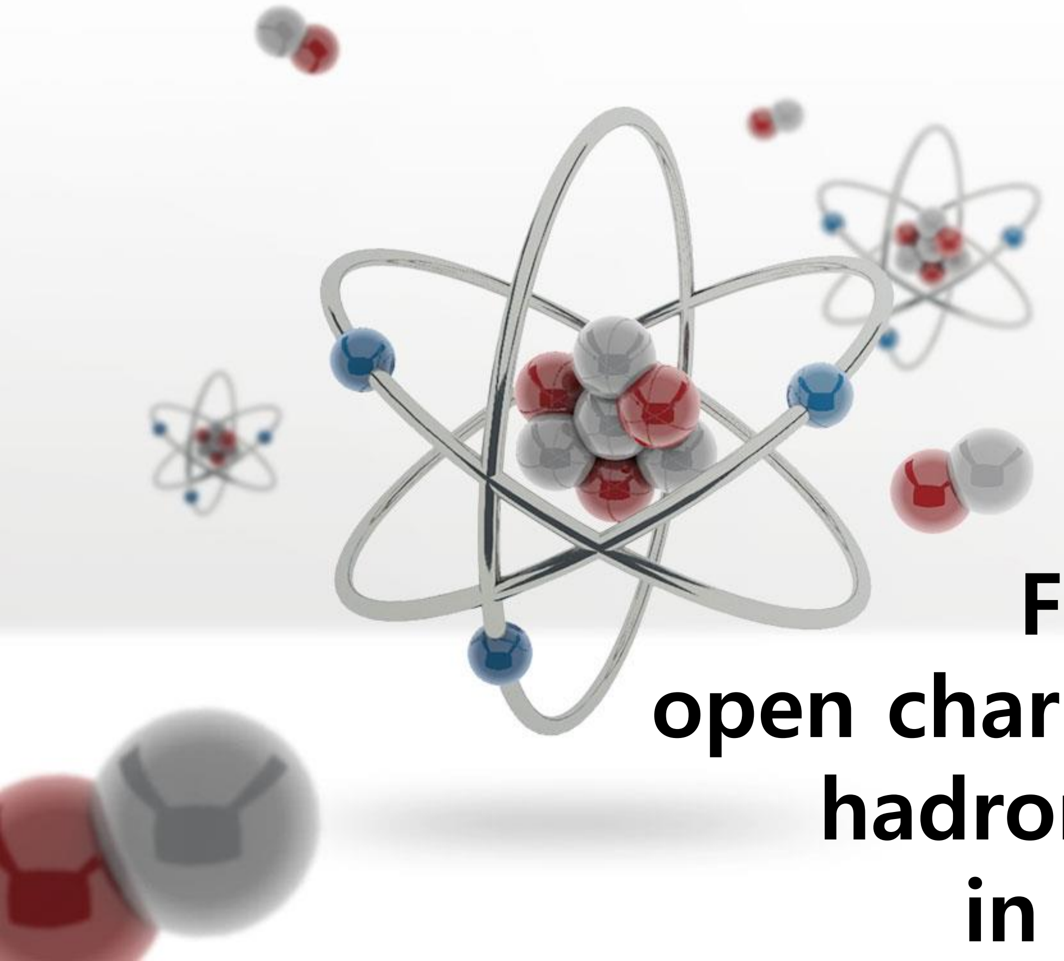
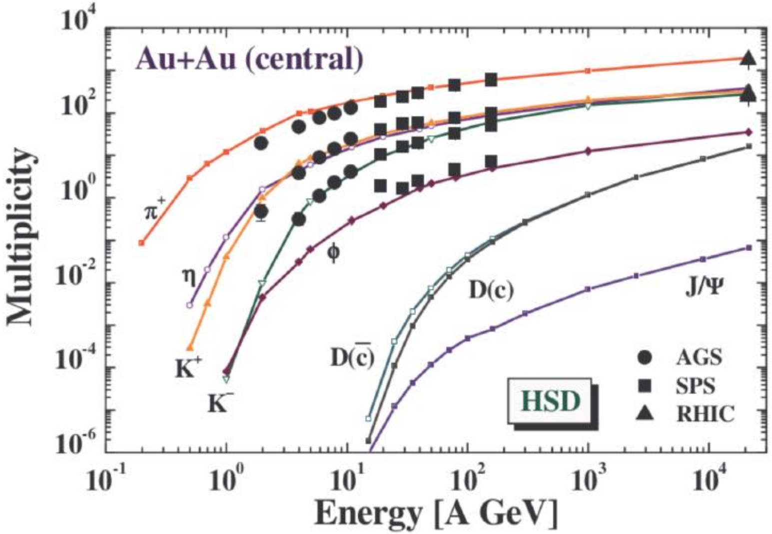


Feasibility of open charm and multi-strange hadron measurements in NA61/SHINE

Open charm simulations

200k of the 0-10% most central Pb+Pb collisions at 150AGeV/c were generated using the AMPT (A MultiPhase Transport) model



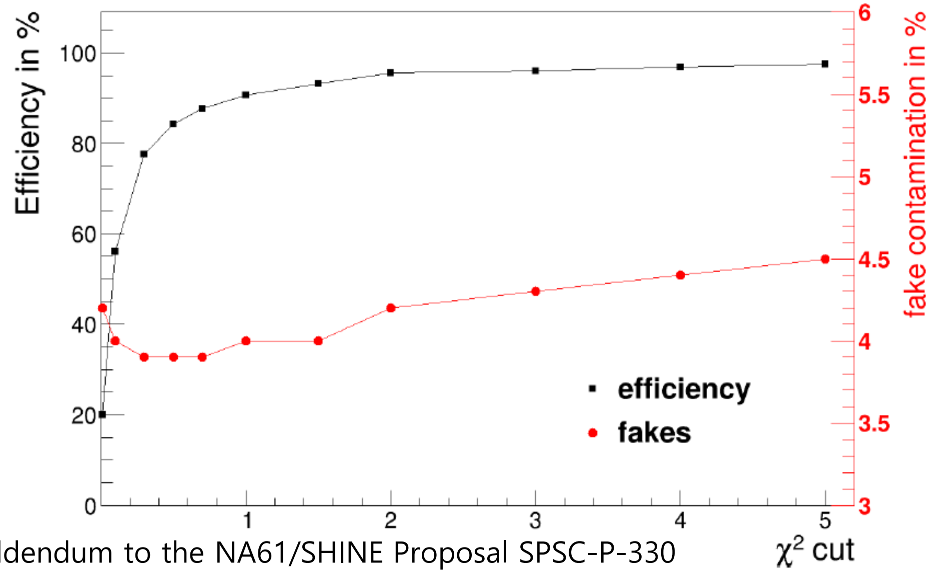
The model properly describes production of charged pions and kaons which contribute most of the combinatorial background in the mass distribution of pion-kaon pairs from which the open charm signal.

The AMPT model predicts an average multiplicity of about 0.01 for $D^0 + \overline{D}^0$ mesons produced in central Pb+Pb collisions at 150*A* GeV/c.
This value is significantly lower than the predictions based on the PYTHIA and HSD.
It was decided to scale the AMPT mean multiplicity for $D^0 + \overline{D}^0$ mesons to the HSD prediction.

L. Zi-Wei et al. Phys. Rev. **C72** (2005) 064901
E. Linnyk, Bratkovskaya and W. Cassing Int. J. Mod. Phys. **E17** (2008) 1367.

Open charm – track reconstruction

The track reconstruction is based on the hits generated by particles passing through the Small Acceptance Vertex Detector (SAVD), the VTPC-1 and the VTPC-2.

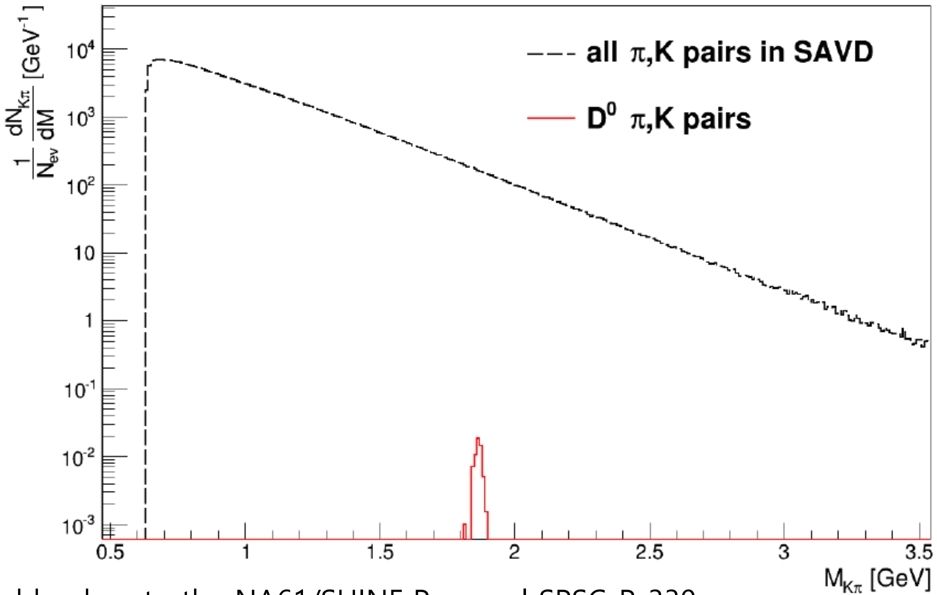


Addendum to the NA61/SHINE Proposal SPSC-P-330
CERN-SPSC-2015-038 / SPSC-P-330-ADD-8

Straight-line tracking based on the Hough-transform method is employed for standalone tracking in the VD.
Hits in the VD are assigned to track parameterizations, to which they may potentially fit. The tracks with the largest number of "votes" are considered as true tracks, while the others are discarded as noise
Three or four stations are required to consider the associated hits a track candidate. Next, straight-line fits are performed on the track candidates and those with χ^2 values below the cut limit are considered as reconstructed.

The strategy for reconstructing open charm

The invariant mass distribution for kaon-pion pairs accepted in the SAVD



Addendum to the NA61/SHINE Proposal SPSC-P-330
CERN-SPSC-2015-038 / SPSC-P-330-ADD-8

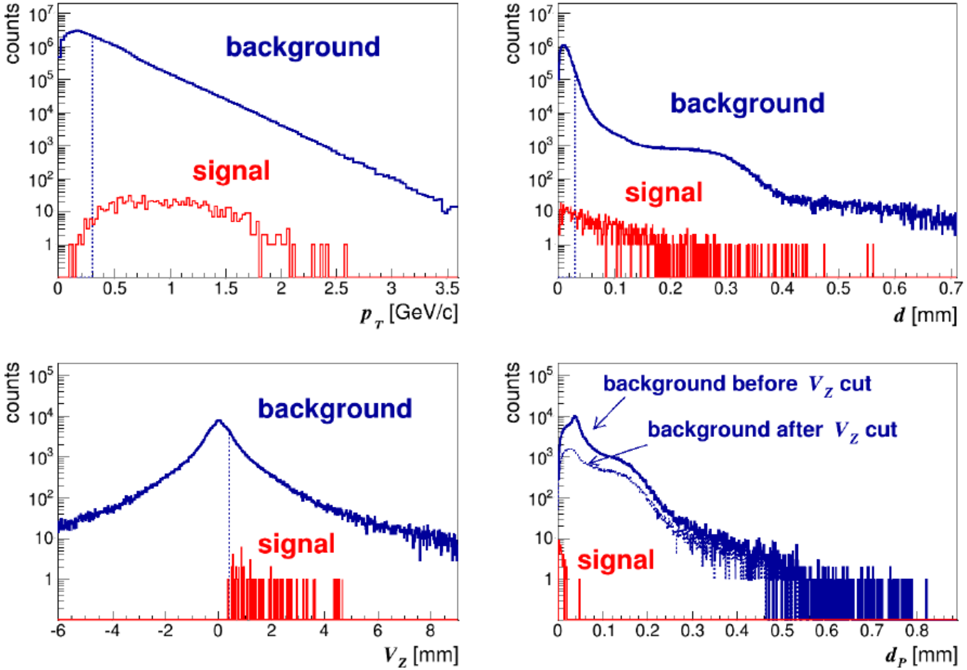
The combinatorial background is several orders of magnitude higher than the signal shown in red color.

D^0 mesons typically decay tens to hundreds of microns downstream of their production point.

To select pion and kaon pairs that originate from D^0 decays, one needs to reconstruct the decay vertex with a precision of about 50 μm. This precision can be reached with a VD added to the NA61/SHINE set-up.

The strategy for reconstructing open charm

In order to reduce the large combinatorial background, four kinematical and topological cuts are applied:



(i) A cut on the track transverse momentum p_T,

(ii) a cut on the track impact parameter d,

(iii) a cut on the longitudinal distance V_Z between the D decay candidate and the interaction point,

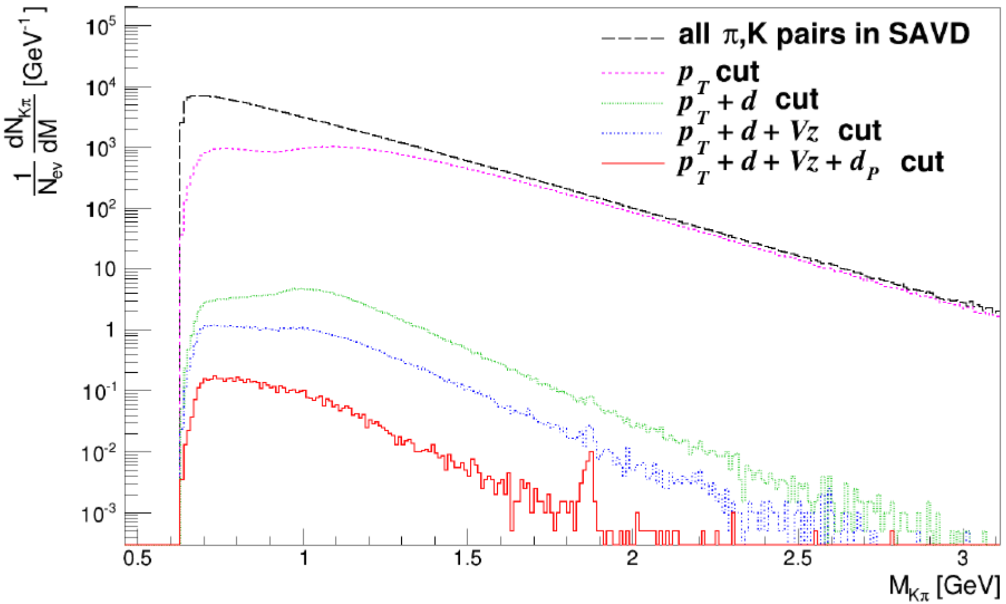
(iv) a cut on the impact parameter d_P of the back-extrapolated D candidate momentum vector.

We select tracks with p_T > 0.31 GeV/c, d > 31 μm, and track pairs with V_z > 400 μm, d_P < 20 μm.

Addendum to the NA61/SHINE Proposal SPSC-P-330 CERN-SPSC-2015-038 / SPSC-P-330-ADD-8

The strategy for reconstructing open charm

The cuts reduce the number of **signal pairs by a factor of 2**, while the number of **background** pairs in the signal region is reduced **by a factor of 2x10^5**



The distributions were obtained assuming perfect particle identification.

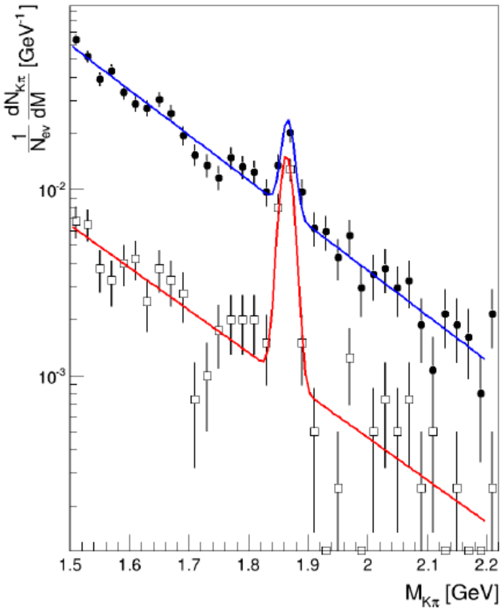
Addendum to the NA61/SHINE Proposal SPSC-P-330
CERN-SPSC-2015-038 / SPSC-P-330-ADD-8

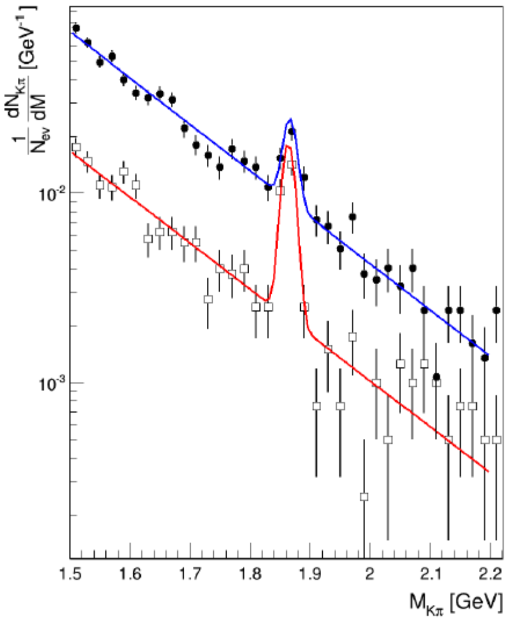
SAVD simulations results

The invariant mass of pion-kaon pair candidates after the cuts for the SAVD. The curves represent the fit with a sum of exponential (background) and Gaussian (D^0 signal) functions.

Left: The results for perfect PID (open symbols) and without PID (solid symbols).

Right: The results for realistic PID (open symbols) and without PID (solid symbols).





SAVD simulations results

The total number of measured $D^0 + \overline{D}^0$ decays in 4 millions central Pb+Pb collisions at 150*A* GeV/c (statistics after 1 day of data taking beyond 2020) is estimated to be about 1500.

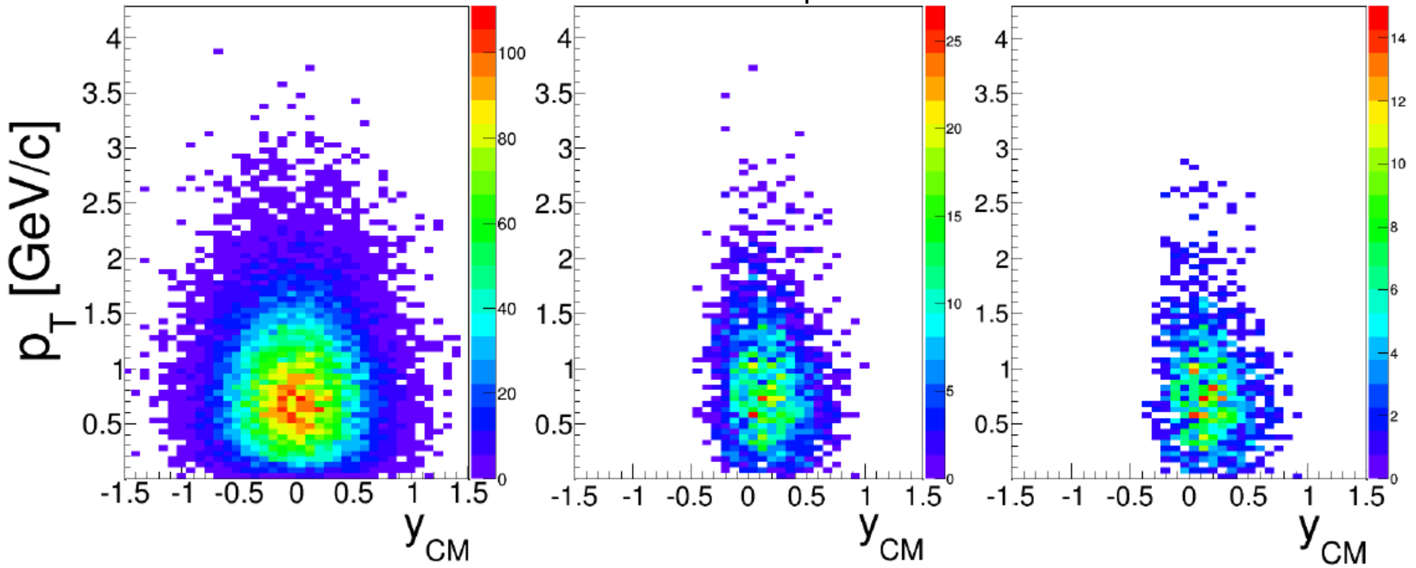
The signal to background ratio (S/B) is 5 (0.5) and the SNR is 34 (22) assuming perfect PID (without PID).

To obtain a first guess of the feasibility of open charm measurements at 75*A* GeV/c, we scaled the results obtained for 150AGeV/c with the open charm production multiplicities predicted for 75*A* GeV/c. According to this scaling, the SAVD is expected to reconstruct 350 D^0 from 4 million central Pb+Pb collisions at 75*A* GeV/c. Given that the multiplicity of the background is smaller at the lower energy, we assume that this yield is sufficient to create a significant peak in the invariant mass spectrum.

SAVD simulations results

Population of D^0 mesons in transverse momentum p_T and rapidity y.

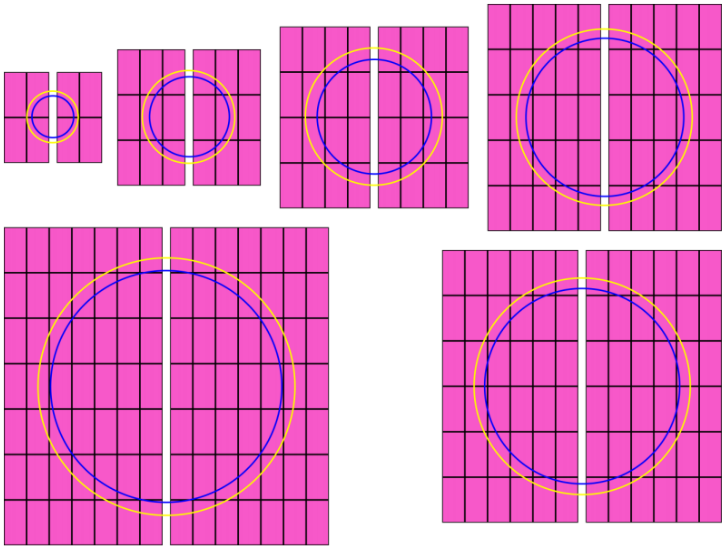
all generated | within the SAVD acceptance | within the SAVD acceptance and after all cuts



Results are plotted for the 0-20 % most central Pb+Pb collisions at 150*A* GeV/c and correspond to 4 million events.

Vertex Detector beyond 2020

In the VD beyond 2020 the stations are located at the same distances as in the SAVD.

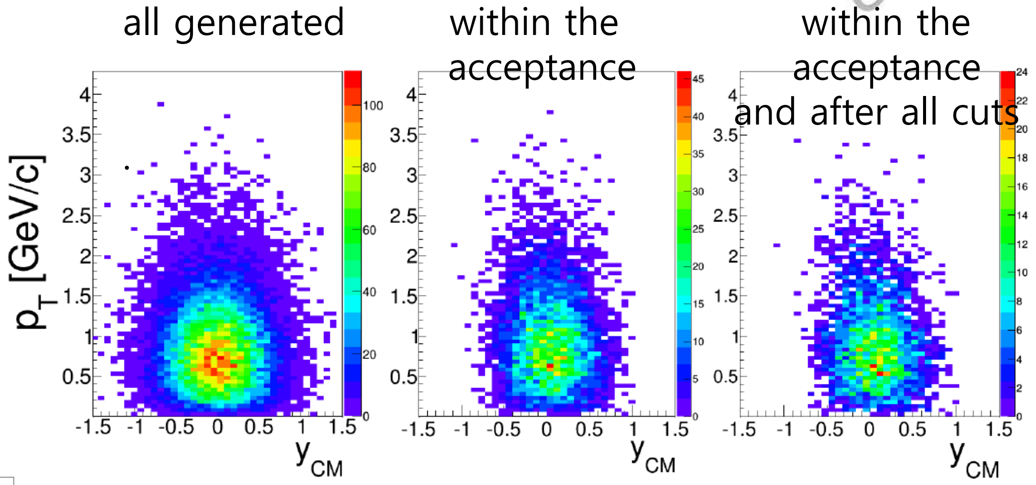


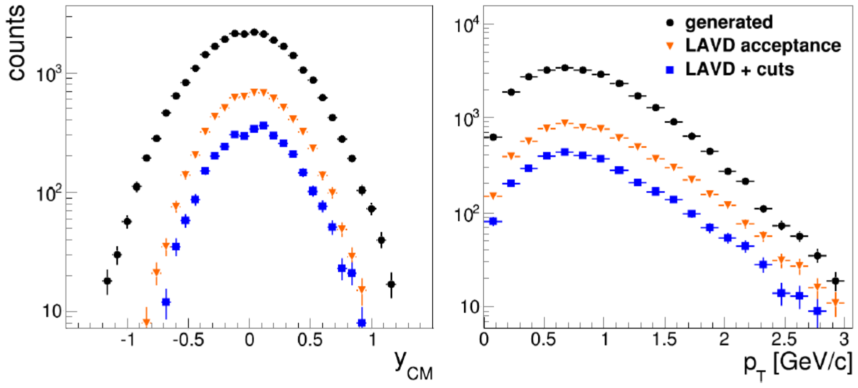
Approximately 6 layers with 220 ALPIDE sensors (fake hits rate 1000 times lower). Basically geometry of LAVD with additional layers.

Vertex Detector beyond 2020

Results are plotted for the 0-20 % most central Pb+Pb collisions at 150*A* GeV/c and correspond to 4 million events. –

1 day of data taking beyond 2020



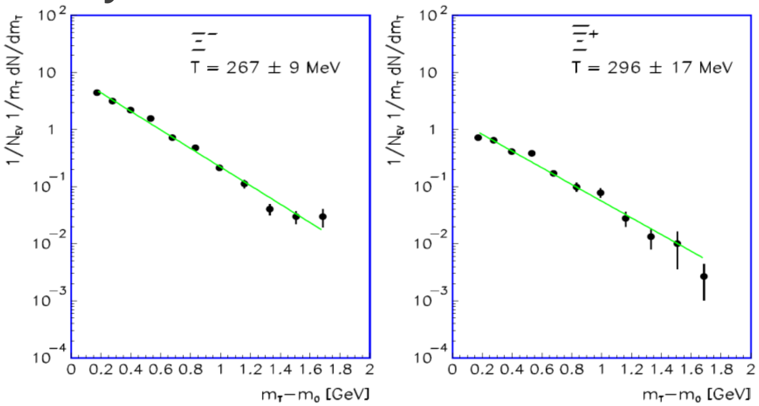


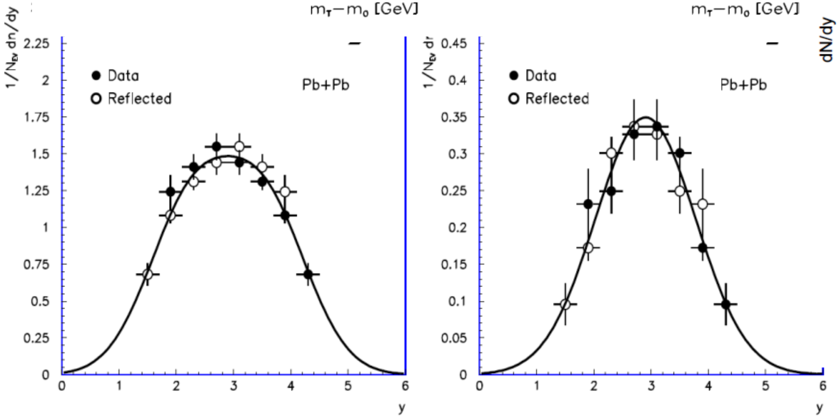
10 days of Pb+Pb data taking in 2021 (40M events):

Beam momentum	40*A* GeV/c	75*A* GeV/c	150*A* GeV/c
D^0 candidates	1000	7000	40000

Multi-strange hadrons beyond 2020

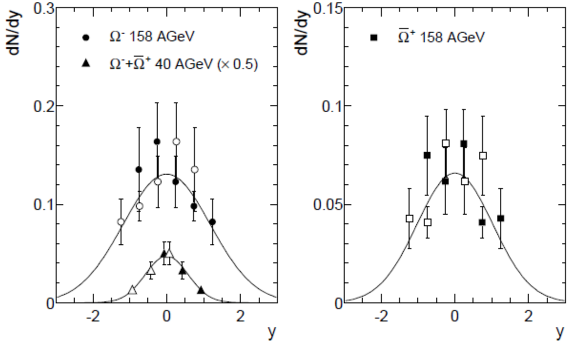
History

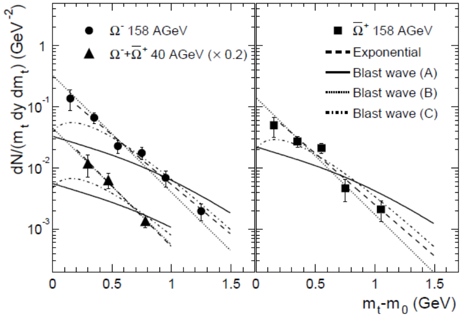




NA49 experiment measured Ω production in Pb+Pb collisions (with centrality window 22%) based only on candidates with decay length higher than 25 cm from interaction point

and Ξ production (with centrality window 7%) based only on candidates with decay length higher than 35 cm from interaction point

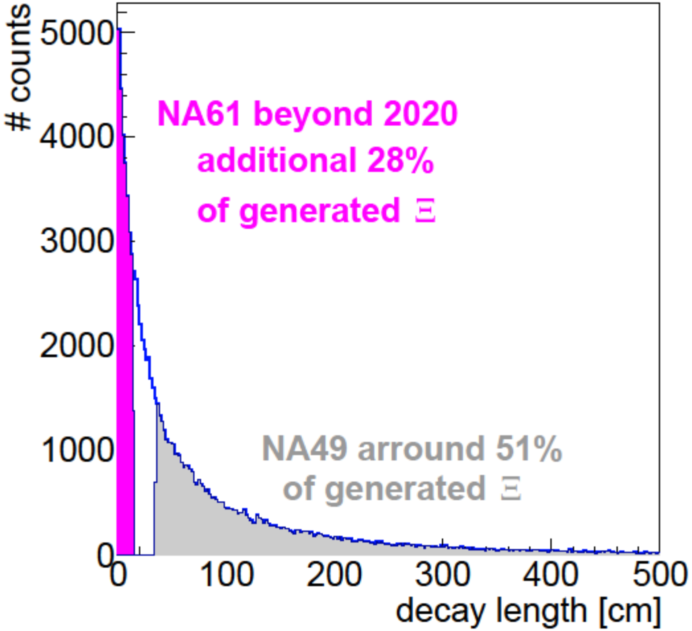




NA49 Collaboration: **Phys.Rev.Lett. 94 (2005) 192301, Phys.Lett. B538 (2002) 275-281**

Multi-strange hadrons beyond 2020

Impact of vertex detector for Ξ measurements



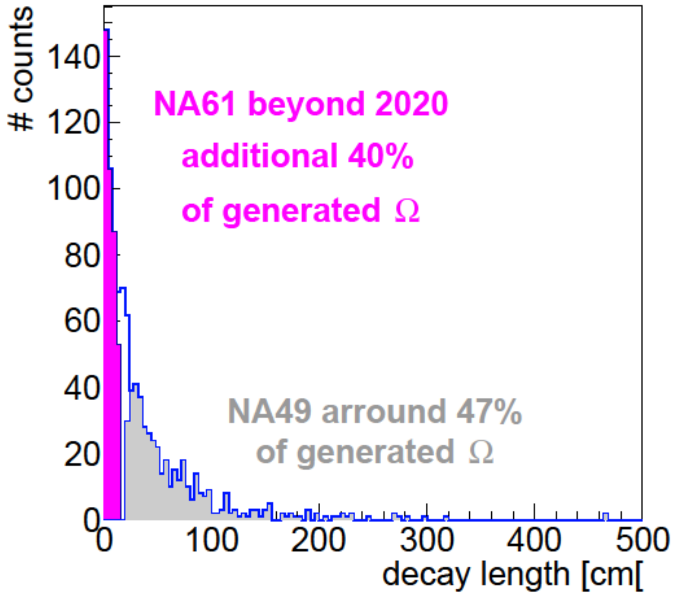
Precise vertex measurement should automatically reduce combinatorial background.
Acceptance similar to NA49.
Additional 28% of Ξ visible.

Pb+Pb at 158*A* GeV/c:

Source	Ξ^-	$\overline{\Xi}^+$
NA49 (400k events)	4800	900
VD improvement (400k events)	7400	1400
Readout rate (40M events)	740000	140000

Multi-strange hadrons beyond 2020

Impact of vertex detector for Ω measurements



Precise vertex measurement should automatically reduce combinatorial background.
Acceptance similar to NA49.
Additional 40% of Ω visible.

Pb+Pb at 158*A* GeV/c:

Source	Ω^-	$\overline{\Omega}^+$
NA49 (400k events)	~350	~100
VD improvement (400k events)	650	185
Readout rate (40M events)	65000	18500

Summary

NA61 beyond 2020 will be well suited to precisely measure open charm and multi strange hadrons produced in Pb+Pb collisions at 40-150A GeV/c

- Statistics should be sufficient to obtained two dimensional spectra of Ξ, Ω, D^0 and their antiparticles.
- Expected number of measured particles produced in central Pb+Pb collisions at 150*A* GeV/c during 10 day of data taking in 2021:

	D^0	Ξ^-	Ω^-
statistic	40000	740000	65000

- Peak of D^0 produced in central Pb+Pb collisions at 40*A* and 75*A* should be visible.
- Additionally high precision of produced Ξ, Ω in central Pb+Pb collisions at 40*A* and 75*A* GeV/c will be possible.