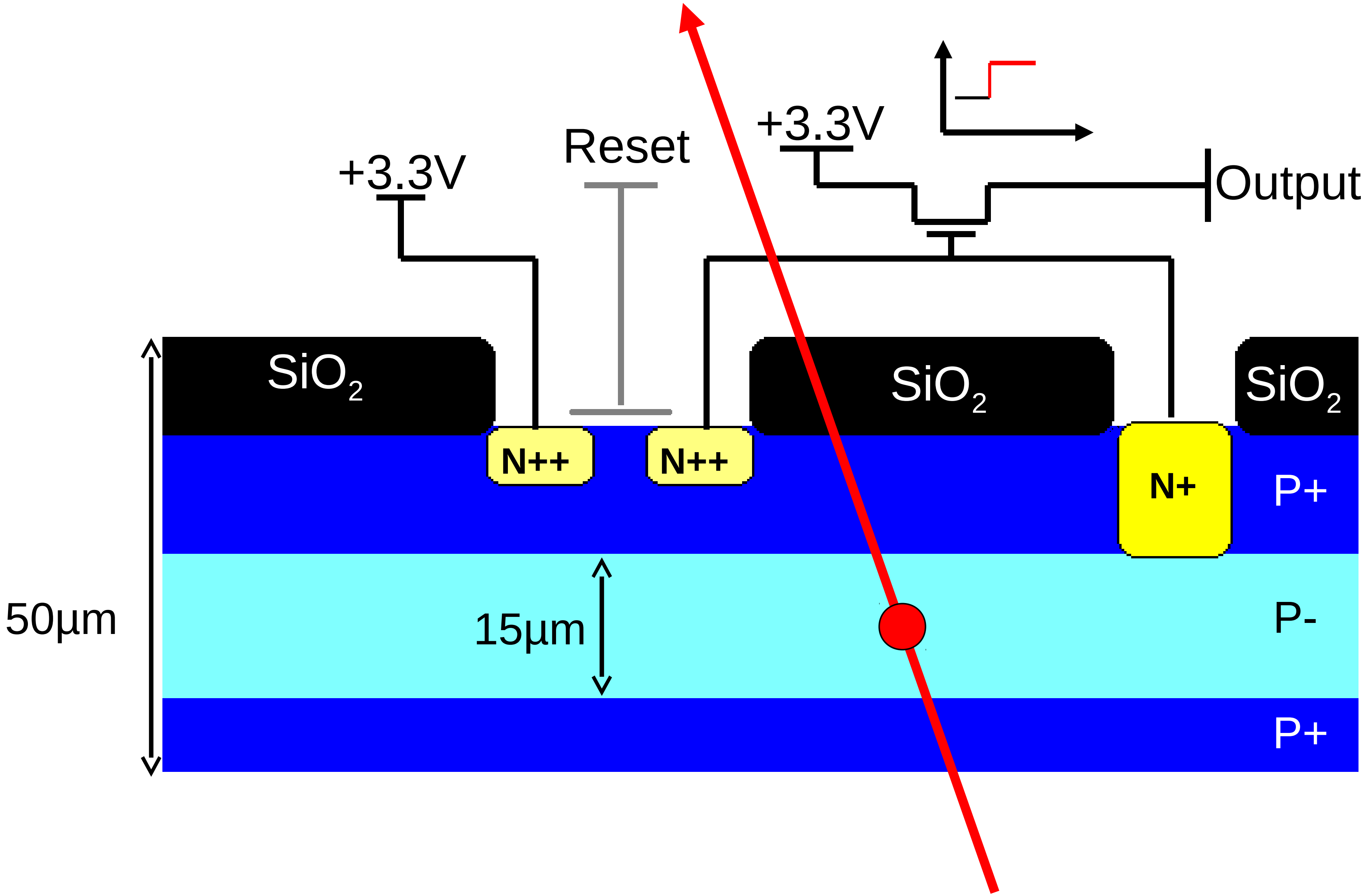
Estimates of NA61/SHINE requirements and limits for different chip technologies

	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

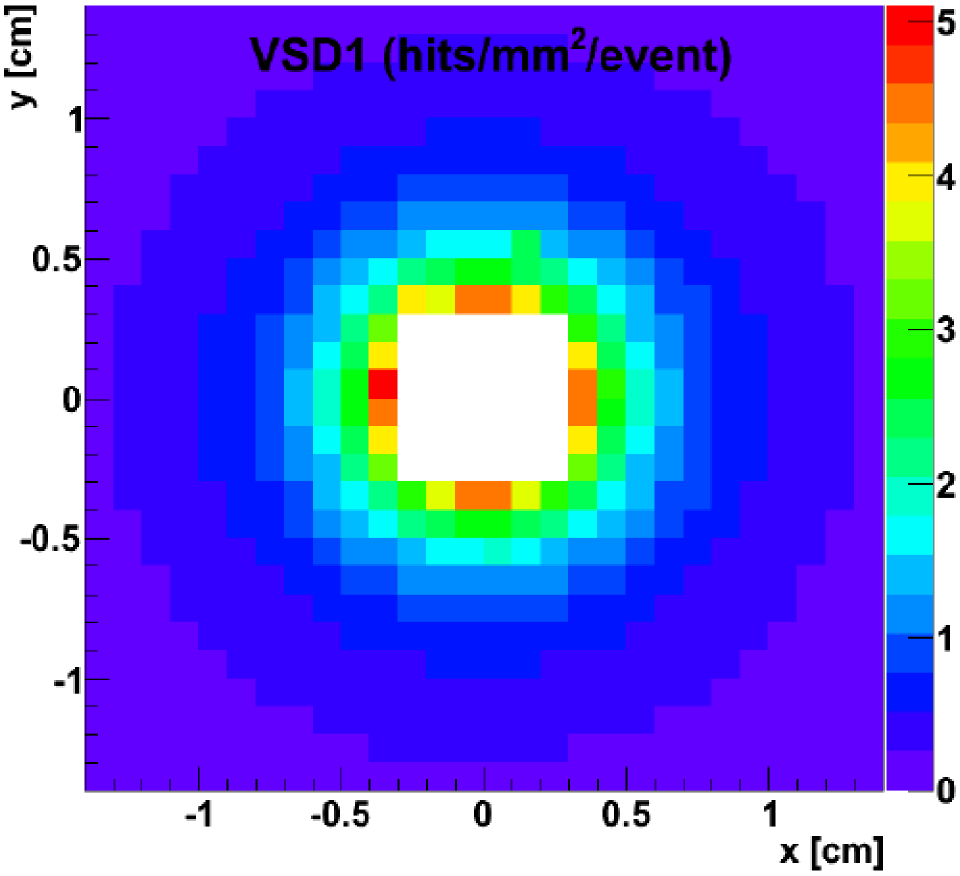
Rad. Tol (1) and (2) refers to non ionizing and ionizing dose per week beam on Target

→ MIMOSA-26 seems to be very much feasible device

MIMOSA-26: The operation principle



We used developed simulation to determine requirements for the detector which are:

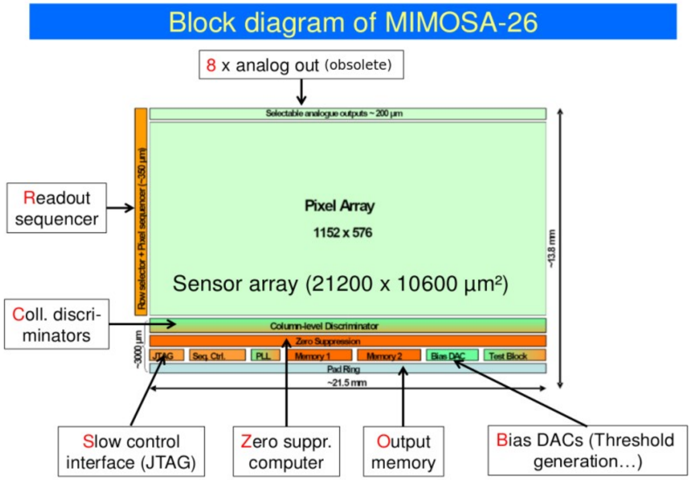


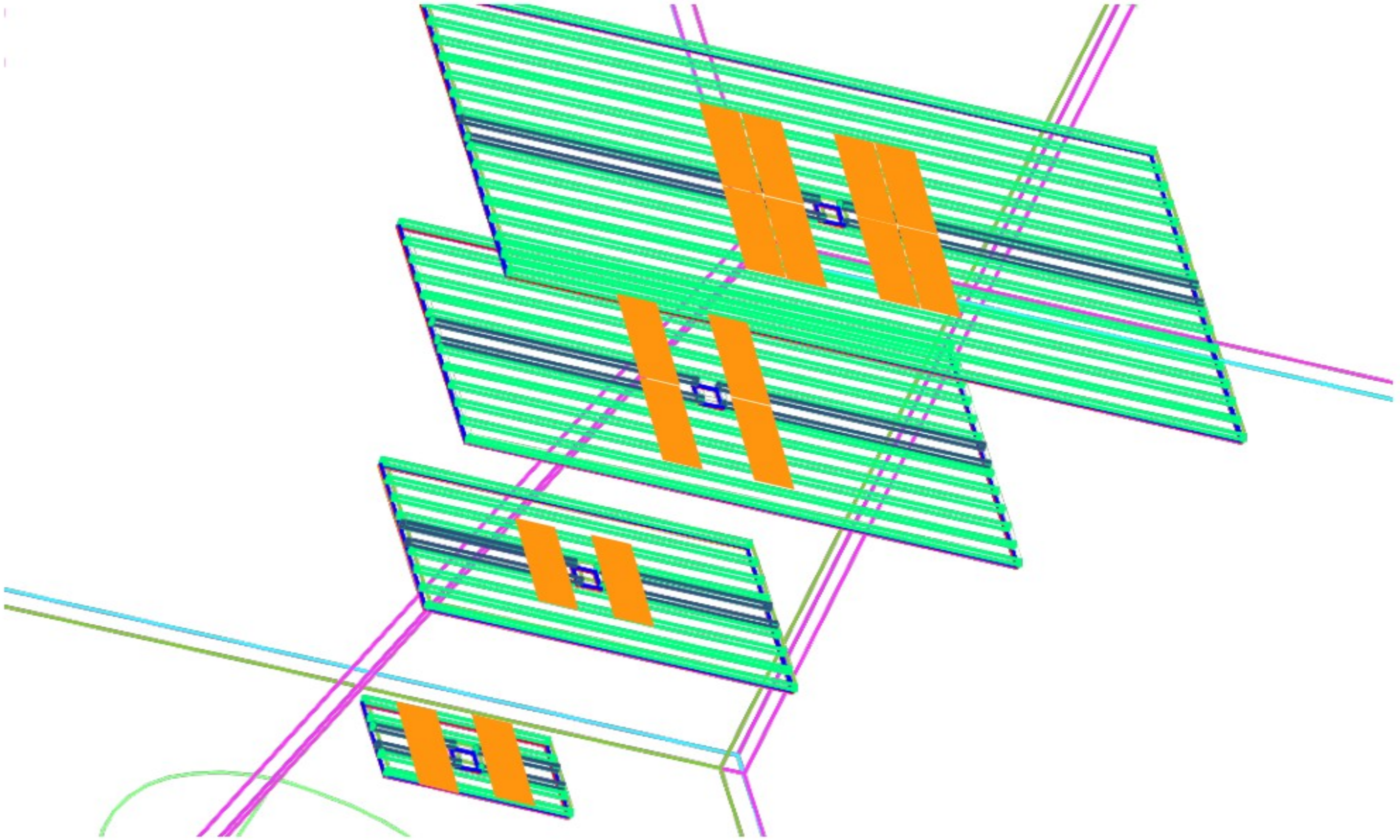
We can expect very high hit occupancy on the level of 5 hit/mm^2/event in the most inner part of the vertex detector.

It suggests that silicon pixel sensors would provide a good solution for us.

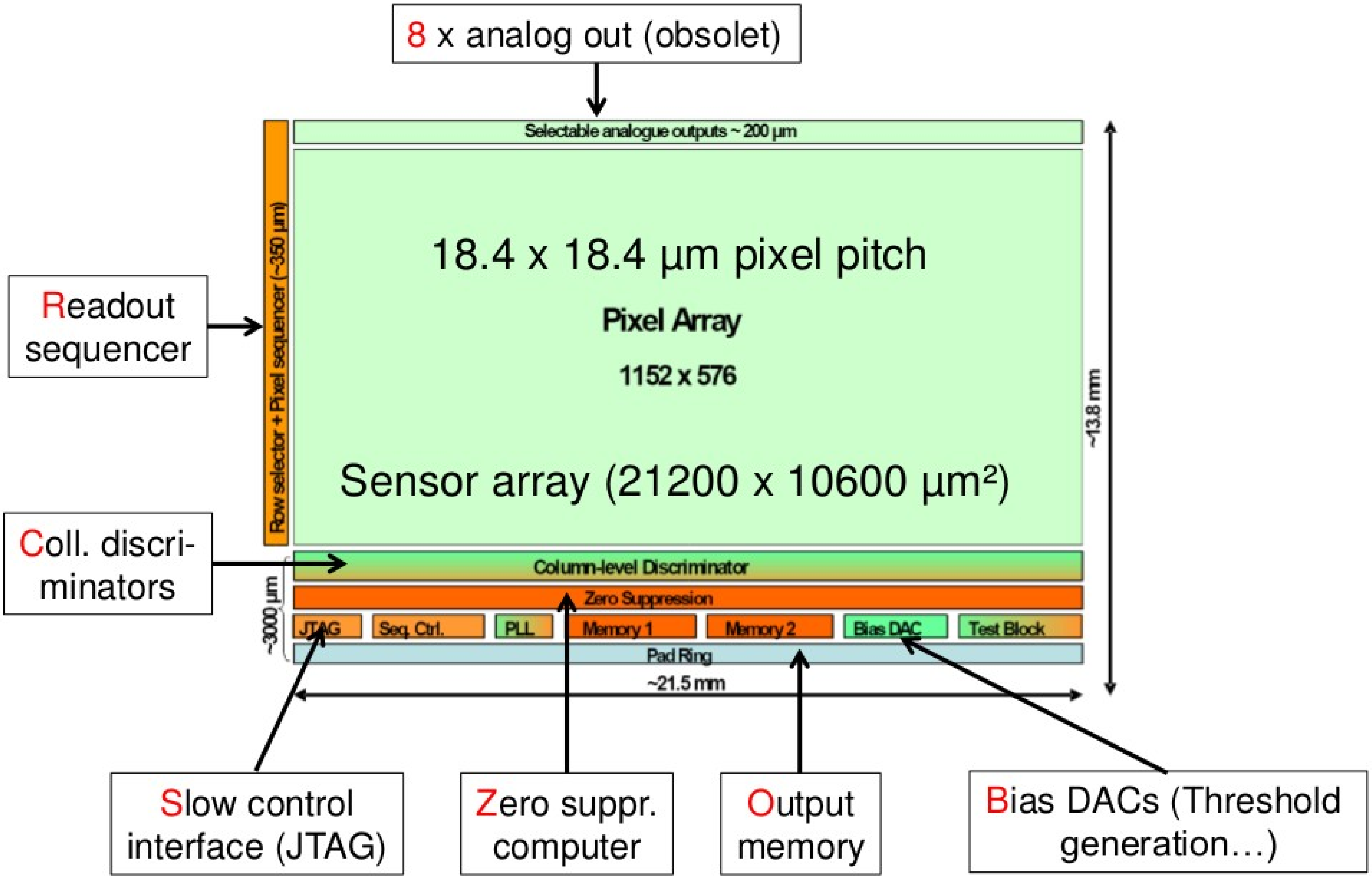
Charged particles produced in Pb+Pb 0-10% central interactions

Sensors on VD stations vertical layout (prototype)

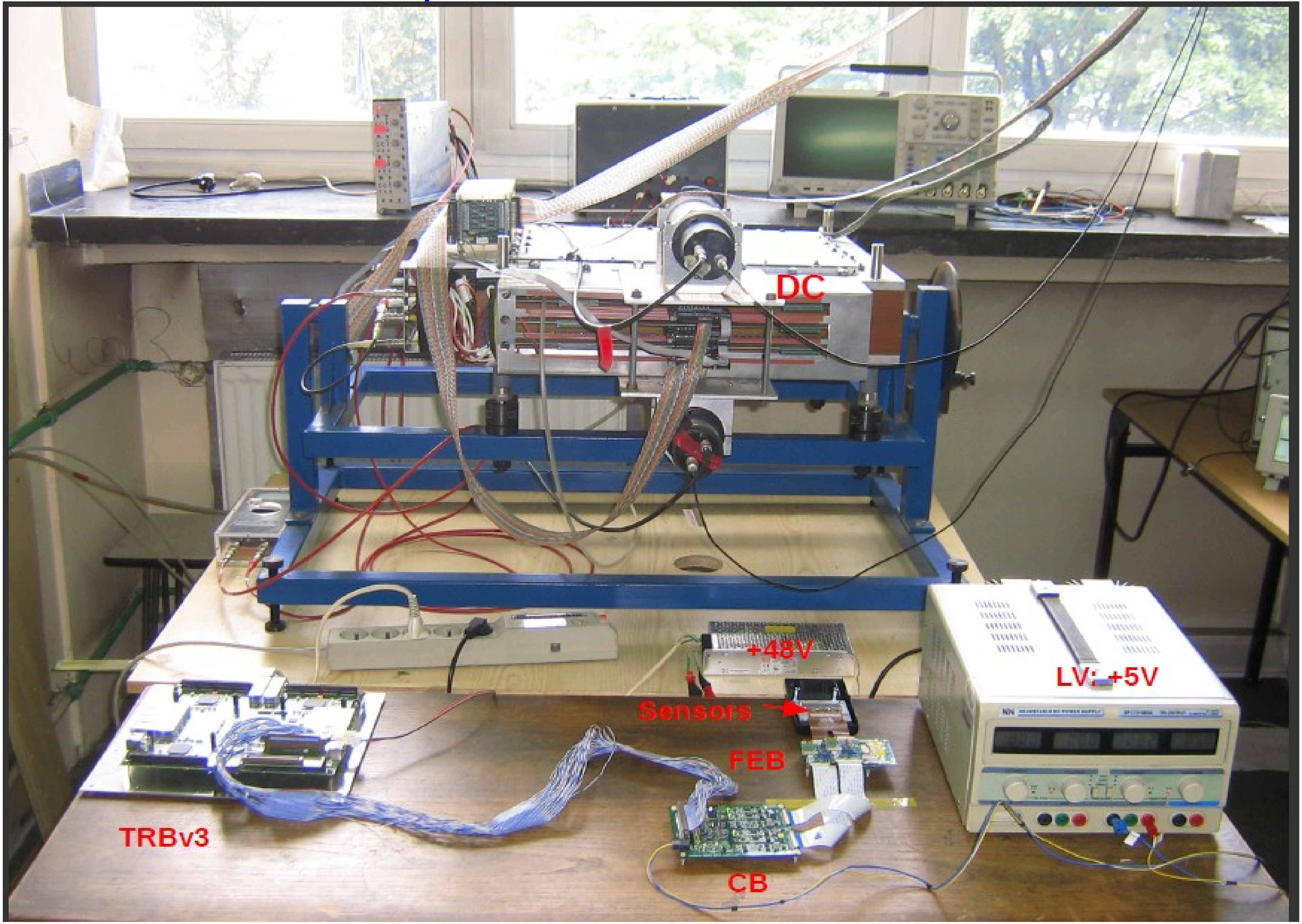




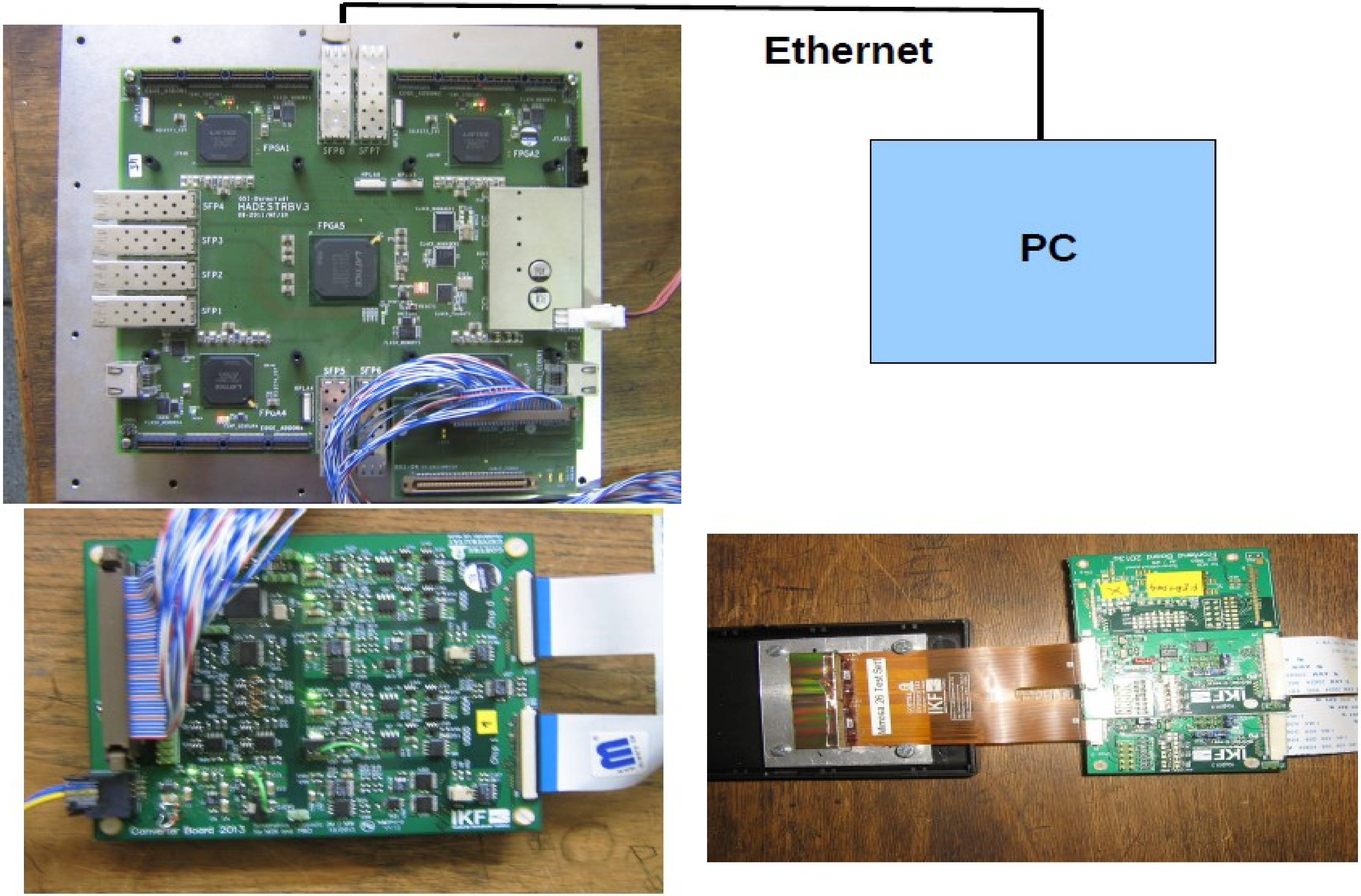
Block diagram of MIMOSA-26



Test Read out setup



Setup overview



Summary

→ Direct measurement of hadrons containing charm quark carries important information about the initial stage of the nucleus-nucleus collision at relativistic energies.

→The measurements of the D0 and $\overline{D0}$ mesons in NA61 experiment with a dedicated vertex detector equipped with MIMOSA-26 sensors as detection units is feasible.

→ Full simulation:

Digitization for VD & matching with VTPC is done

Efficiency and Fakes study of tracking is on going.

Testing of readout setup is on going.

→ Need to run Full simulation.

→ Building Prototype and tests (on beam) in 2015.

List of Publications from project and NA61 collaboration:

→ Y. Ali , P. Staszel, A. Marcinek J. Brzychczyk, R.Płaneta
Acta Physica Polonica B 10, 44 (2013).

→ Y. Ali, P. Staszel *Acta Phys Polon B Supp. 6, 1081-1084 (2013)*

→ Y. Ali, P. Staszel *J. Phys. Conf. Ser. 509, 012083 (2014).*

→ Y. Ali, P. Staszel *EPJ Web of Conferences 71, 00004 (2014).*

→ N. Abgrall,.. Y. Ali, ... et al. *JINST 9, P06005 (2014).*

→ N. Abgrall,.. Y. Ali,.. et al.. *Eur. Phys. J. C 74:2794 (2014).*

→ N. Abgrall,.. Y. Ali, ... et al.. *PRC 89, 025205 (2014)*

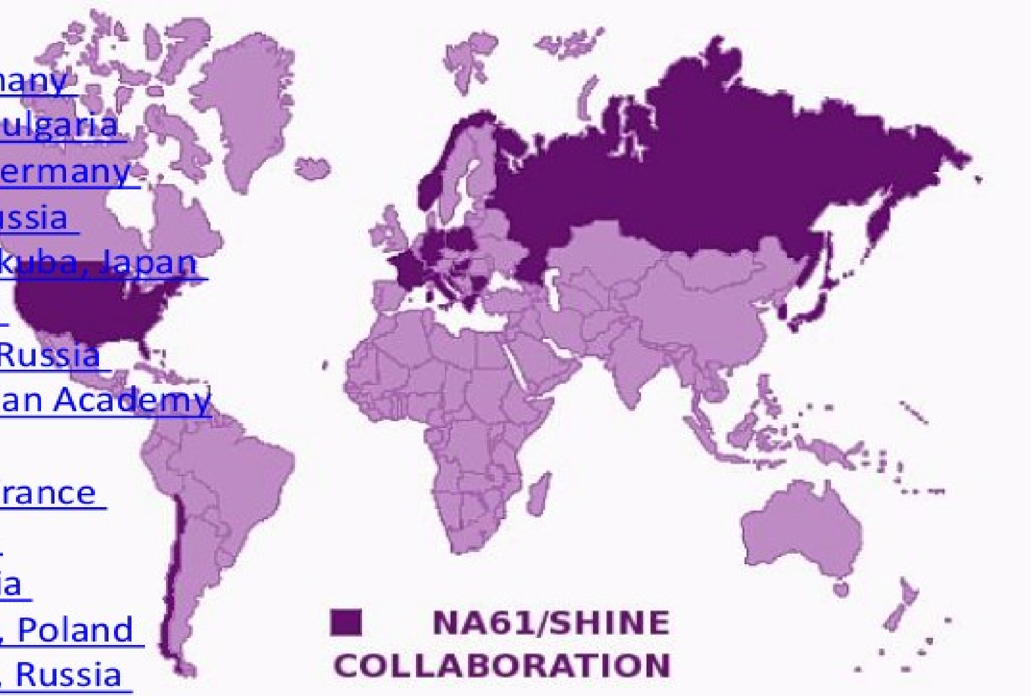
→ ***Status report to the proposal SPSC-P-330***
CERN-SPSC-2013-028 / SPSC-SR-124

→ ***Addendum 6 to the proposal P330 NA61/SHINE plans beyond the approved program***

Acknowledgments

- We acknowledge the support by the Foundation for Polish Science - MPD program, co-financed by the European Union within the European Regional Development Fund & NA61 Collaboration

ETH, Zurich, Switzerland
Fachhochschule Frankfurt, Frankfurt, Germany
Faculty of Physics, University of Sofia, Sofia, Bulgaria
Karlsruhe Institute of Technology, Karlsruhe, Germany
Institute for Nuclear Research, Moscow, Russia
Institute for Particle and Nuclear Studies, KEK, Tsukuba, Japan
Jagiellonian University, Cracow, Poland
Joint Institute for Nuclear Research, Dubna, Russia
Wigner Research Centre for Physics of the Hungarian Academy of Sciences, Budapest, Hungary
LPNHE, University of Paris VI and VII, Paris, France
University of Silesia, Katowice, Poland
Rudjer Boskovic Institute, Zagreb, Croatia
National Center for Nuclear Research, Warsaw, Poland
St. Petersburg State University, St. Petersburg, Russia
Laboratory of Astroparticle Physics, University Nova Gorica, Nova Gorica, Slovenia
Jan Kochanowski University in Kielce, Poland
University of Athens, Athens, Greece
University of Bergen, Bergen, Norway
University of Bern, Bern, Switzerland
University of Frankfurt, Frankfurt, Germany
University of Geneva, Geneva, Switzerland
University of Warsaw, Warsaw, Poland
Warsaw University of Technology, Warsaw, Poland
University of Wrocław, Wrocław, Poland
University of Belgrade, Belgrade, Serbia

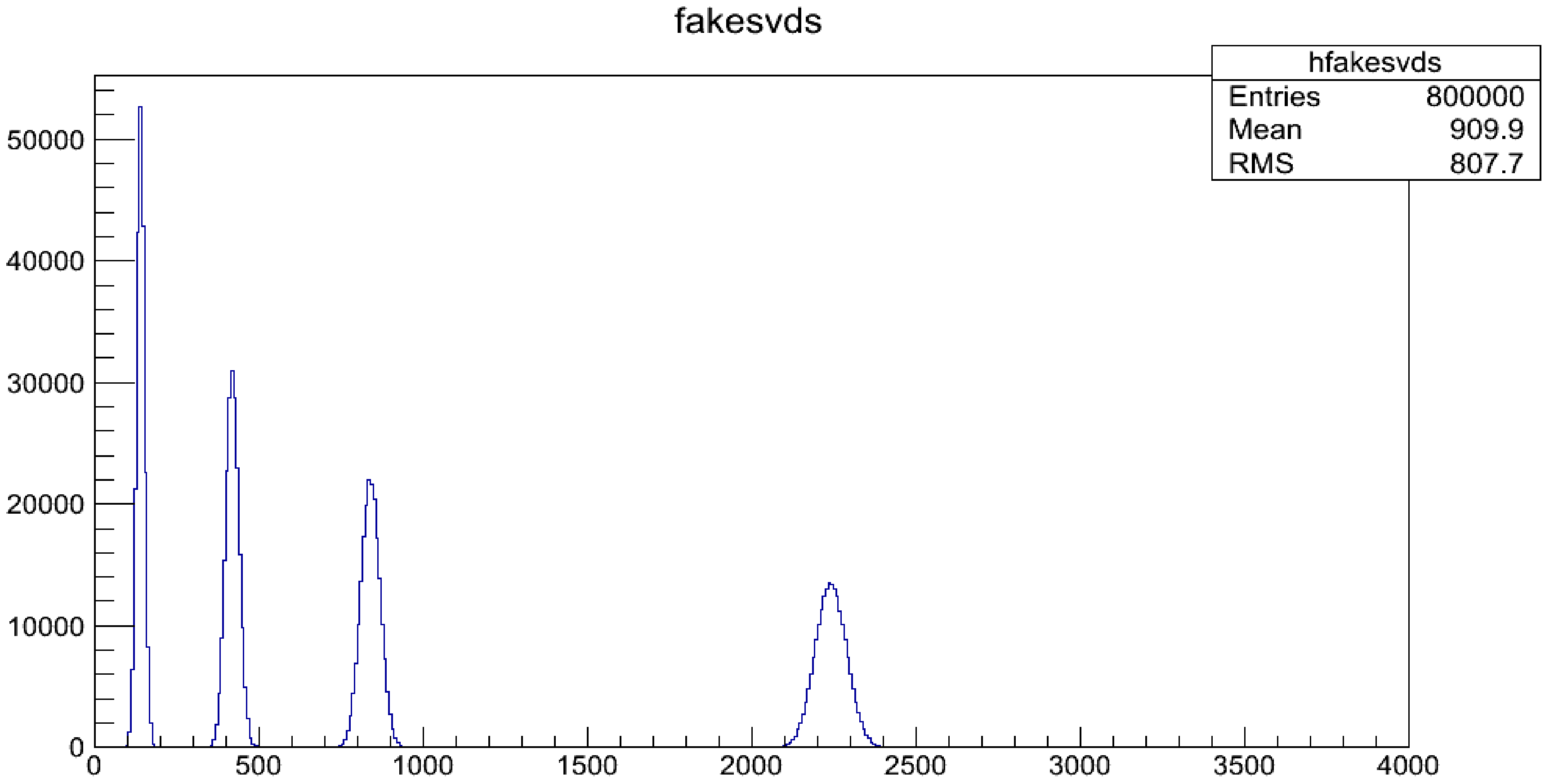


~ 150 Participants
16 Countries

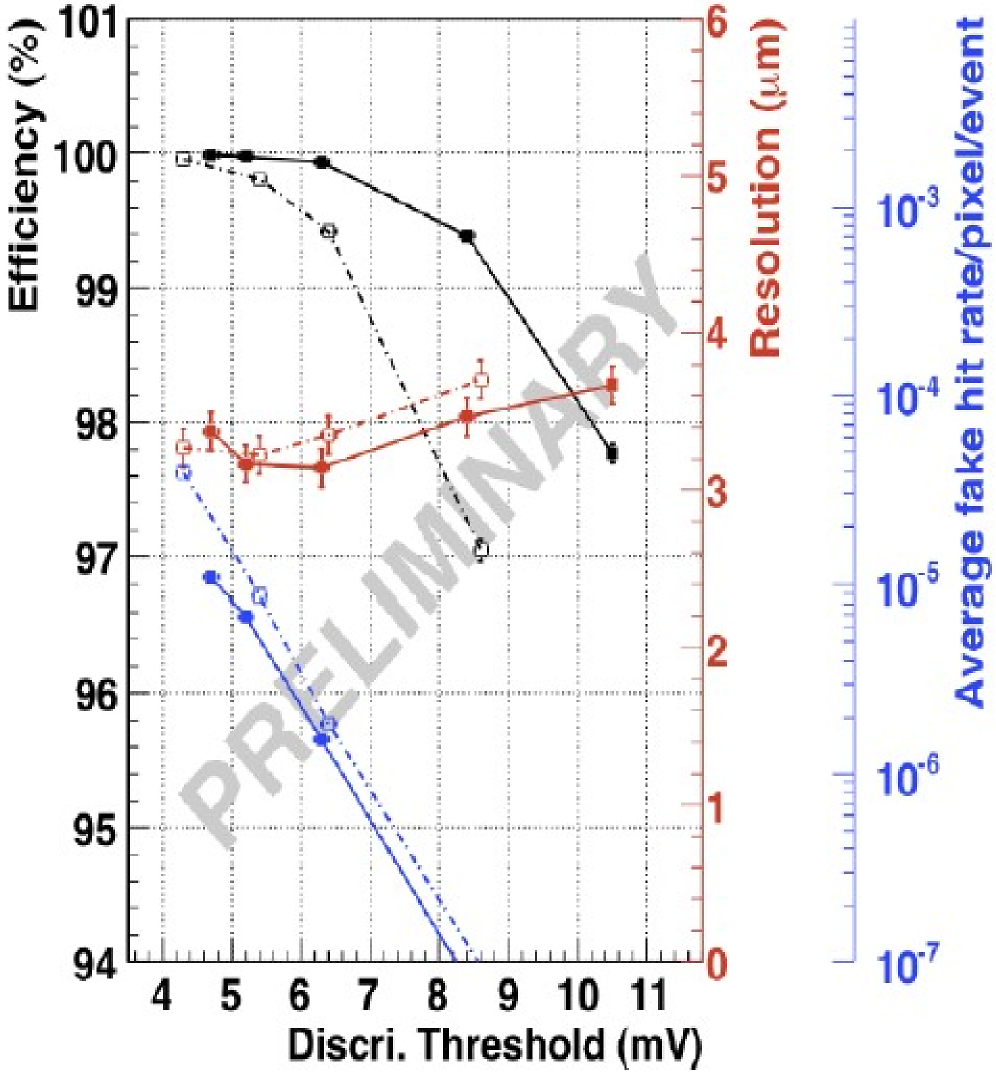
THANK YOU!

Study of efficiency and fakes of track reconstruction is on going….

Efficiency % = Reco tracks/Reff tracks (GEANT 4)
Fakes % = Fakes / Reco tracks



Performance of MIMOSA-26 → test on beam



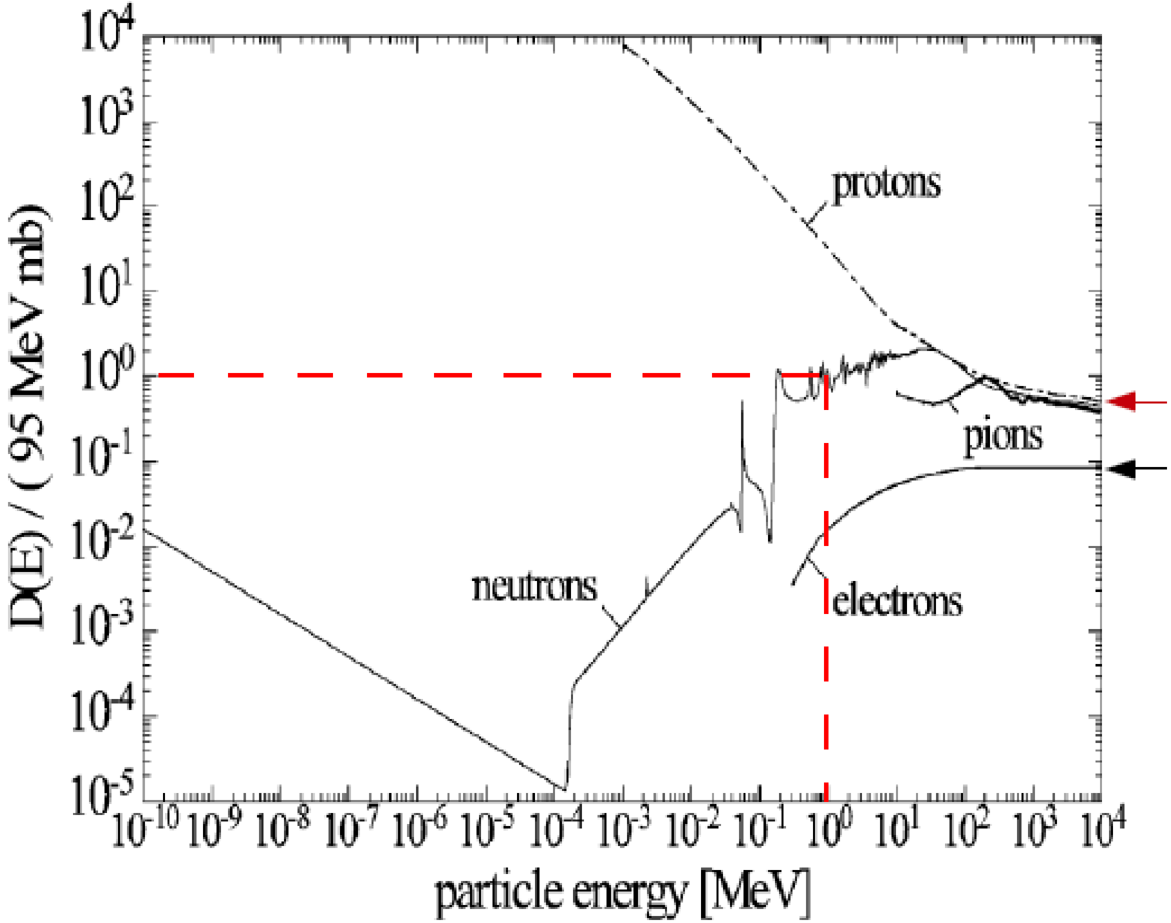
(M.Winter, CBM Progress Report 2010)

Temperature: $+ 30^0$ C
Readout Time: 125 µs
Pitch size : 20.7 µm
Irradiated with to
fluence = 3 x 10^{12} n_{eq}/cm^2

For disc. Threshold= 5 mV:
detection efficiency ~ 99.8%,
fake hits < 10^{-4}
resolution ~ 3.5 µm

Displacement Damage Function

Bulk damage exclusively depends upon non ionizing energy lose (NIEL). This is described by the displacement damage functions D(E)



Hadronic interactions: flux = (10^5 * 0.005) event/s * 1.6 particles/mm²/event = 800 Hz/mm²

0.62

0.62/5

Electromagnetic interactions (δ - electrons): flux = 10^5 event/s * 0.04 particles/mm²/event = 4000 Hz/mm²

(A. Vasilescu, ROSE Internal Note ROSE/TN/97-2 (1997))

Fluence Calculations

Φeq 1MeV = $\varkappa\Phi$ $\varkappa$ - radiation hardness parameter

$\varkappa$ = 0.62/5 for electrons

$\varkappa$ = 0.62 for particles from hadronic interactions

Fluence for electrons in [for 1 month] (upper limit):

= 4 x 105 /cm2/sec * 0.62/5 * 2592000 sec = $1.28 * 10^{11}$ n_{eq}/ cm^2

For Spill of the beam (20%) = $2.57 * 10^{10}$ n_{eq}/cm^2

→ Φ for charge Particles = 800 Hz/mm^2

` Fluence for charged particles [for 1 month] (upper limit):

= 8 x 104 /cm2/sec * 0.62 * 2592000 sec = $1.28 * 10^{11}$ n_{eq}/ cm^2

For Spill of the beam (20%) = $2.57 * 10^{10}$ n_{eq}/cm^2

Factor of 40 below the tested range

Pixel occupancy

→ As usually looking at the most critical area of Vds1 where the track occupancies are:

1. 5 tracks/mm^2/event for central Pb+Pb collisions
2. 1.6 tracks/mm^2/event from averaging over minimum bias Pb+Pb collision
3. 0.04 δ-electrons/mm^2/event for Pb ion on 200 μm target

P(0) = 95% - empty frame
P(1) = 4.7% - single event
P(2) = 0.12% (pile-up P(2)/P(1) = 2.5%)
Beam intensity of 100kHz will lead to 10 ions in 100 μs
Single Pixel Occupancy = 0.25% (+0.01% contribution from fake hits)
→ Not very dense environment → probability of overlap low, however we need full simulation to prove the reconstruction feasibility