"Feasibility of the detection of D^0 mesons in the NA61/SHINE experiment"

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On behalf of NA61/SHINE Collaboration

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Presentation Plan

- Physics motivation
- NA61/SHINE detector overview
- Input for simulation
- Vertex detector simulation
- Results and discussion
- Summary

Introduction

- A feasibility study of $D^0 \rightarrow K^+ \pi^-$ channel in central Pb+Pb collisions at the CERN SPS energies will be presented. The study is done for 158 AGeV and 40 AGeV

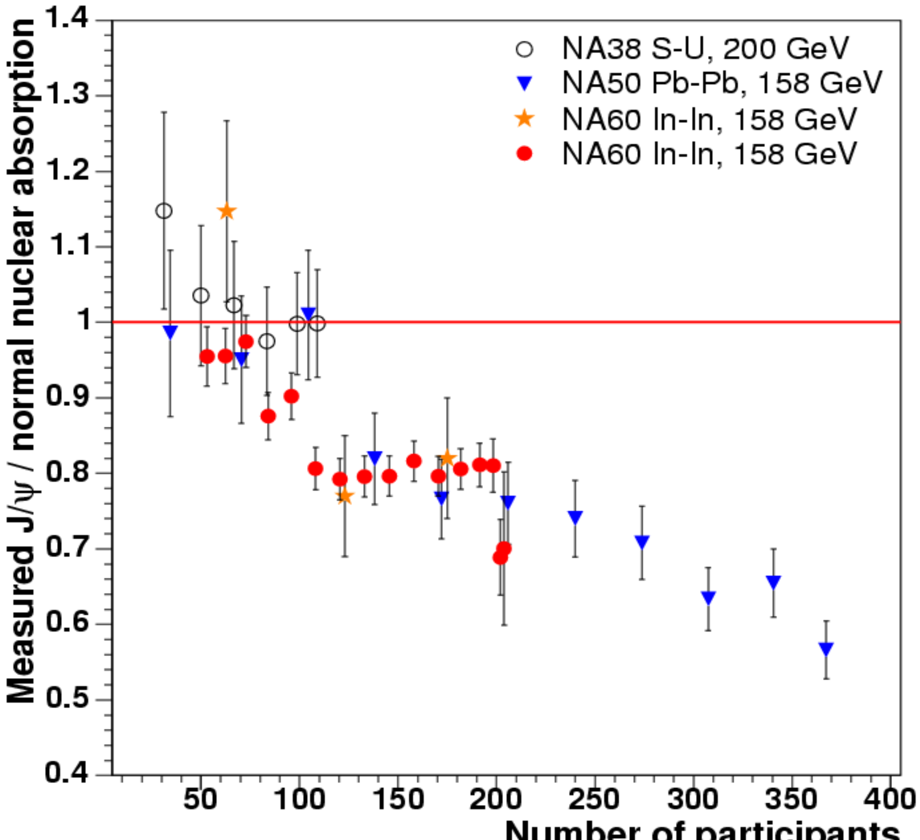
- The NA61 requires upgrade with a new vertex detector that will allow precise track and vertex reconstruction at the target proximity.

- The obtained results focusing on the predicted yields of D^0 mesons and vertex detector optimization regarding its geometry and applied detection technologies

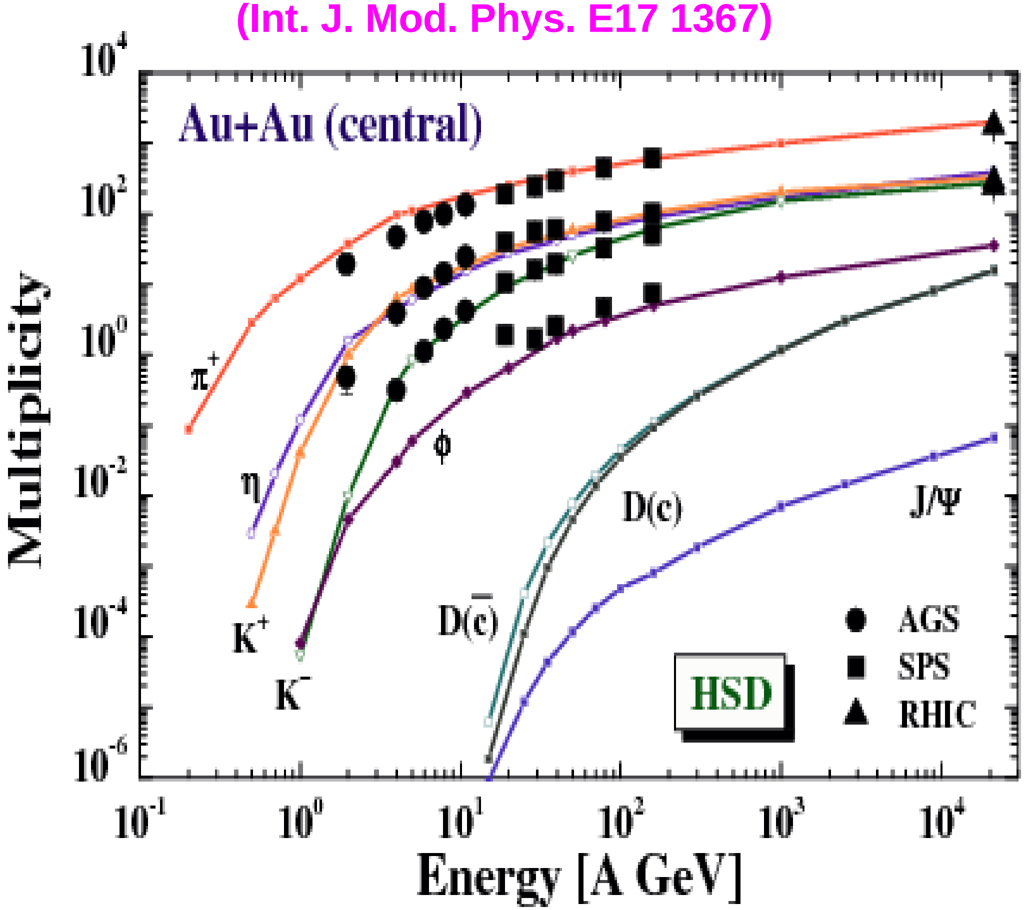
Physics motivation

- So far no direct open charm measurements at SPS energies
- Only J/Ψ has been measured at top SPS energy by (NA50 and NA60) experiments
- Open charm measurement provides unique opportunity to test the validity of p-QCD based and statistical models of nucleus-nucleus collisions at higher energies **(Acta. Phy. Pol. B Vol 31 (2000))**
- Differential measurements for open charm

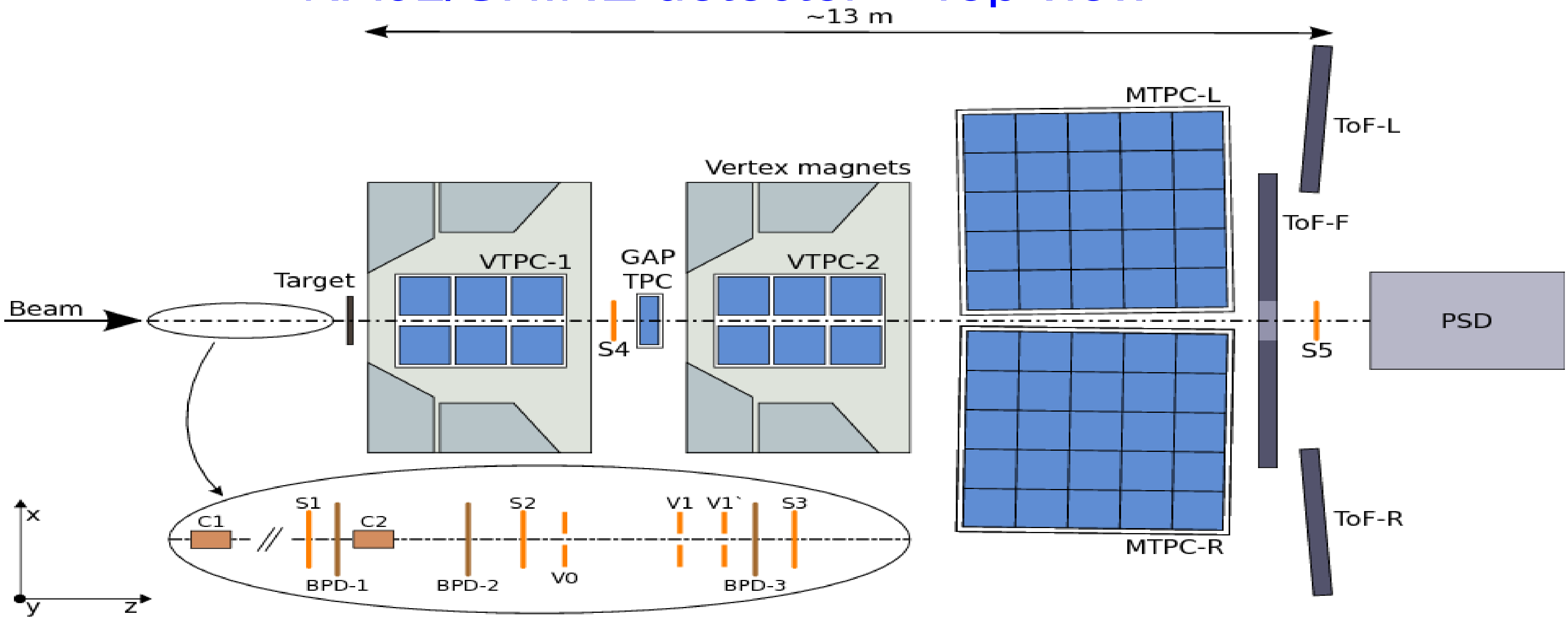
(Nucl. Phys. A 774 (2006) 67-76)



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



NA61/SHINE detector – Top view



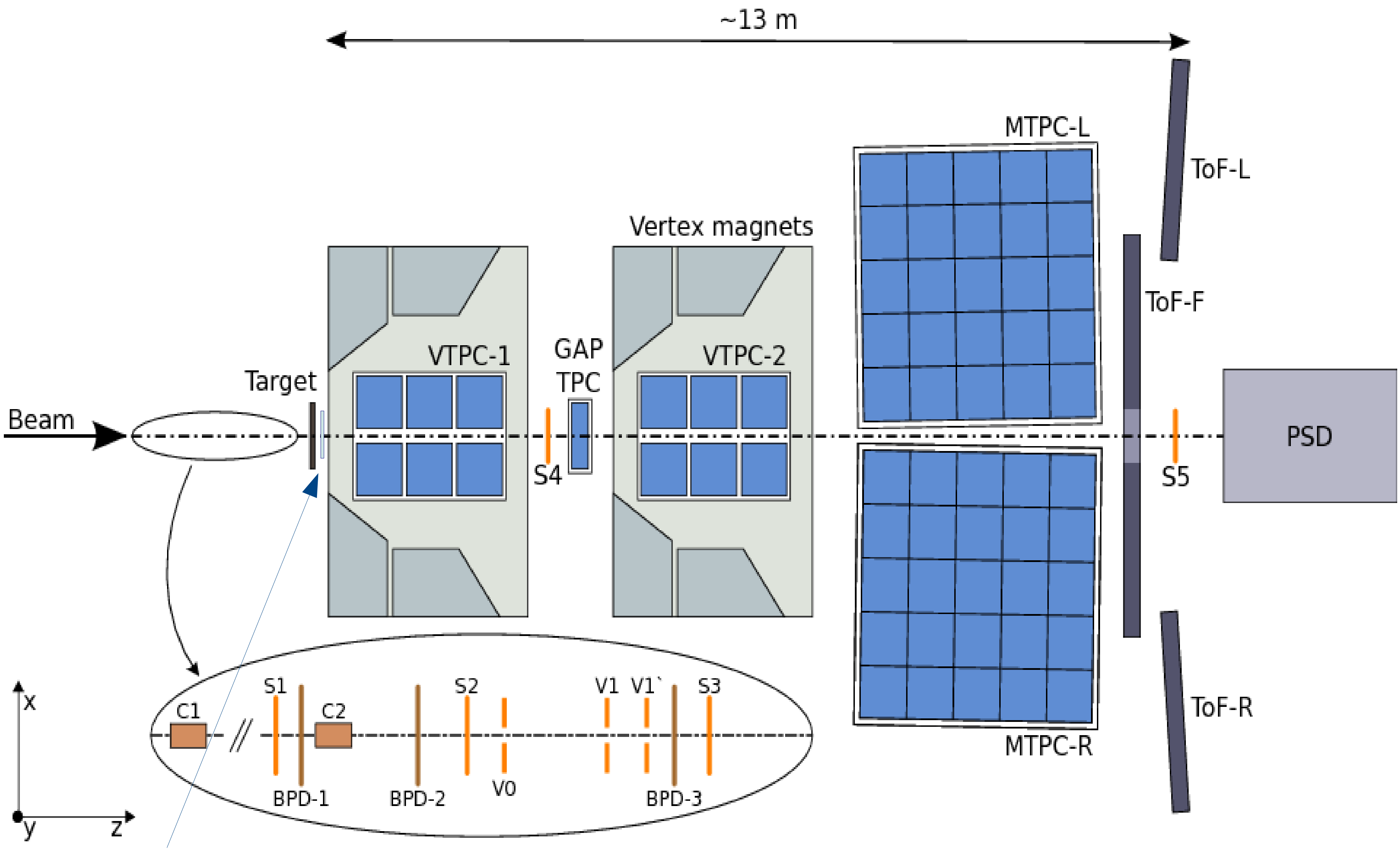
Beam detectors and triggering ► A set of upstream scintillation or Cherenkov counters and beam position detectors, provides precise timing reference, charge and position measurement of the incoming beam particles

Time Projection chambers ► Four large volume TPCs serve as tracking detectors

Time of Flight walls ► Mainly used for Hadron Identification

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

NA61/SHINE detector – Top view
Vertex detector Position



VERTEX DETECTOR (VD)

Feasibility Studies

Physical Input

→ AMPT (A MultiPhase Transport model) event generator used to generate 200k Pb+Pb events at 158 AGeV for 0-10% centrality

→ AMPT predicts 0.01 of $\langle D^0 \rangle + \langle \overline{D}^0 \rangle$ per central Pb+Pb event. this seems to be under-predicted value, e.g. PYTHIA run for N-N and scaled to central Pb+Pb gives 0.21 **(P. Braun-Munzinger, J. Stachel, PLB 490 (2000) 196)**

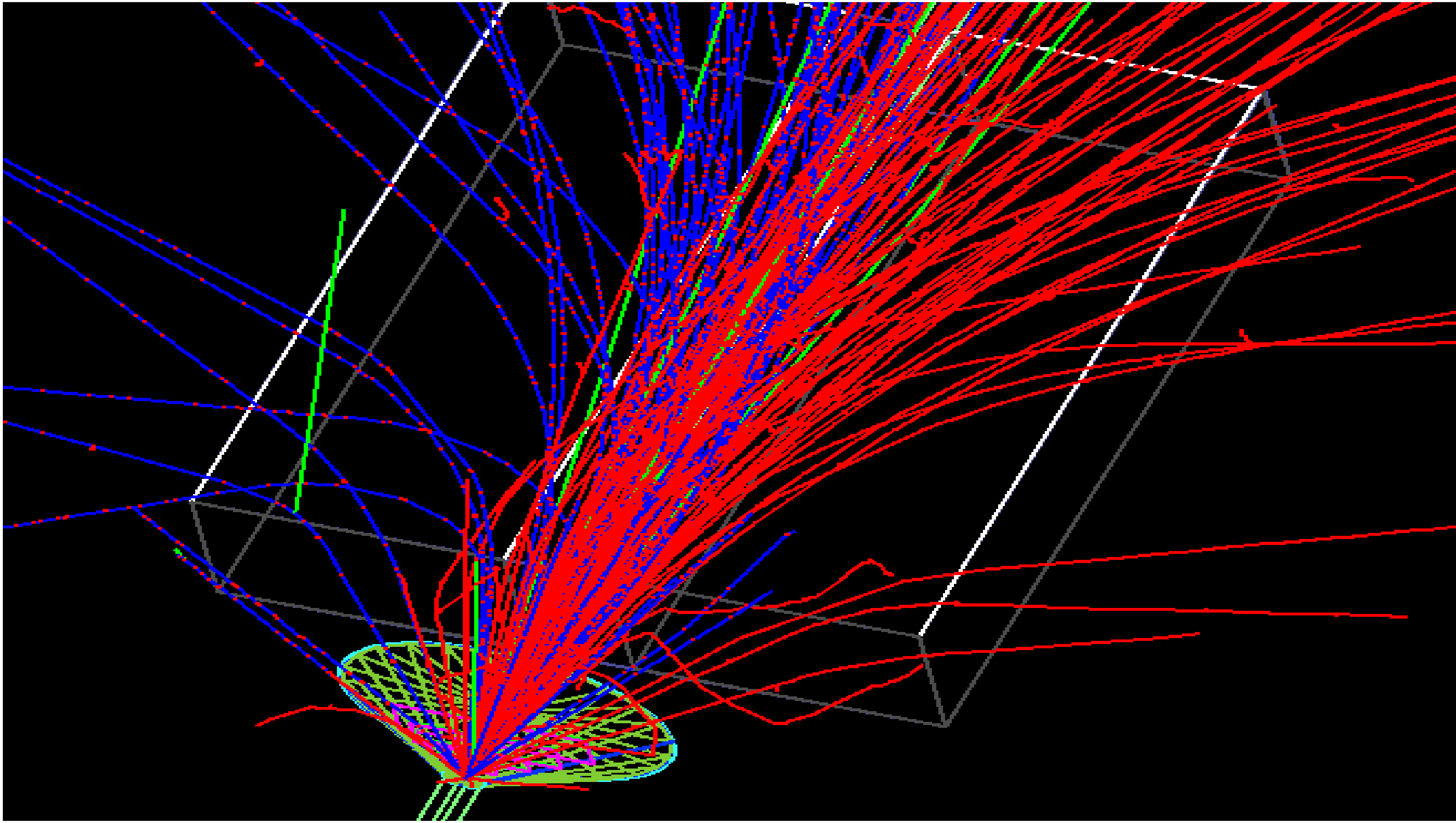
→ HSD Model predictions are consistent with scaled PYTHIA → We scaled AMPT predictions to be consistent with HSD and PYTHIA.

→ AMPT does not generate “Open Charm” at 40 AGeV, We assume open charm phase space distribution characteristic same as for 158 AGeV and yields as predicted by HSD model.

→ Rapidity distribution and Invariant mass slope parameter does not change more than 10% for Kaons while going from 158 AGeV to 40 AGeV

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

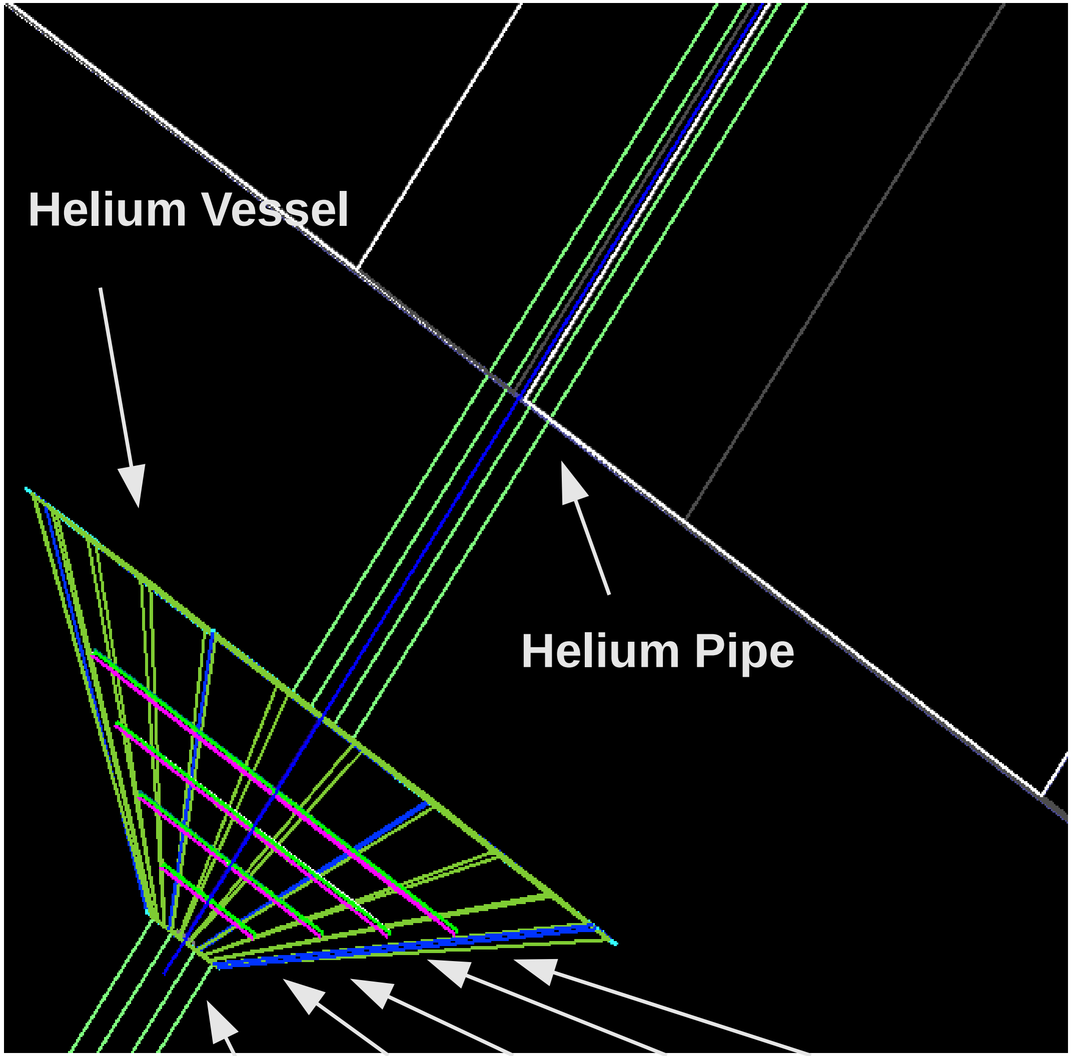
AMPT Event: Pb+Pb at 158 AGeV

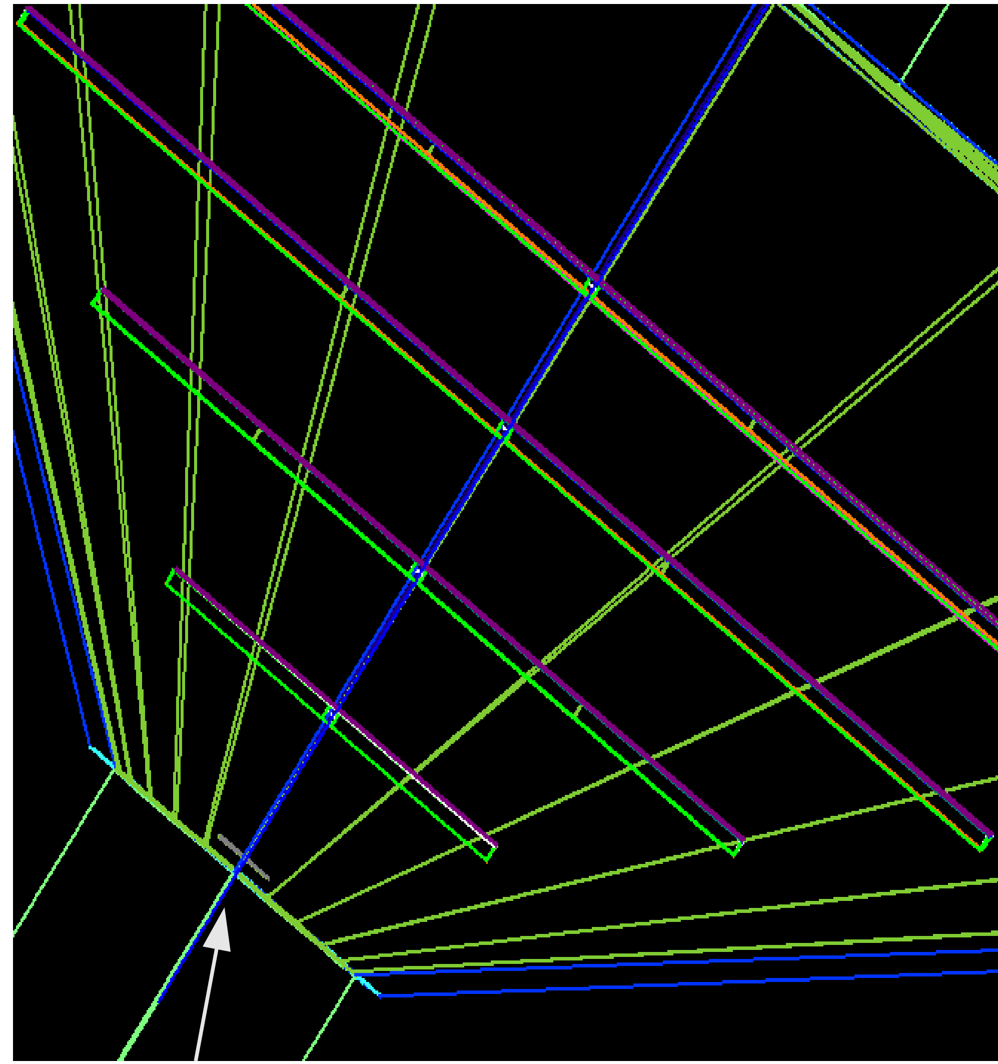


- **VTPCs filled with Ar-CO_2 mixture, location and dimensions as in NA61 setup.**
- **Uniform magnetic field: 1.5 T in VTPC-1 and 1.1 T in VTPC-2**

Design of the Future Vertex Detector

Zoom in



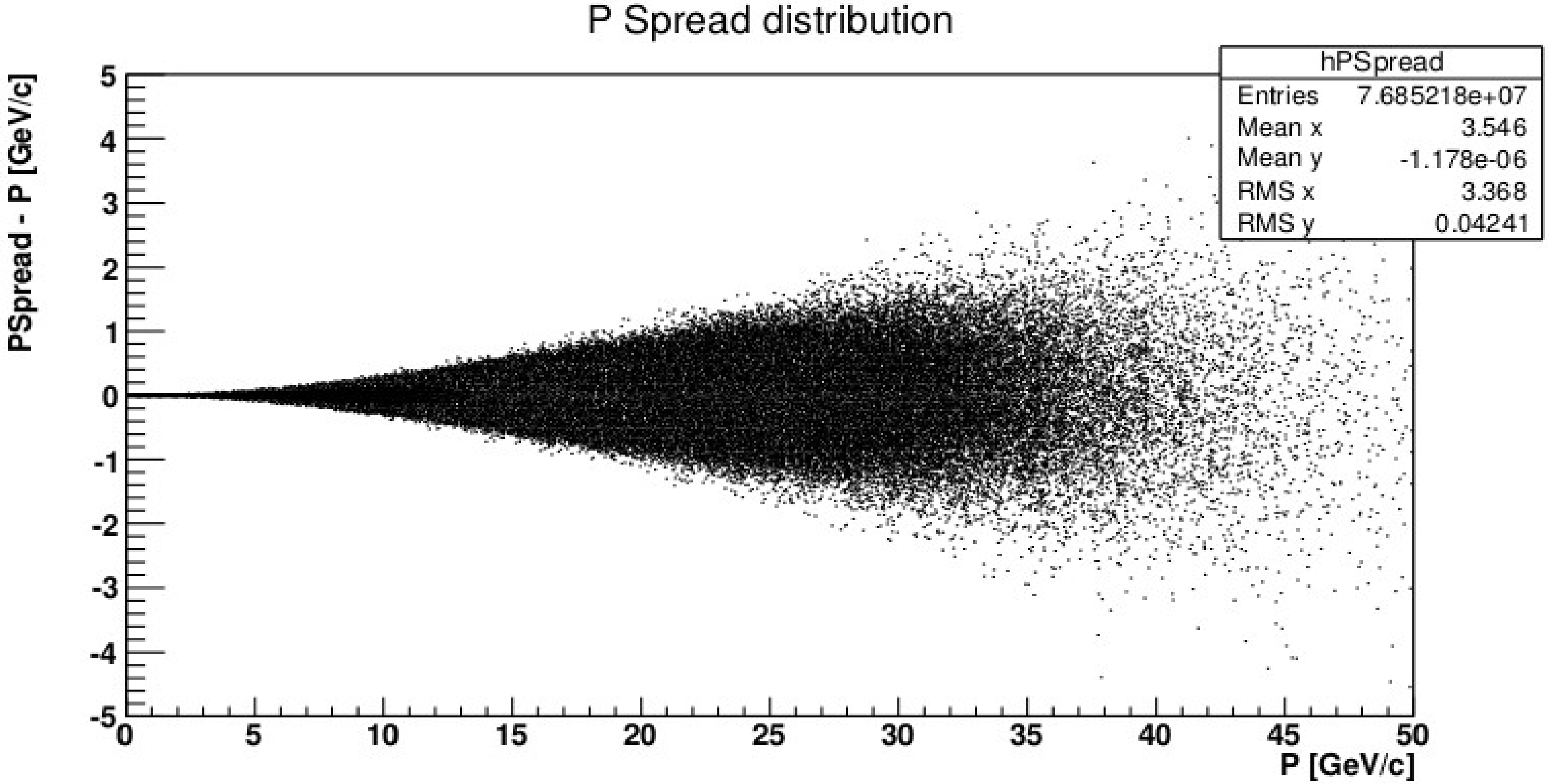


VDS Stations are located at the distance of 5, 10, 15 and 20 cm respectively from the Target

Reconstruction

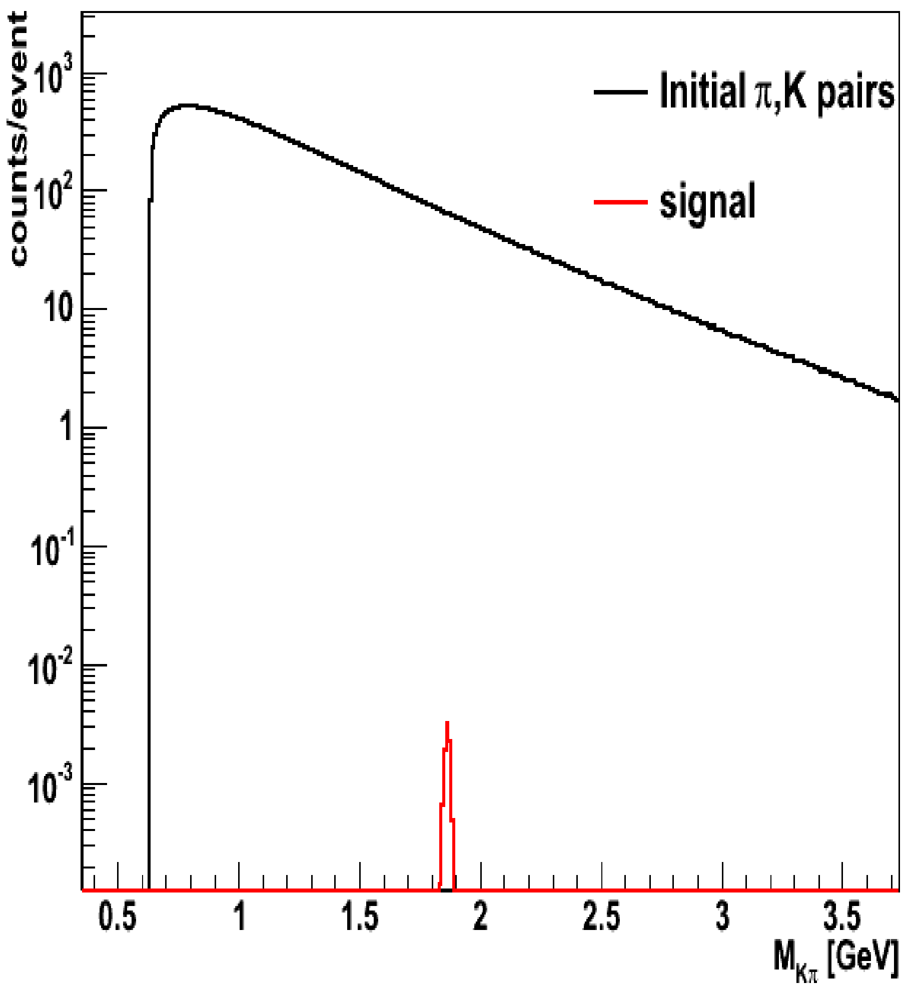
- Track distance in VTPC1 + VTPC2 > 1m
- Require hit at least in the three Vertex detector stations
- NA61/SHINE Momentum and Position resolutions are assumed

1. momentum resolution $dp/p^2 = 7.0 \times 10^{-4} (GeV/c)^{-1}$ **(Nuclear Instruments and Methods in Physics Research A 430 (1999) 210 - 244)**
2. position resolution is 10 μm → hits are spread in y and x around geant hit according to the Gaussian distribution (σ = 10 μm). Track line is taken from the fit to the spread points



Background Suppression strategy

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



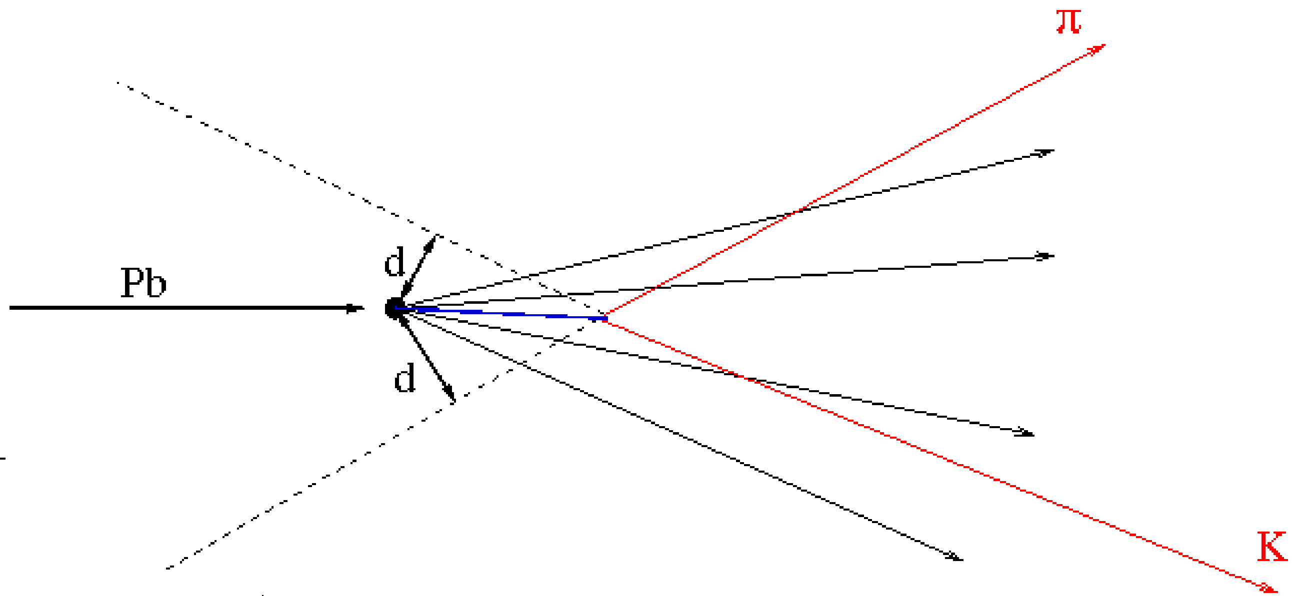
Single particle cuts:

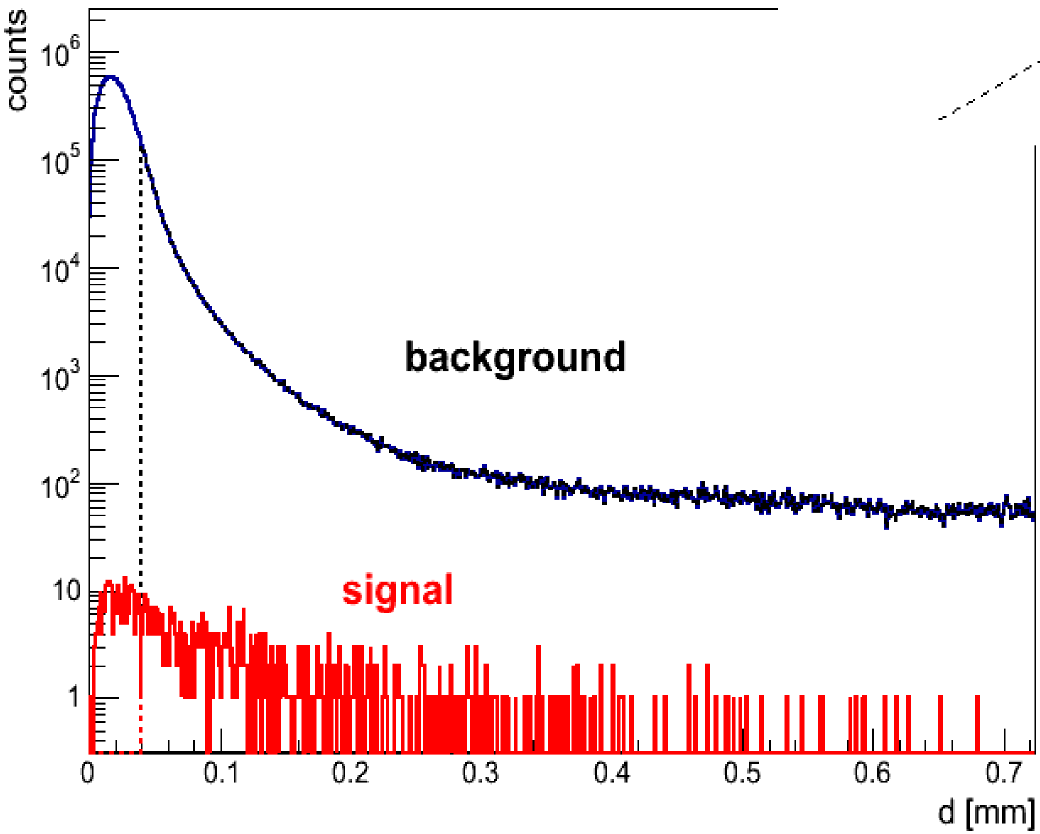
1. cut on **p_T** (< 0.4)
2. cut (track impact parameter **d** (< 40μm)

Two particle cuts:

3. Cuts in Armenteros-Podolanski space to remove background from K_s and Λ
4. Two track vertex cut **V_z** (< 500μm)
5. Reconstructed parent impact parameter cut **D** (> 22μm)

1. Cut on **d**

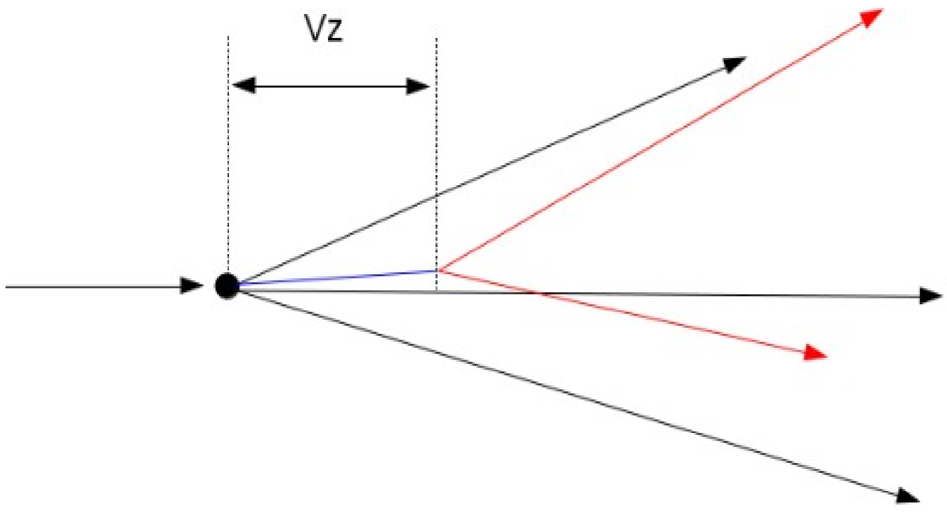


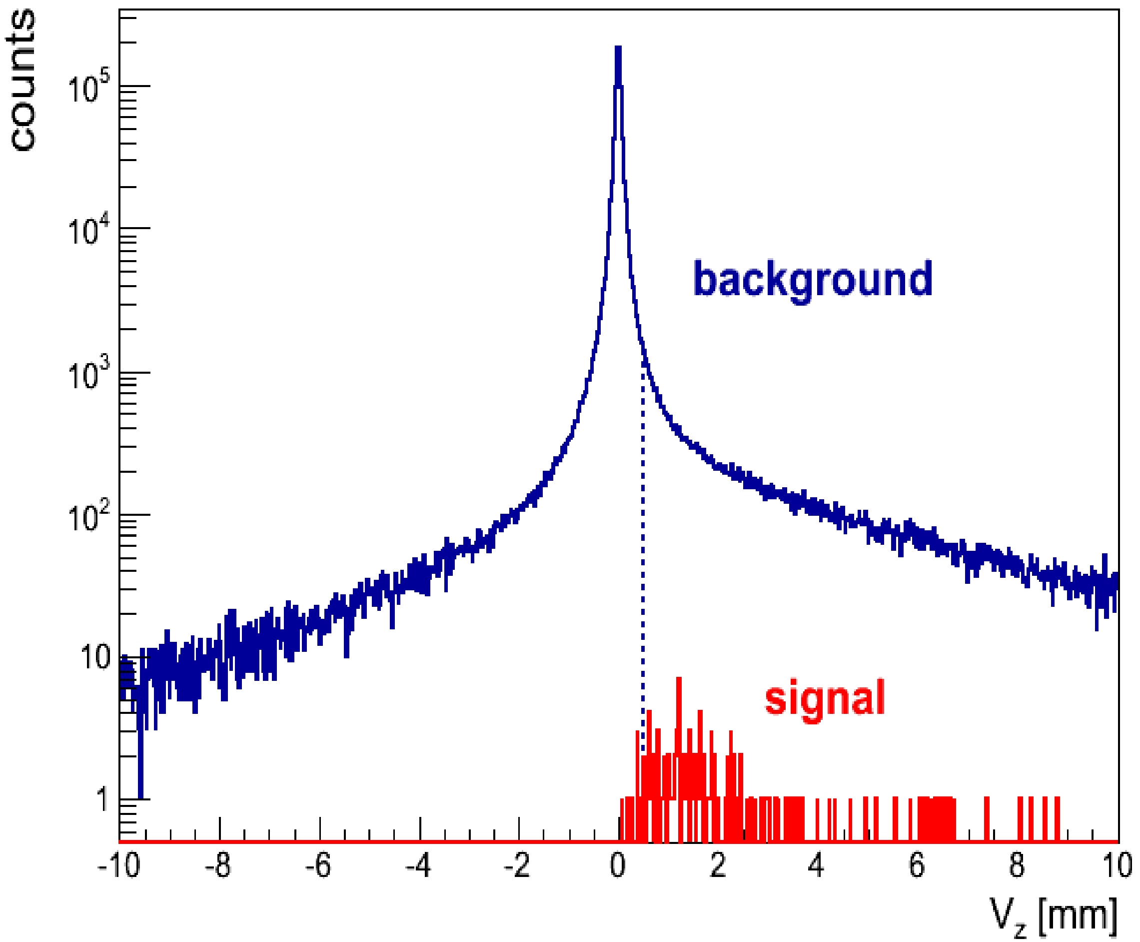


Relatively smooth shape of background at ~ 0 is due to uncertainly in reconstruction of track position and angle.
Some uncertainly comes from multiple scattering.

→ cut on d < 40 μm as indicated

2. cut on **Vz**

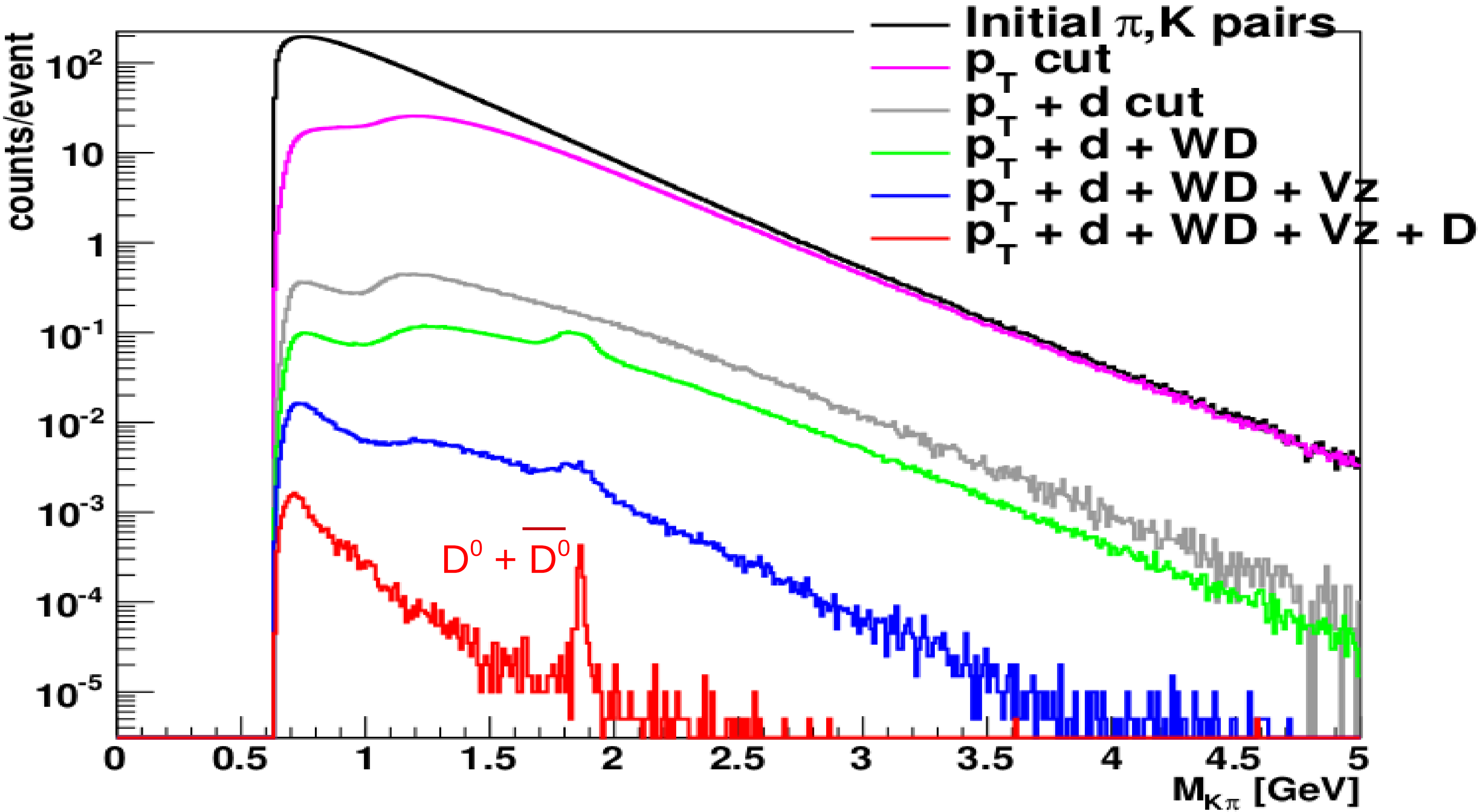




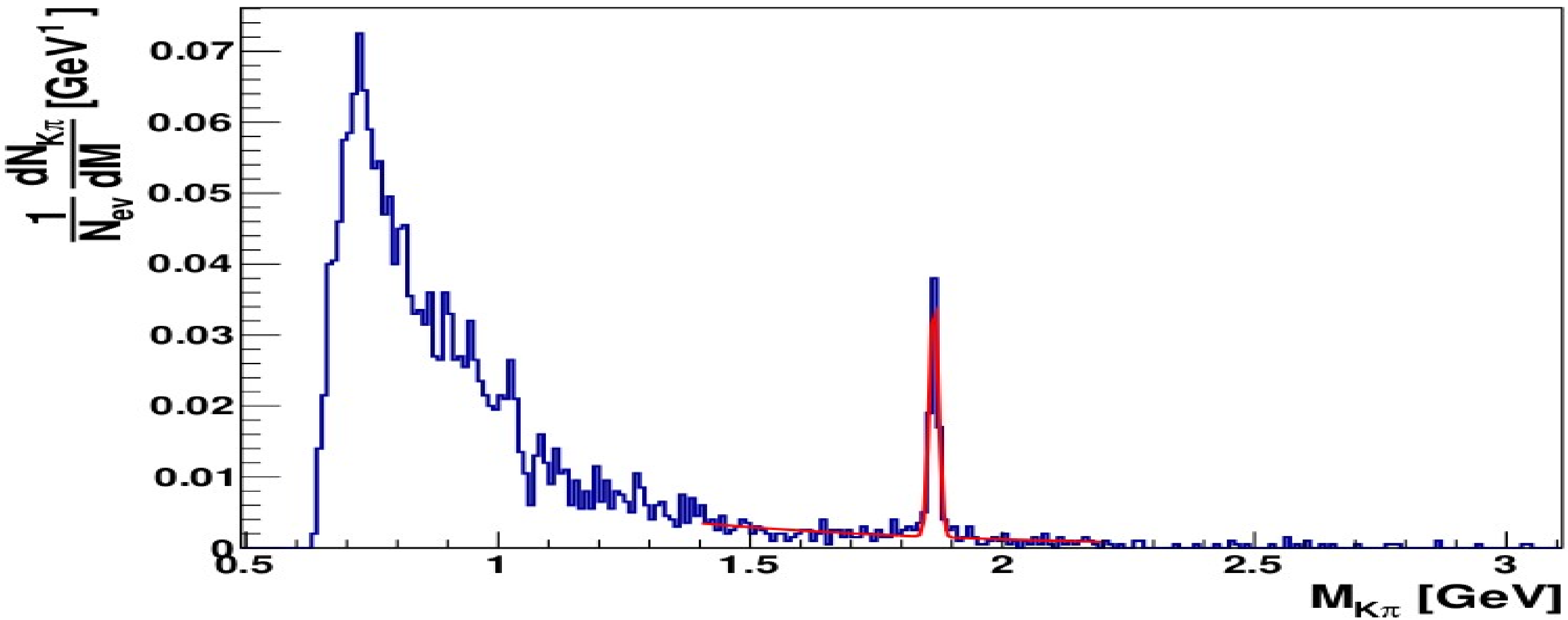
→ cut on **Vz** < 500 μm as require

Spectrum after selection Cuts

Reduction of Background ≈ 10^6



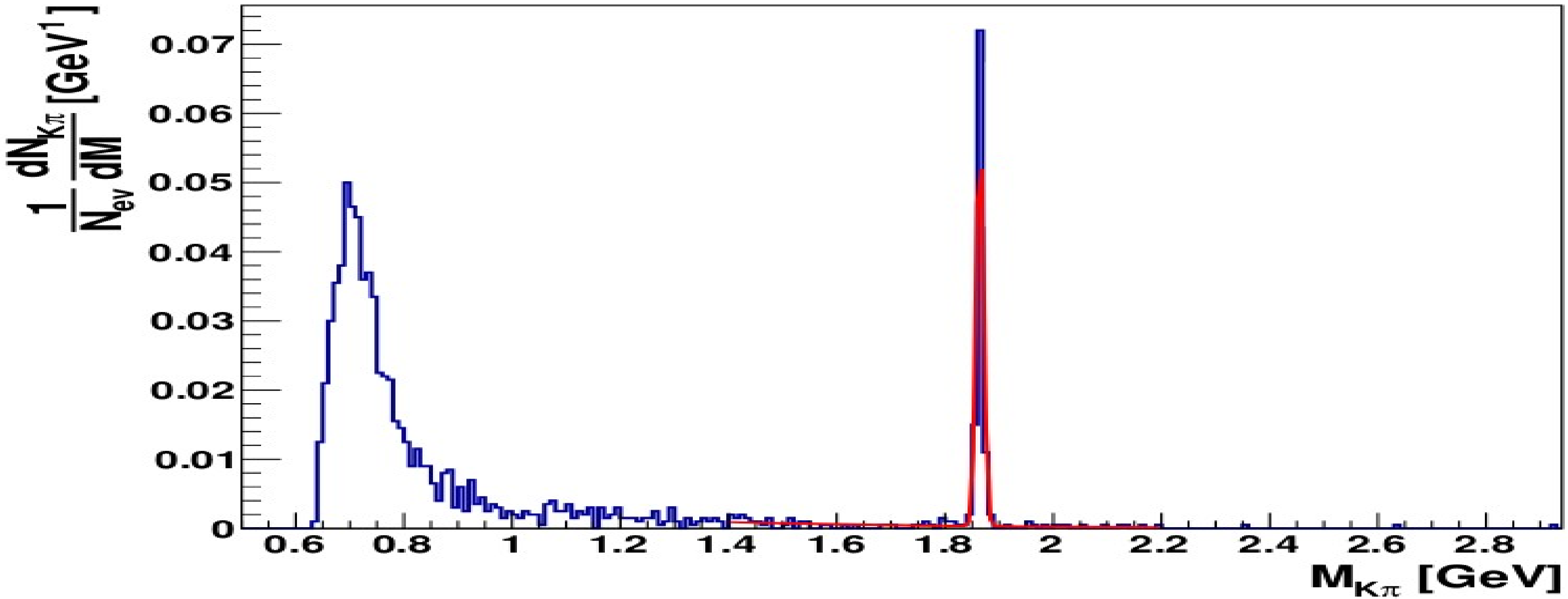
Reconstructed yield for $D^0 \rightarrow K^+ \pi^-$, 200k 0-10% cent. Pb+Pb at 158 AGeV



Beam Pos. Res (μm)	10	10	15	15
Beam hole(mm)	2.5	3.0	2.5	3.0
S/B	9.6	10.0	4.5	6.5
Signal Significance (SNR) ★	209.6	199.4	175.4	174
$\langle D^0 \rangle + \langle \overline{D^0} \rangle$ ★	48K	43K	37K	36K

★ Results Extrapolated to 50M Events

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



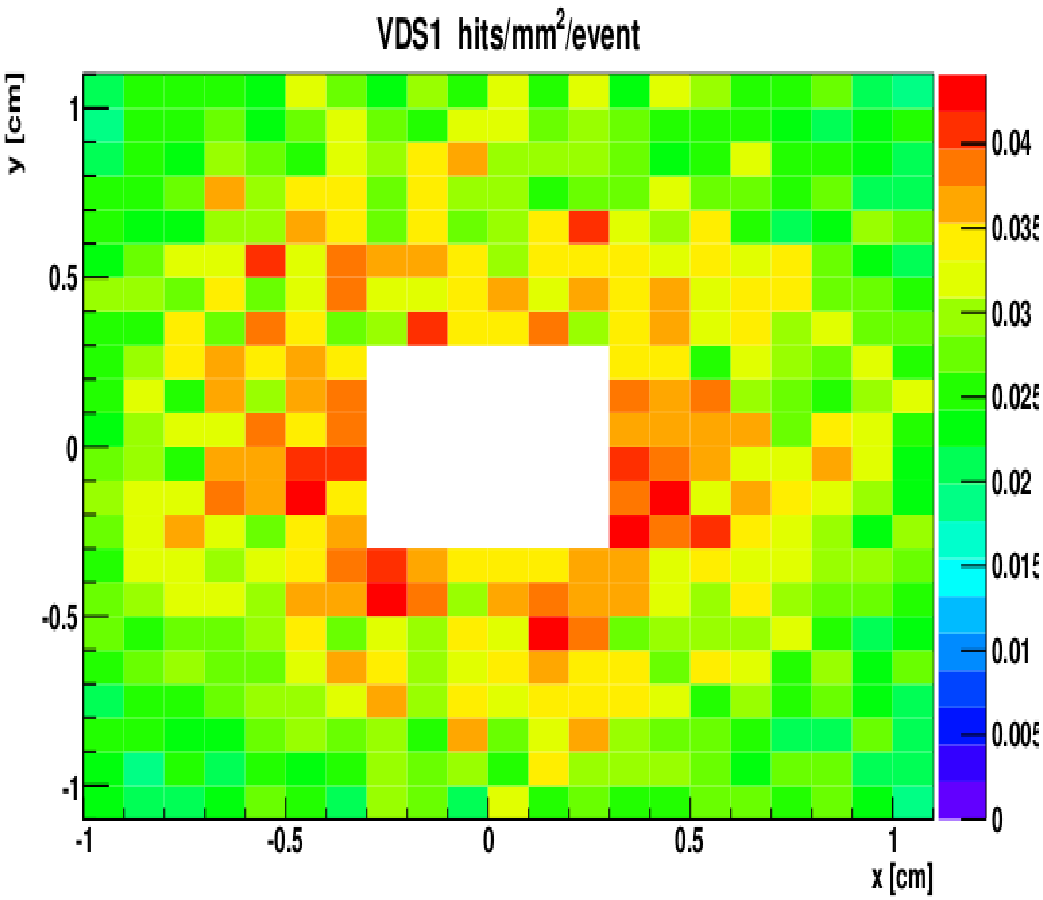
Beam Pos. Res (μm)	10	10	15	15
Beam hole(mm)	2.5	3.0	2.5	3.0
S/B	1.5	2.0	1.0	1.5
Signal Significance (SNR) ★	33.3	32.7	8.0	7.3
$\langle D^0 \rangle + \langle \overline{D^0} \rangle$ ★	1846	1759	1769	1692

★ Results Extrapolated to 50M Events

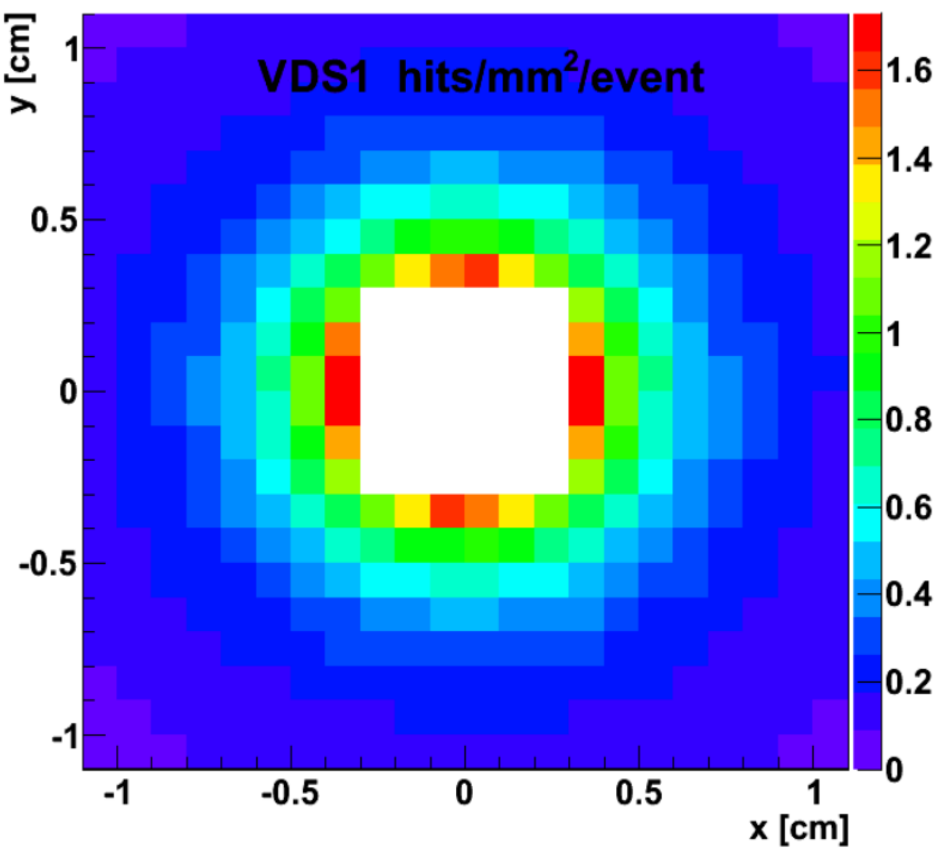
Vertex Detector Studies

δ-electrons and charge particles produced in Pb+Pb interaction

Delta electrons
(averaged over 10k Pb events)



Charged particles produced in
Pb+Pb interactions



Particle Flux:

- During spill the anticipated beam intensity is 10^5 Pb ions per second.
- For 200 μm Pb target interaction probability is 0.5% which leads to 500 Hz interaction rate

Hadronic interactions:

flux = (10^5 * 0.005) event/s * 1.6 particles/mm^2/event =

= 800 particles/mm^2/s = 800 Hz/mm^2

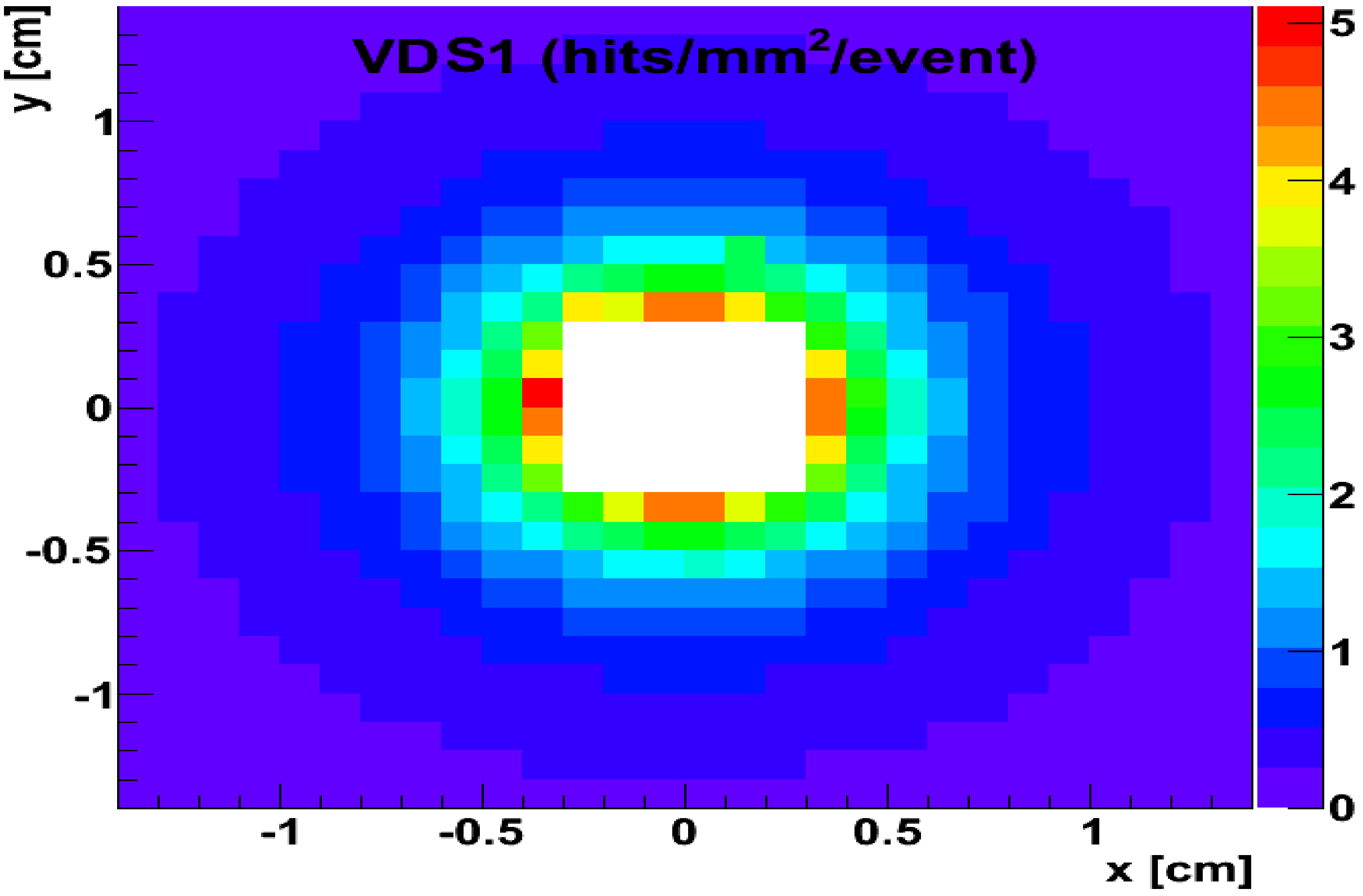
Electromagnetic interactions (δ-electrons):

flux = 10^5 event/s * 0.04 particles/mm^2/event =

= 4000 Hz/mm^2

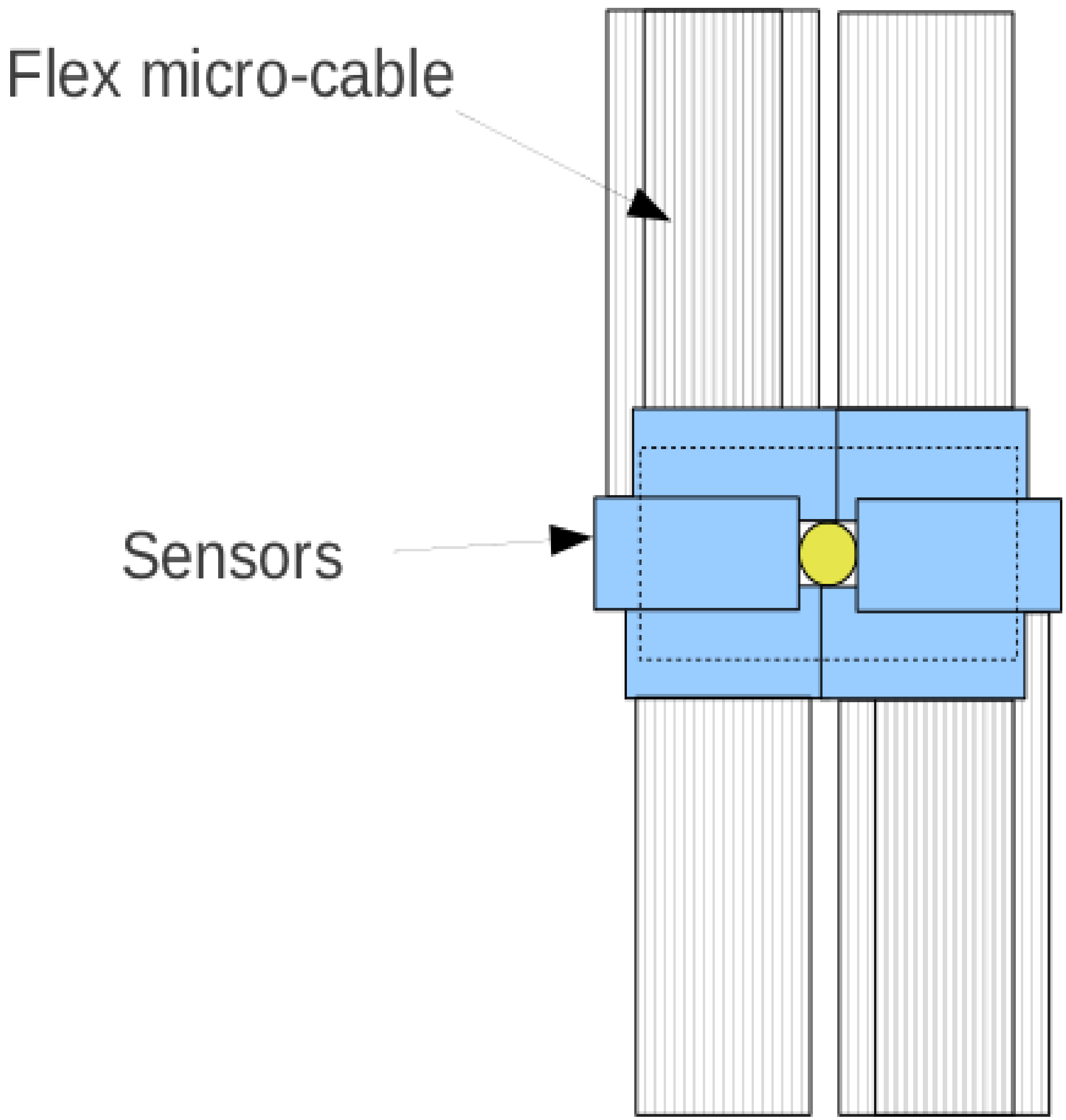
- Rate of Flux is not critical, for the future detectors

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



- High hit occupancy in the inner region (5 hits/mm^2/event)
- Two Particle Resolution ⟶ PIXEL Solution

Preliminary design of the 1st station

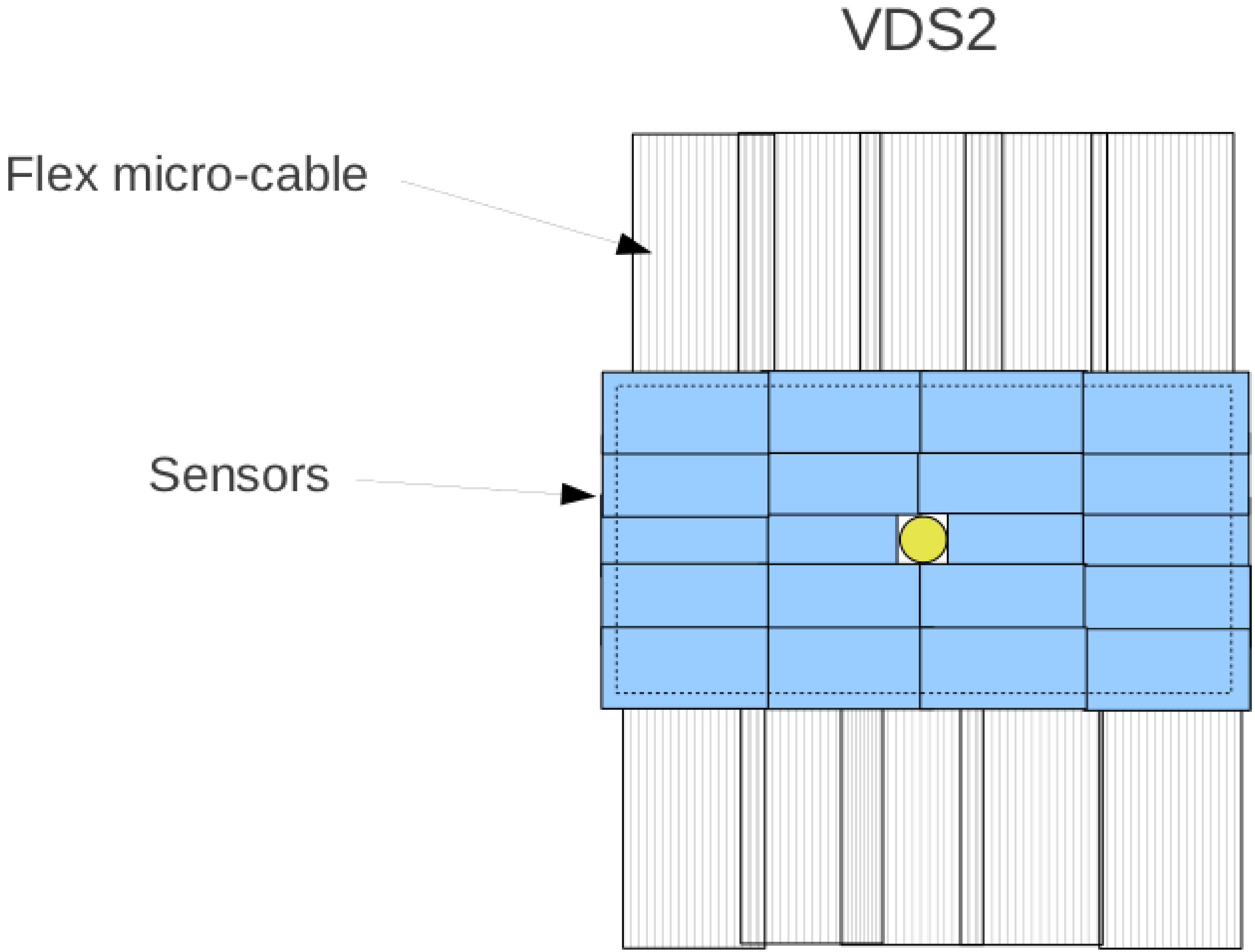


VDS1

Loss: 0.3% for 158 GeV

Loss: 3.0% for 40 GeV

Preliminary design of the 2nd station



Summary

- The Monte Carlo Simulations of D^0 mesons decay into kaon + pion channel shows feasibility of collection of about 40K open charms in 50M events.

- The simulations have shown that the measurements of the D^0 and $\overline{D}^0$ mesons in NA61 experiment with a dedicated vertex detector is feasible.

- In the next stage of the study, need to include the digitization in terms of realistic track reconstruction.

- Also the detection technology for the realization of the new vertex detector must be finalized.

- Measurement of Λ_c and improvement in the multi-strange hyperon measurement


Thank You!

BACK UP SLIDES

Parameters for 40 AGeV

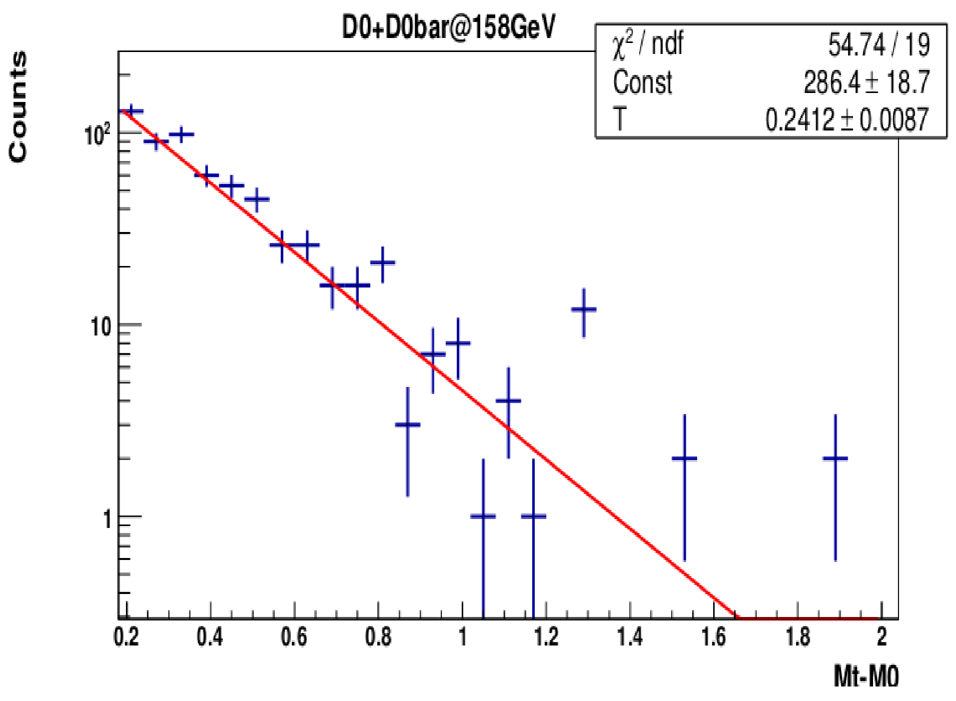
For the studies at 40 AGeV energy the whole phase space (physical input) was not available by AMPT event generator.

Sigma → From the rapidity distributions for kaons at both energies 40 and 158 AGeV and for D0 meson at 158 AGeV respectively.

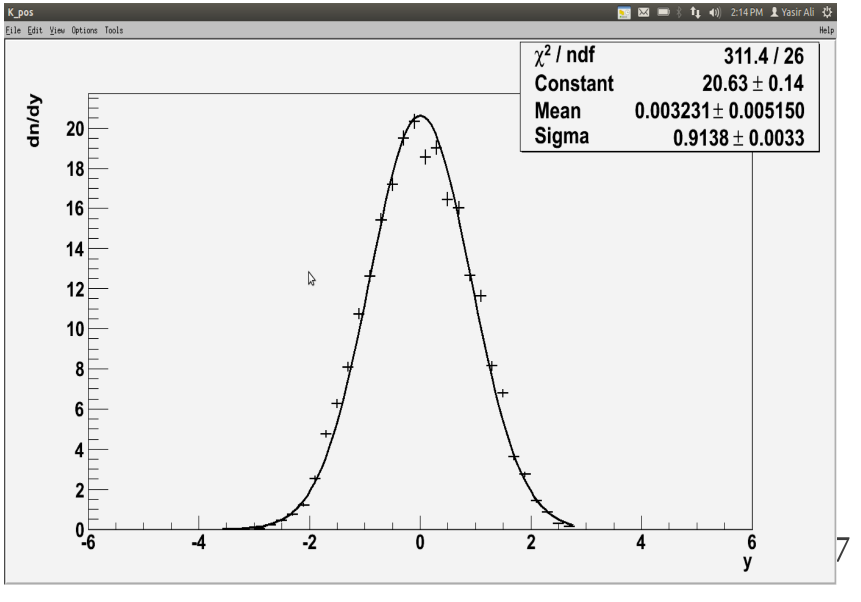
Sigma K(158)/Sigma K(40) = Sigma D(158)/Sigma D(40)

Temperature From transverse mass distributions By Fitting

Exponential Function A Exp(-mt/T)



Kplus @ 40 AGeV



Acknowledgments

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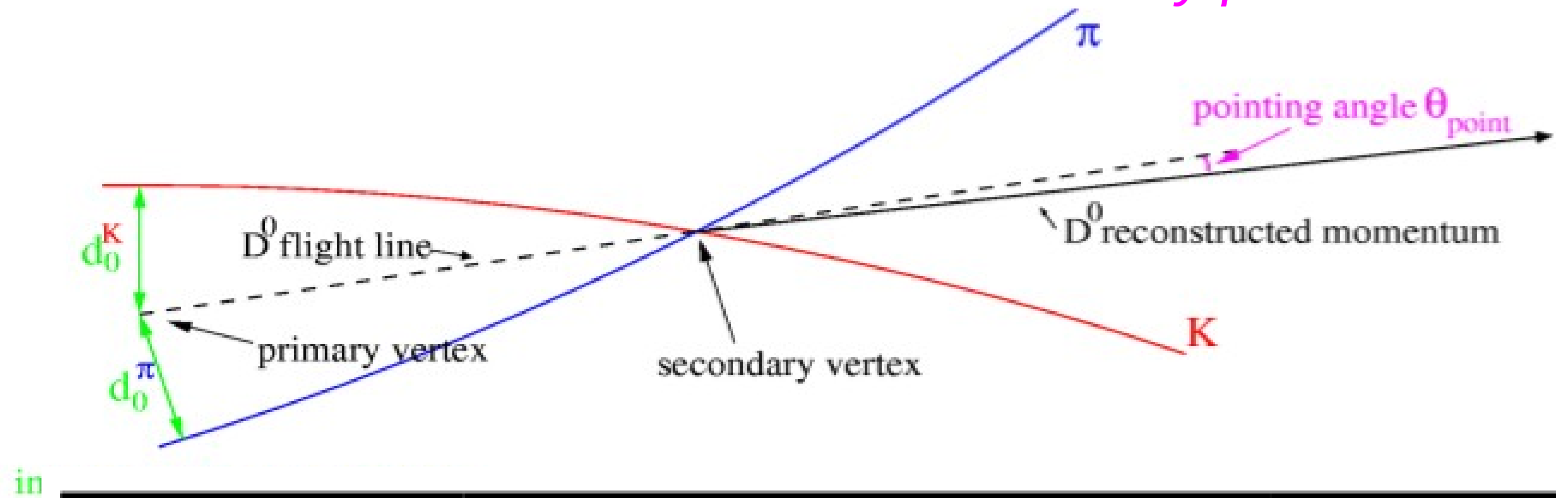
→ NA61 Collaboration

→ Division of Hot Matter Physics
M. Smoluchowski Institute of Physics, Jagiellonian University, Krakow Poland

Detection Strategy

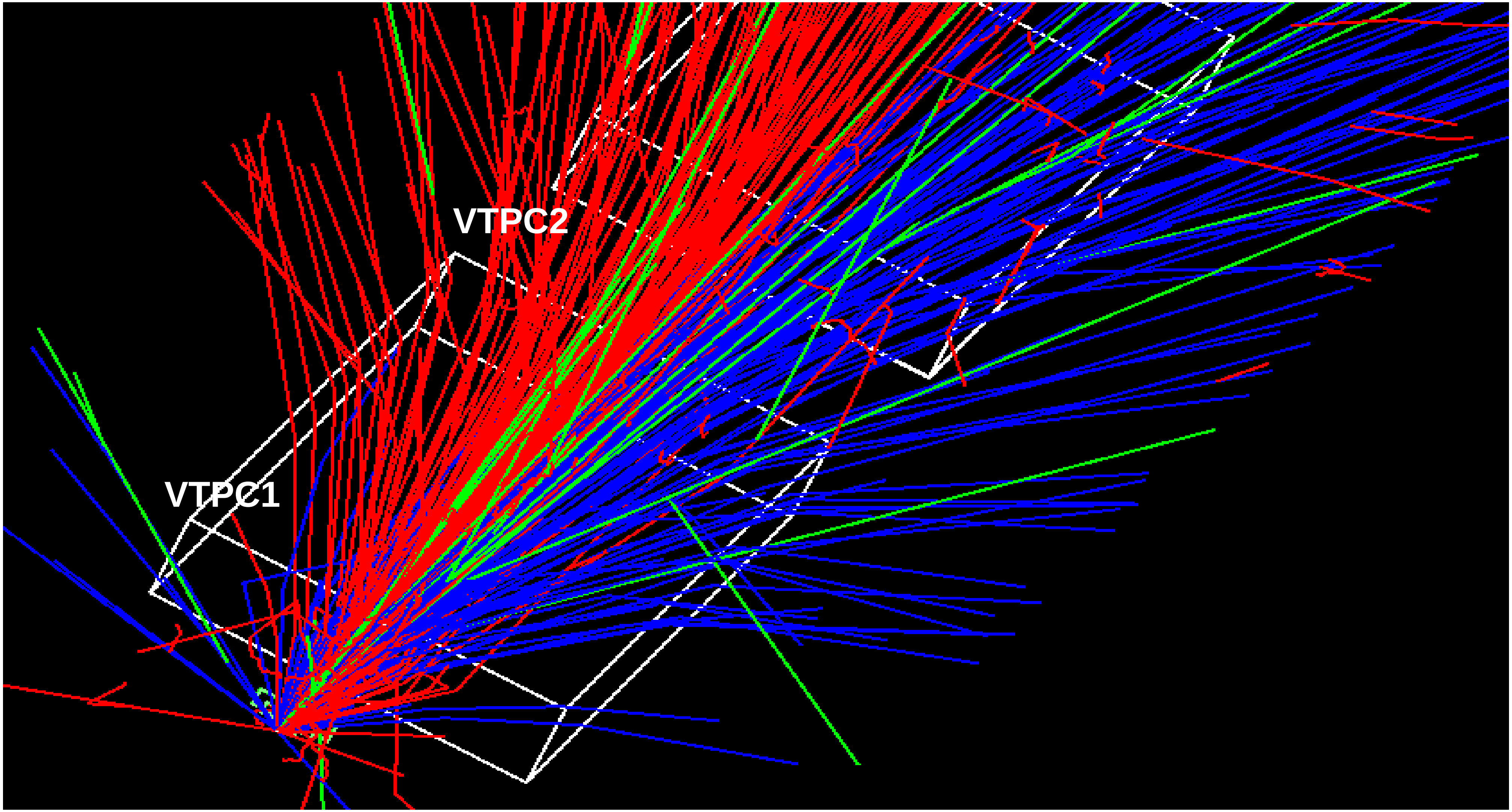
"Distance between interaction Point and decay point is measurable"



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

The average multiplicity for 158AGeV is 0.01 * 1/0.0378 = 0.26 (consistent with HSD) for 40 AGeV it is 0.01

Detector overview in GEANT simulation



→ **VTPCs filled with Ar-CO_2 mixture, location and dimensions as in Na61 setup.**

→ **Uniform magnetic field: 1.5 T in $VTPC_1$ and 1.1 T in $VTPC_2$**

Background suppression strategy (Need to discuss)

List of cuts in the order they are applied

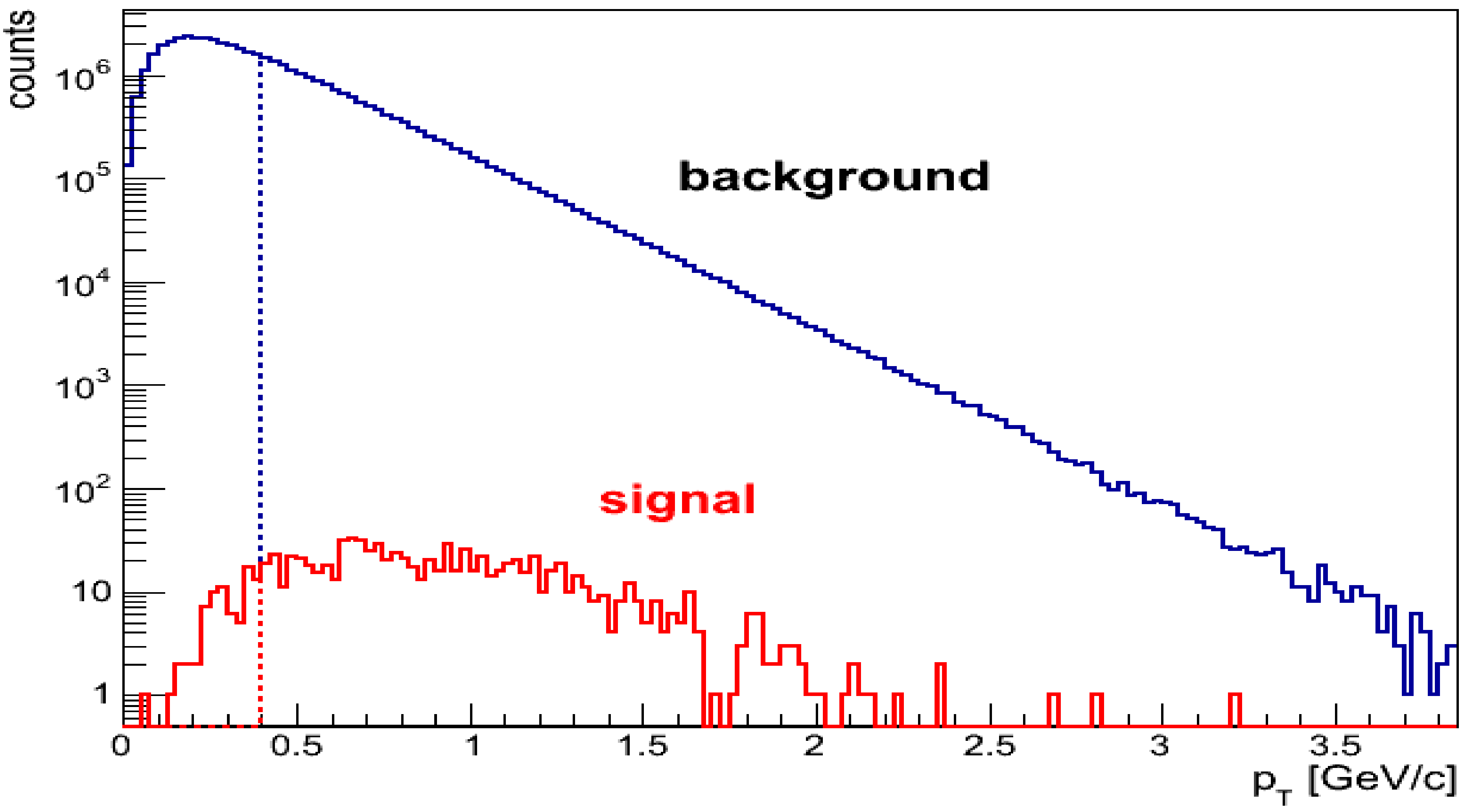
Single particle cuts:

1. track **pT** cut
2. track **d** cut (track impact parameter)

Two particle cuts:

3. cuts in Armenteros-Podolanski space to remove background from Ks and Λ
4. two track vertex cut **Vz**
5. reconstructed parent impact parameter cut **D**

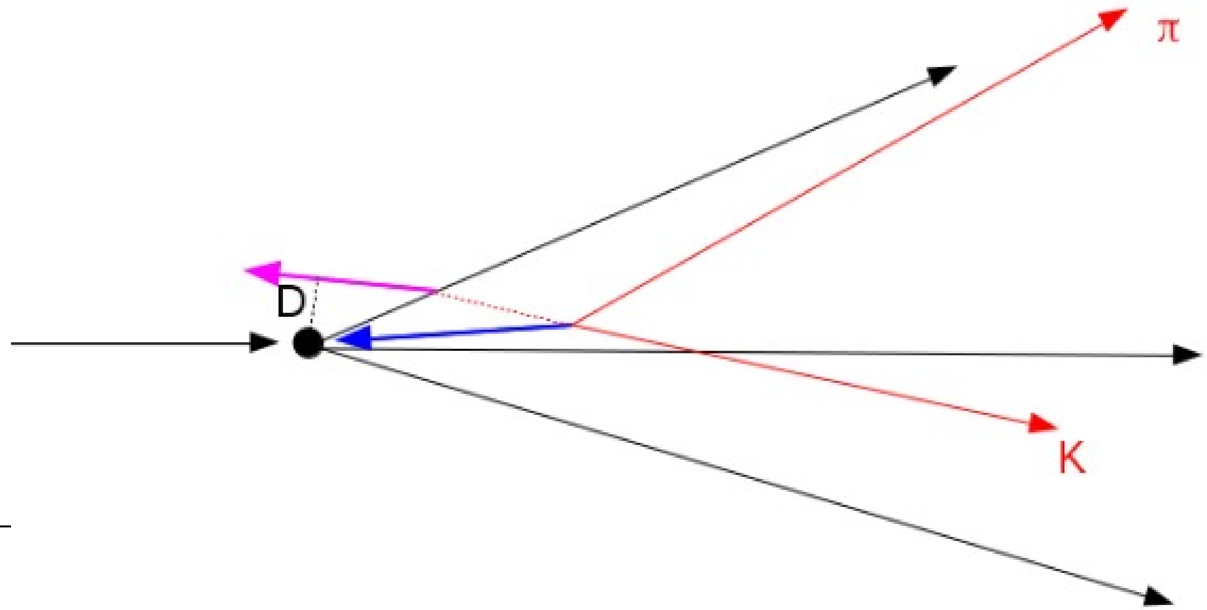
1. cut on **pT**

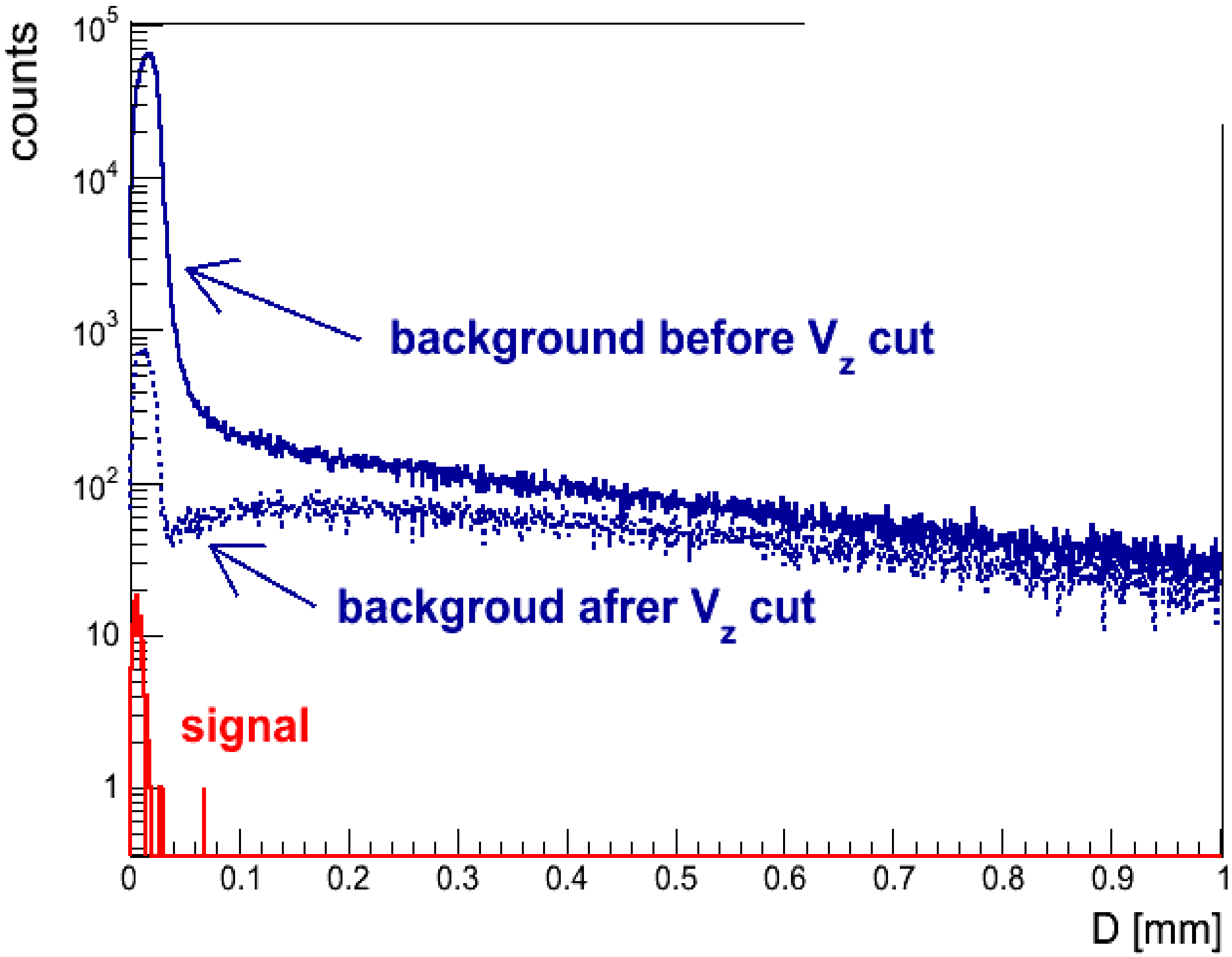


Background pT spectrum has maximum around ~ 0.2GeV/c, wheres maximum of signal distribution is at around 1 GeV/c

→ cut on pT<0.4 as indicated

3. cut on **D**





Vz cut reduces background at D ~ 0, where the signal is located → Vz and D cuts are nicely complementary to each other

→ cut on **D** > 0.022 mm

Charged Particle Fluxes

Sources of particles hitting VD:

1. Charged particles produced in Pb+Pb interactions.
   - during spill the anticipated beam intensity is 10^5 Pb ions per second.
   - for 200 μm Pb target interaction probability is 0.5% which leads to 500 Hz interaction rate
   - used AMPT to generate 100k min. bias Pb+Pb at 158 AGeV

2. Delta electrons produced mostly in target
   - study 10k Pb ions passing through the lead target
   - soft particles – surrounding material might be important
   - production threshold cut in geant4: minimum distance that produced particle will travel in a given material → translates to cut on energy
     If the distance is (too) small – a lot of soft particles is produced (CPU consumption)
     If the distance is (too) large – important component might not be described

→ the influence of the production threshold cut has to be studied