

The logo for SHINE consists of the word "SHINE" in a bold, blue, sans-serif font. The letter "S" is partially obscured by a graphic of several parallel diagonal lines in blue and orange, creating a sense of motion or energy.

SHINE

NAGI/SHINE PLANS FOR 2018 - 2024

M. GAZDZICKI (FRANKFURT, KIELCE)
FOR THE NAGI/SHINE COLLABORATION

PBC, CERN, JUNE 19, 2018

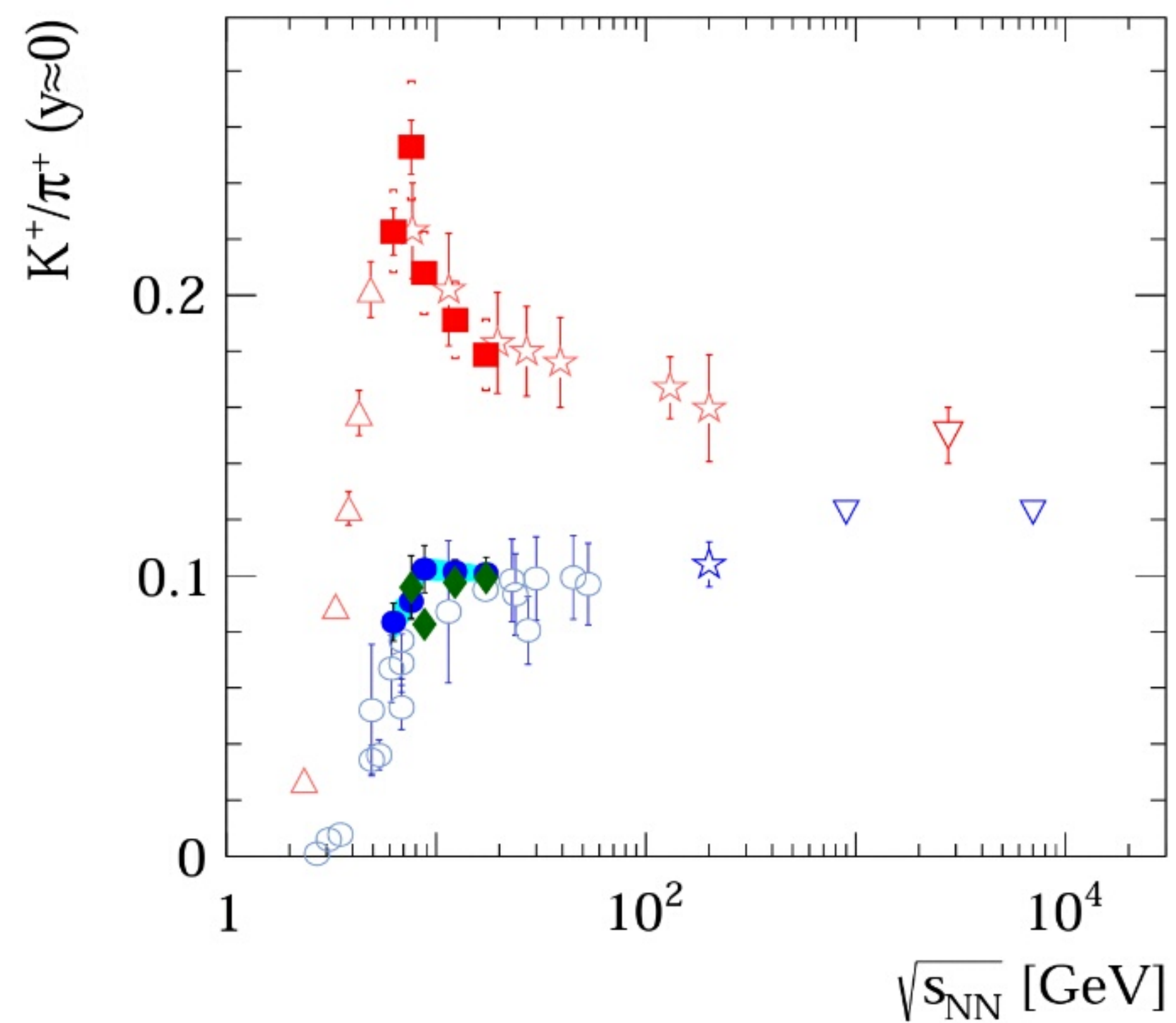
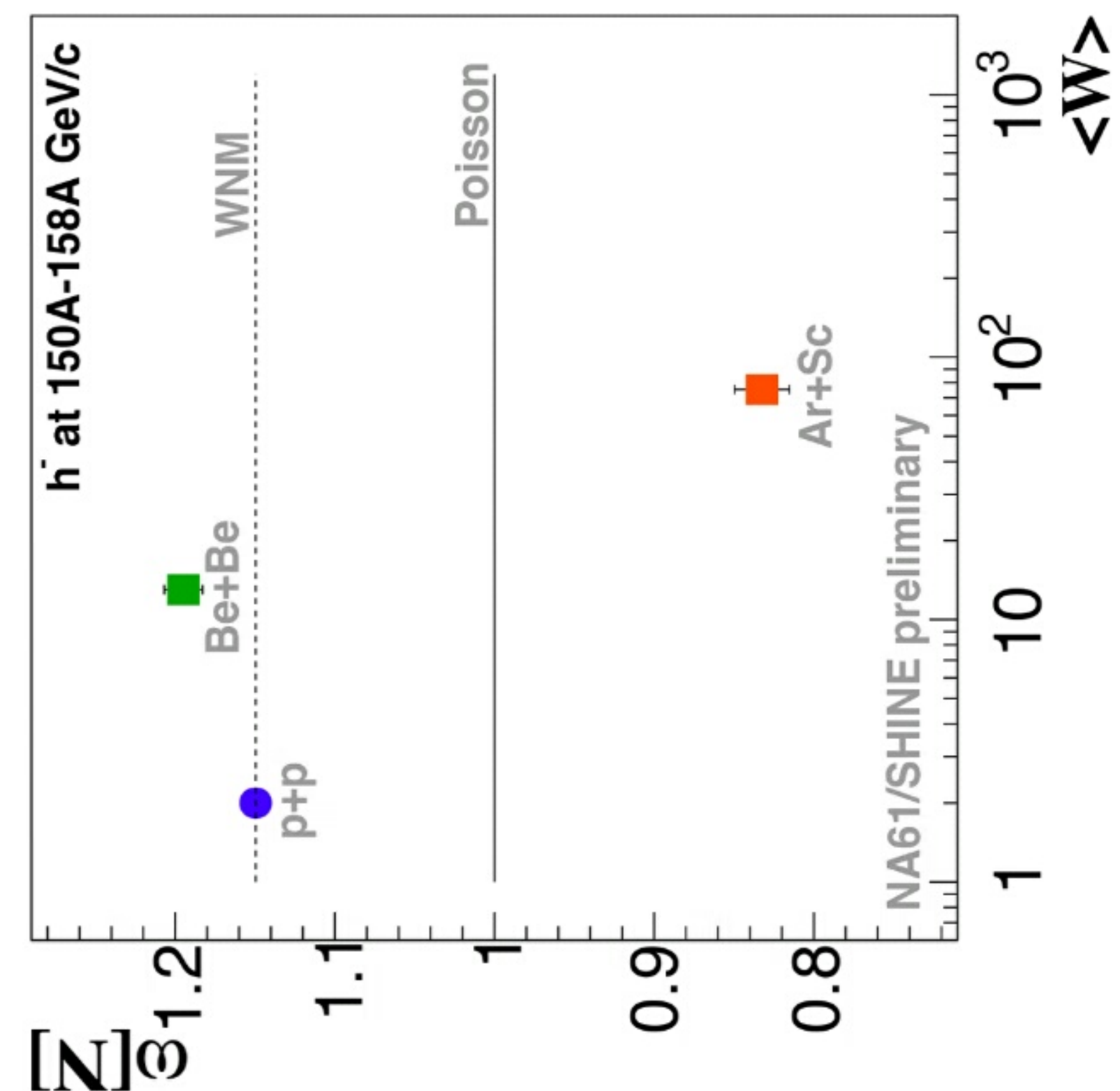
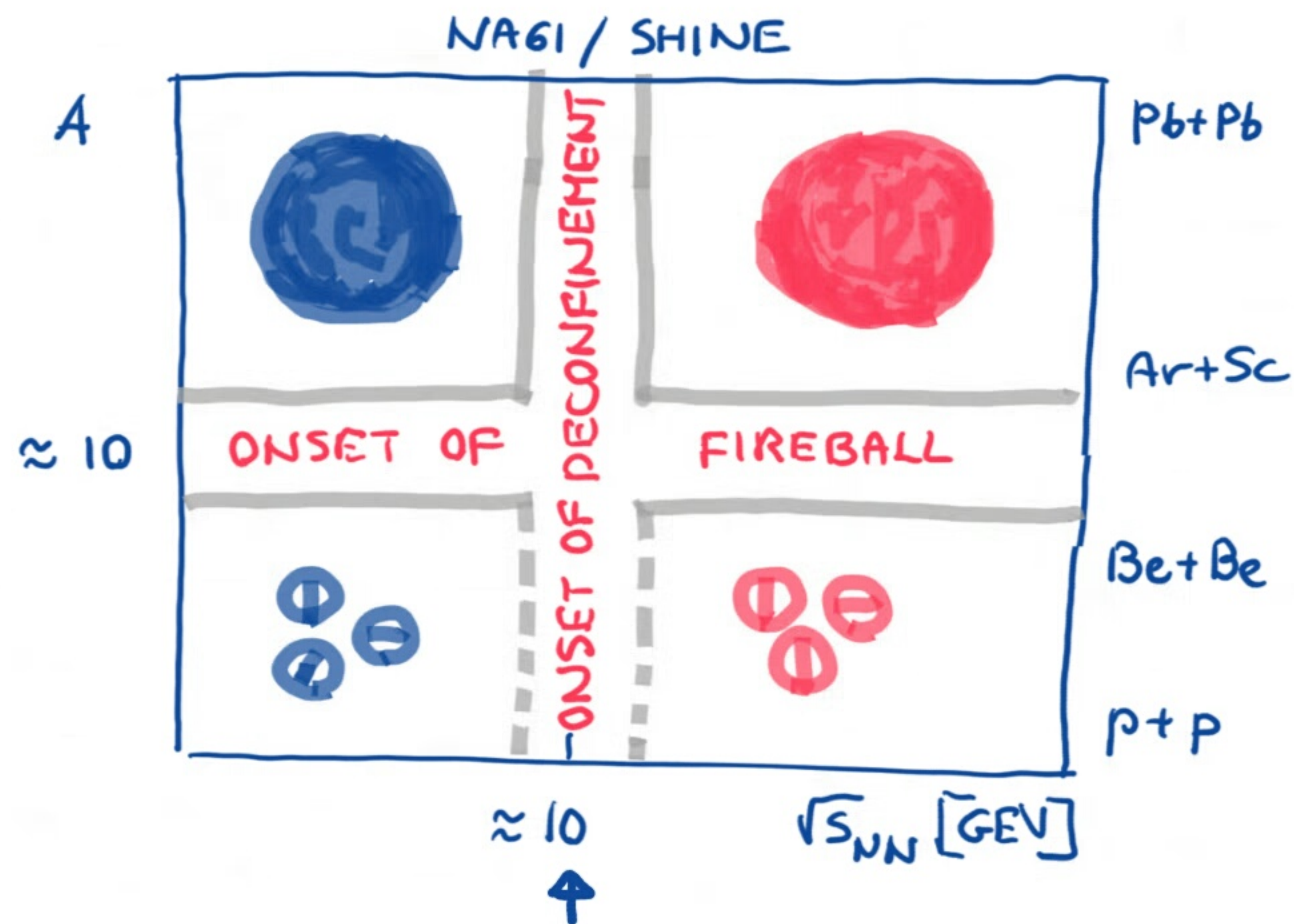
ANALYSIS OF DATA RECORDED IN 2009 - 18

NA61/SHINE RECORDED UNIQUE DATA FOR:

- HEAVY ION PHYSICS (ONSET OF DECONFINEMENT
ONSET OF FIREBALL, CRITICAL POINT)
- NEUTRINO PHYSICS (T2K AT J-PARC
FERMILAB EXPERIMENTS)
- COSMIC-RAY PHYSICS (EXTENSIVE AIR SHOWERS)
AUGER, KASCADE)

DATA ANALYSIS WILL CONTINUE FOR AT LEAST FIVE YEARS

UNIQUENESS OF HEAVY ION PHYSICS AT THE CERN SPS



TWO ONSETS AT SPS

PHYSICS GOALS OF NEW MEASUREMENTS (2021-24)

- FUNDAMENTAL PHYSICS:

- OPEN CHARM MEASUREMENTS IN Pb+Pb AT SPS

- REFERENCE MEASUREMENTS:

- NUCLEAR FRAGMENTATION CROSS-SECTION FOR COSMIC RAY EXPERIMENTS
 - HADRON PRODUCTION FOR NEUTRINO EXPERIMENTS
-

RECENT DOCUMENTS:

- March 21, 2018, Addendum 10:

*Study of Hadron-Nucleus and Nucleus-Nucleus Collisions at the CERN SPS:
Early Post-LS2 Measurements and Future Plans,
CERN-SPSC-2018-008, SPSC-P-330-ADD-10*

- June 5, 2018, Addendum 11:

*Reply to the SPSC questions on Addendum CERN-SPSC-2018-008,
CERN-SPSC-2018-019, SPSC-P-330-ADD-11*

→ JUNE 8: SPSC RECOMMENDED
DATA TAKING IN 2021

OPEN CHARM MEASUREMENTS IN Pb+Pb AT SPS: MOTIVATION

- Q1: WHAT IS THE MECHANISM OF CHARM PRODUCTION ?
- Q2: HOW DOES THE ONSET OF DECONFINEMENT IMPACT CHARM PRODUCTION ?
- Q3: HOW DOES THE FORMATION OF QGP IMPACT J/ψ PRODUCTION ?

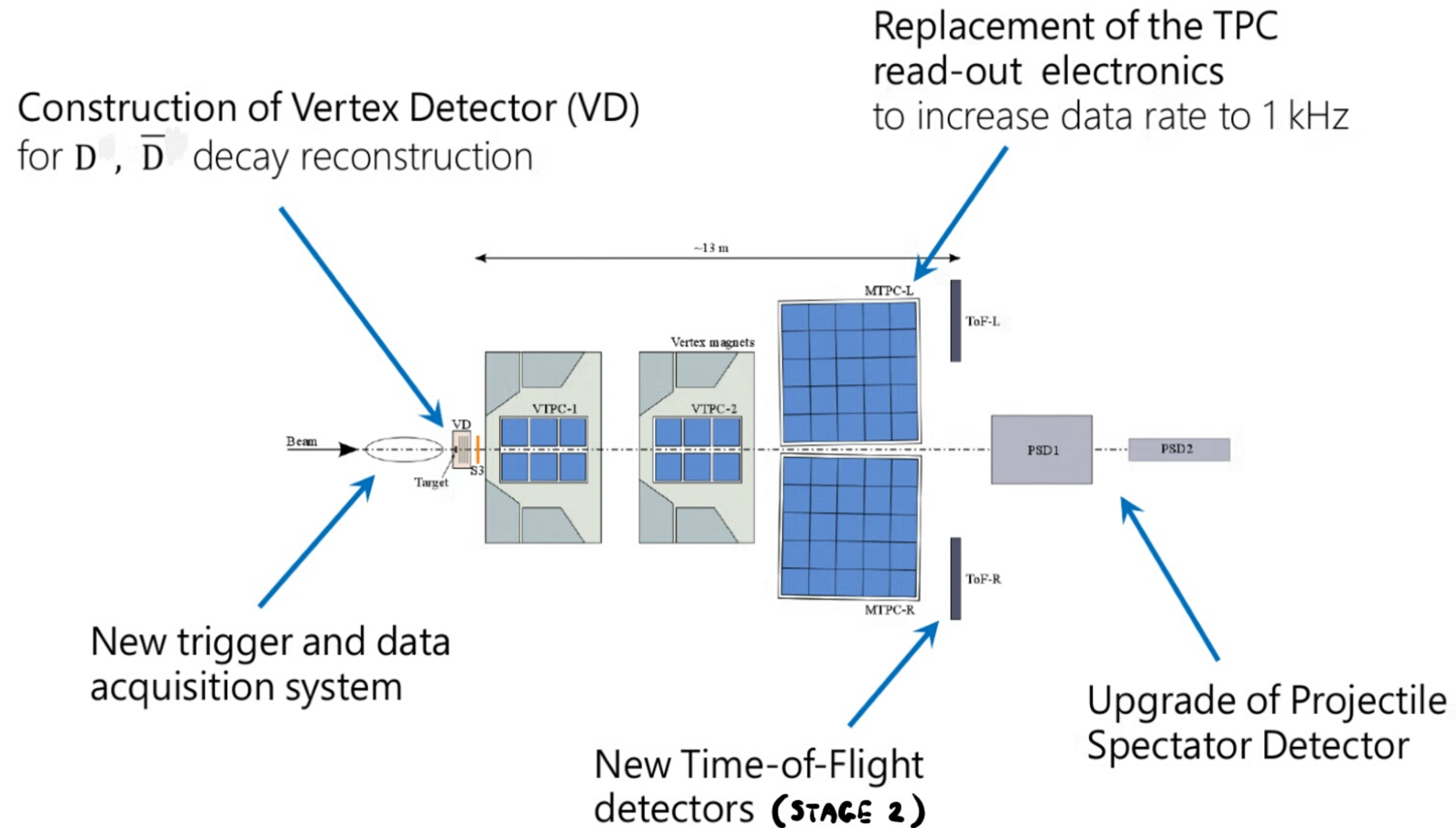
TO ANSWER ONE NEEDS TO KNOW:

MEAN NUMBER OF CHARM QUARK PAIRS PRODUCED
IN THE FULL PHASE SPACE, $\langle c\bar{c} \rangle$, IN Pb+Pb COLLISIONS

UP TO NOW NO CORRESPONDING EXPERIMENTAL DATA

ONLY NA61/SHINE CAN PERFORM NEEDED MEASUREMENTS
IN THE NEAR FUTURE

DETECTOR UPGRADES (2018-2021)

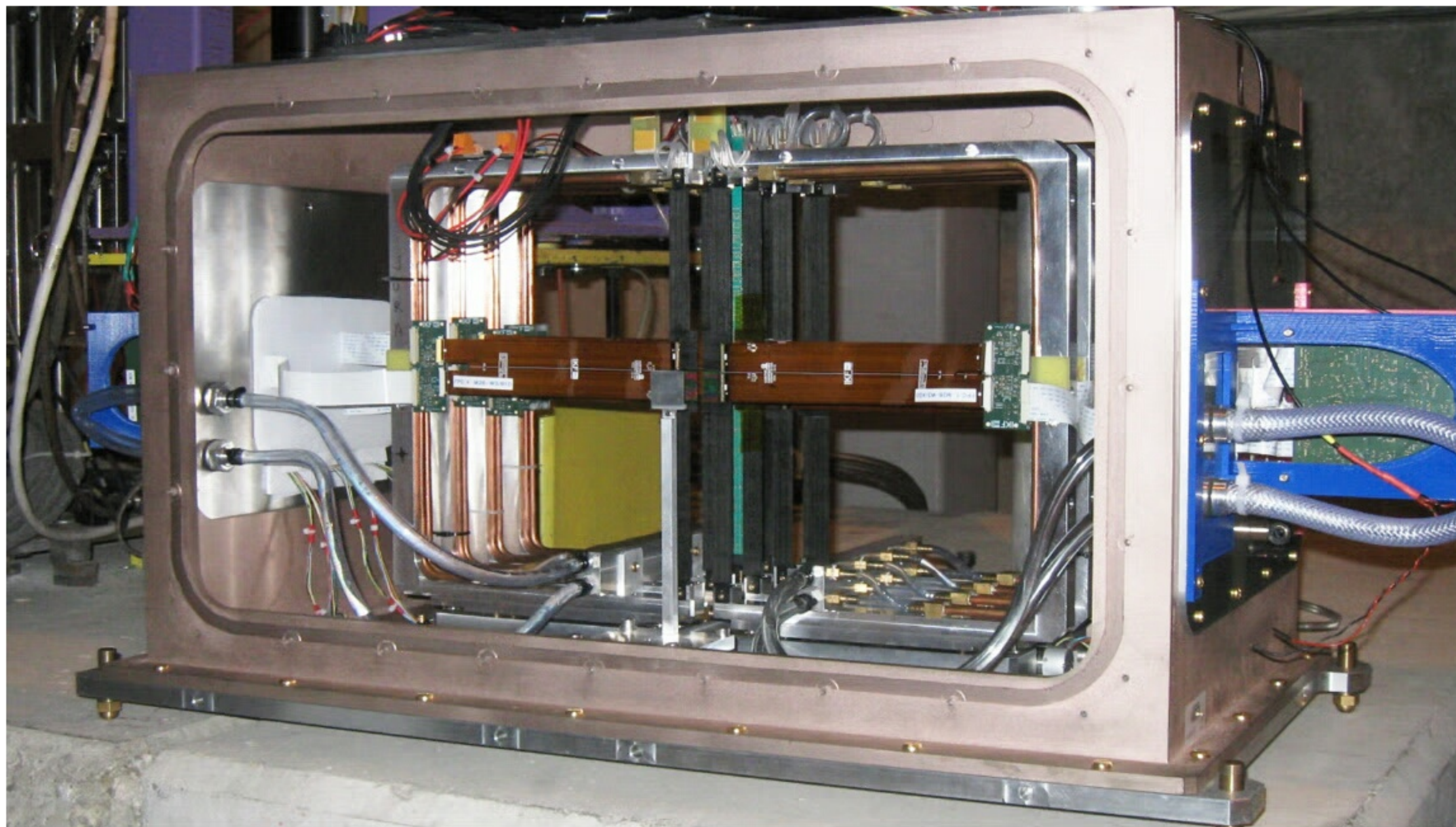


IN TOTAL: ≈ 850 K CHF (STAGE 1, HARDWARE ONLY)

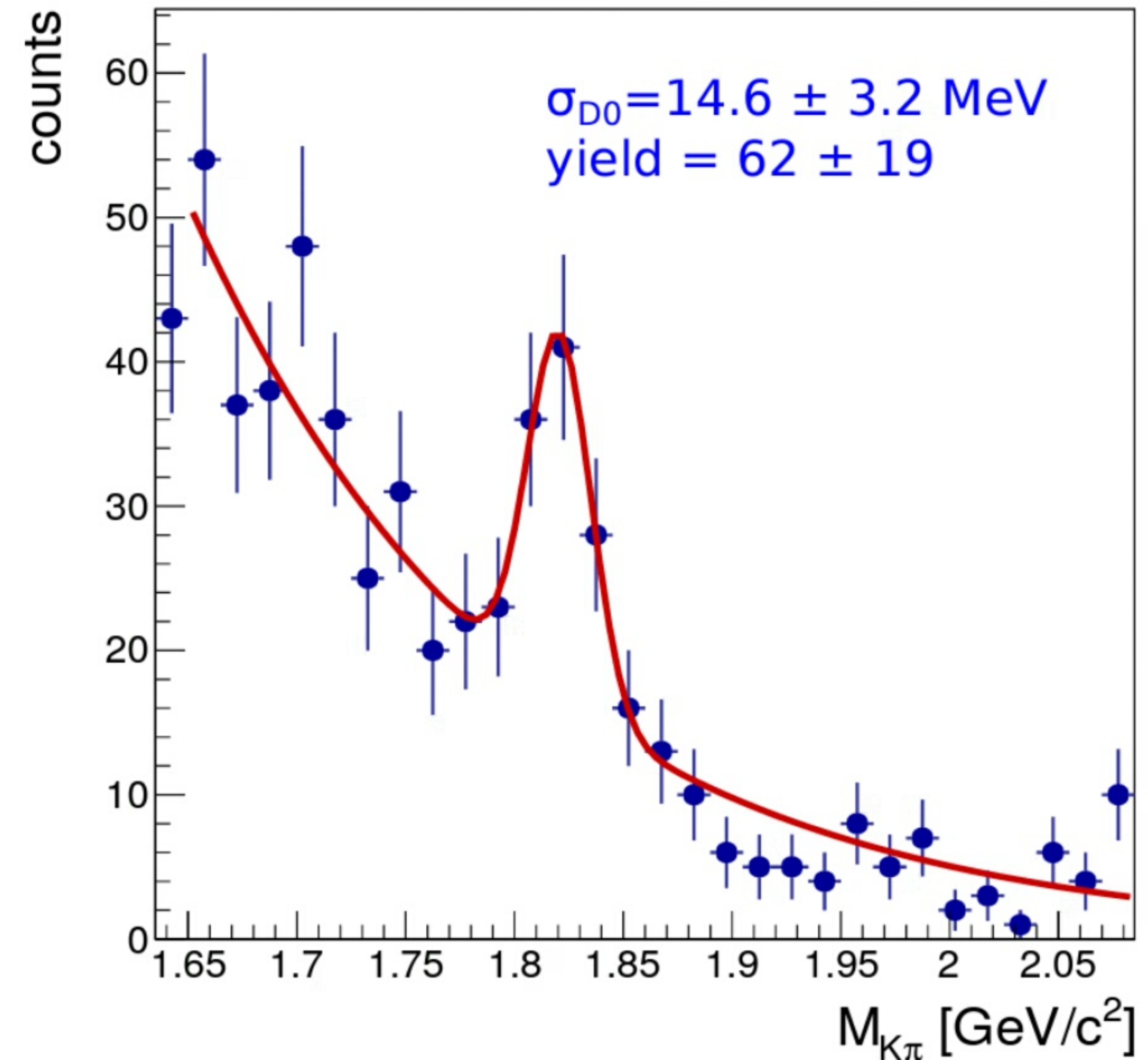
MODERATE COSTS THANKS TO COLLABORATION WITH
ALICE (TPC, VD), CBM (PSD)

RESULTS FROM THE 2016 TEST (Pb+Pb AT 150A GEV/c)

2016-2018:
SMALL ACCEPTANCE VERTEX DETECTOR



BASED ON TECHNOLOGIES DEVELOPED
FOR ALICE AND CBM

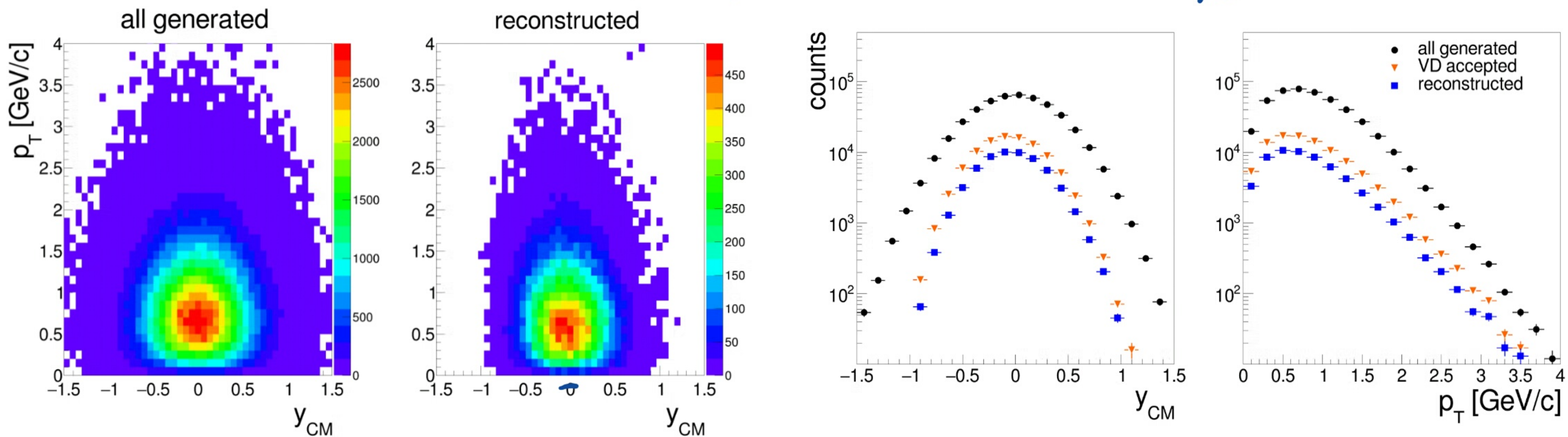


INDICATION OF $D^0 + \bar{D}^0$ PEAK

DATA STATISTICS (2021-24) AND ACCEPTANCE

Reaction	days	events	$\#(D^0 + \bar{D}^0)$	$\#(D^+ + D^-)$
Pb+Pb at 150A GeV/c	84	500M	76k	46k
Pb+Pb at 40A GeV/c	42	250M	3.6k	2.1k

$D^0 + \bar{D}^0$ ACCEPTANCE : Pb+Pb AT 150A GeV/c

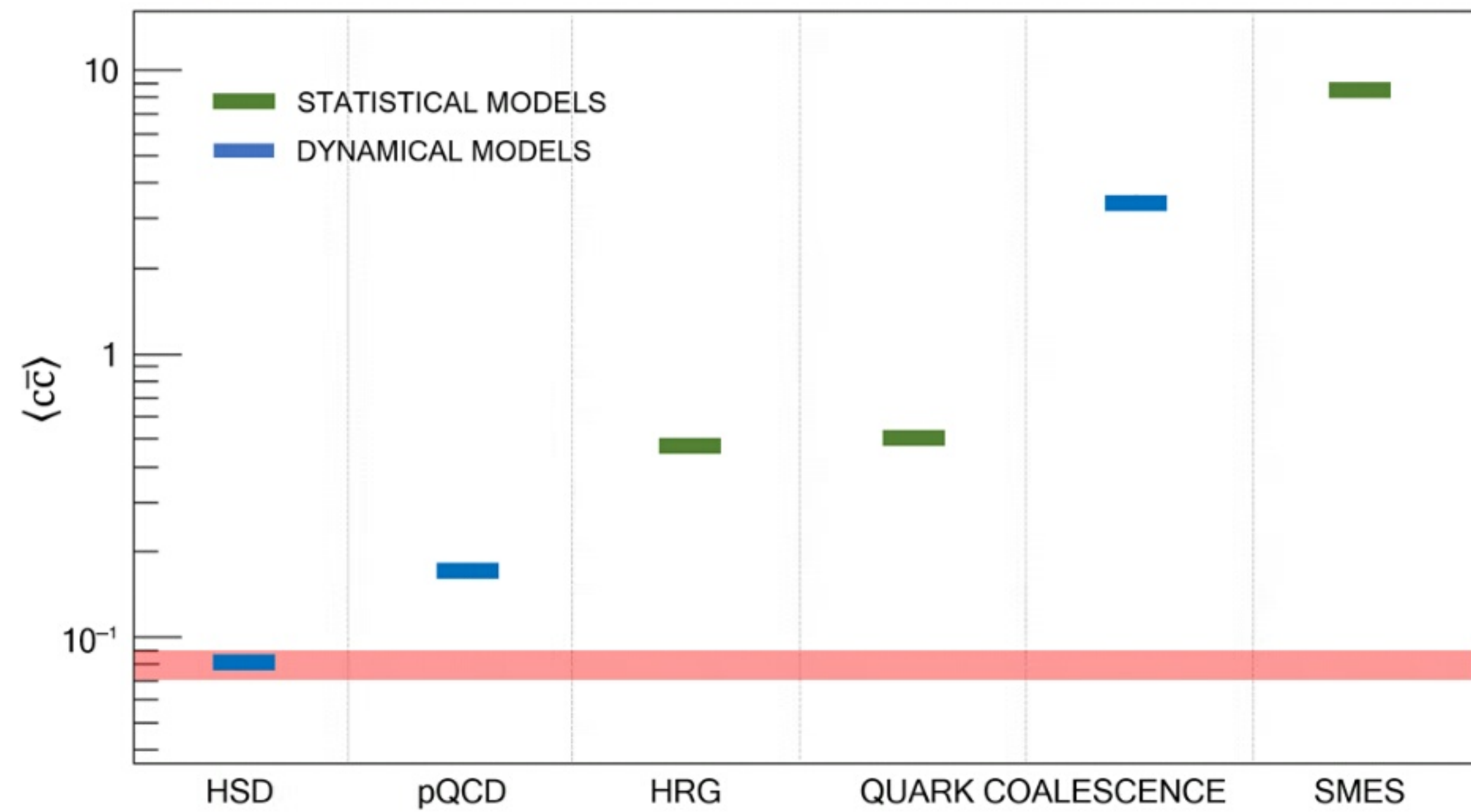


CENTRALITY	0-10%	10-20%	20-30%	30-60%	60-90%	0-90%
$\#(D^0 + \bar{D}^0)$	31k	20k	11k	13k	1.3k	76k
$\#(D^+ + D^-)$	19k	12k	7k	8k	0.8k	46k

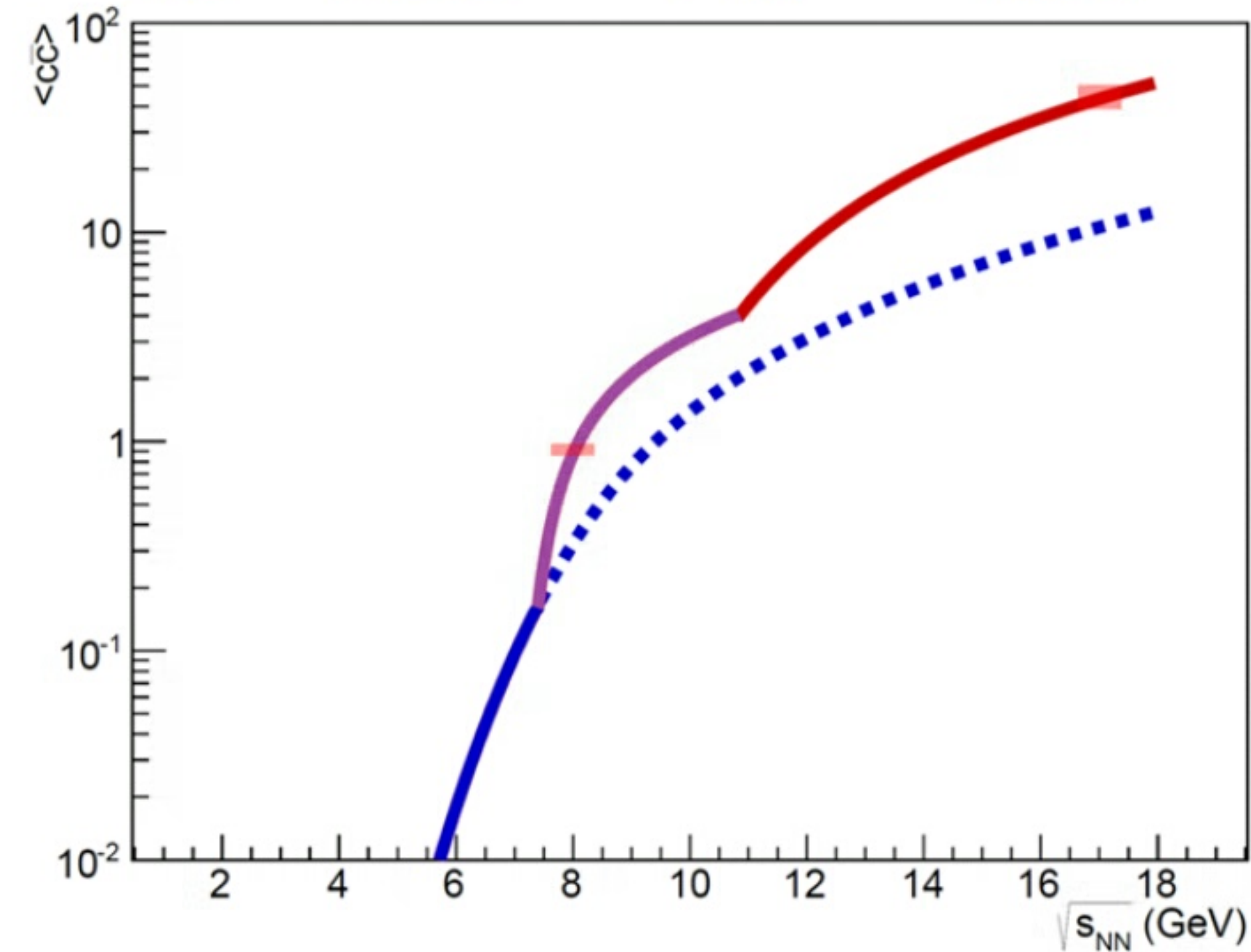
↳ p HSD

EXPECTED PHYSICS IMPACT OF NA61/SHINE $\langle c\bar{c} \rangle$ MEASUREMENTS

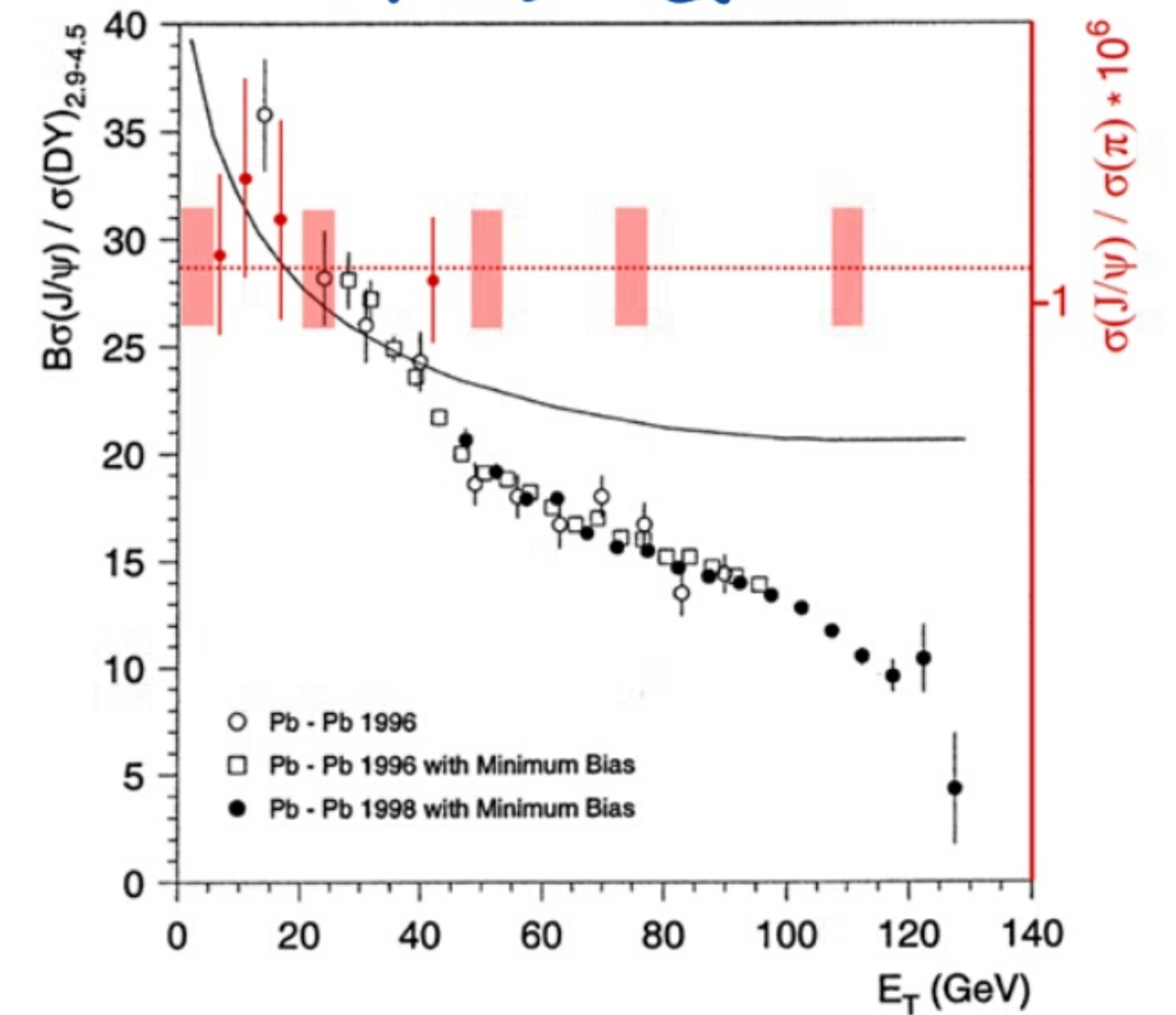
Q1: $\langle c\bar{c} \rangle$ AND MODELS



Q2: $\langle c\bar{c} \rangle$ AND ONSET OF DECONFINEMENT



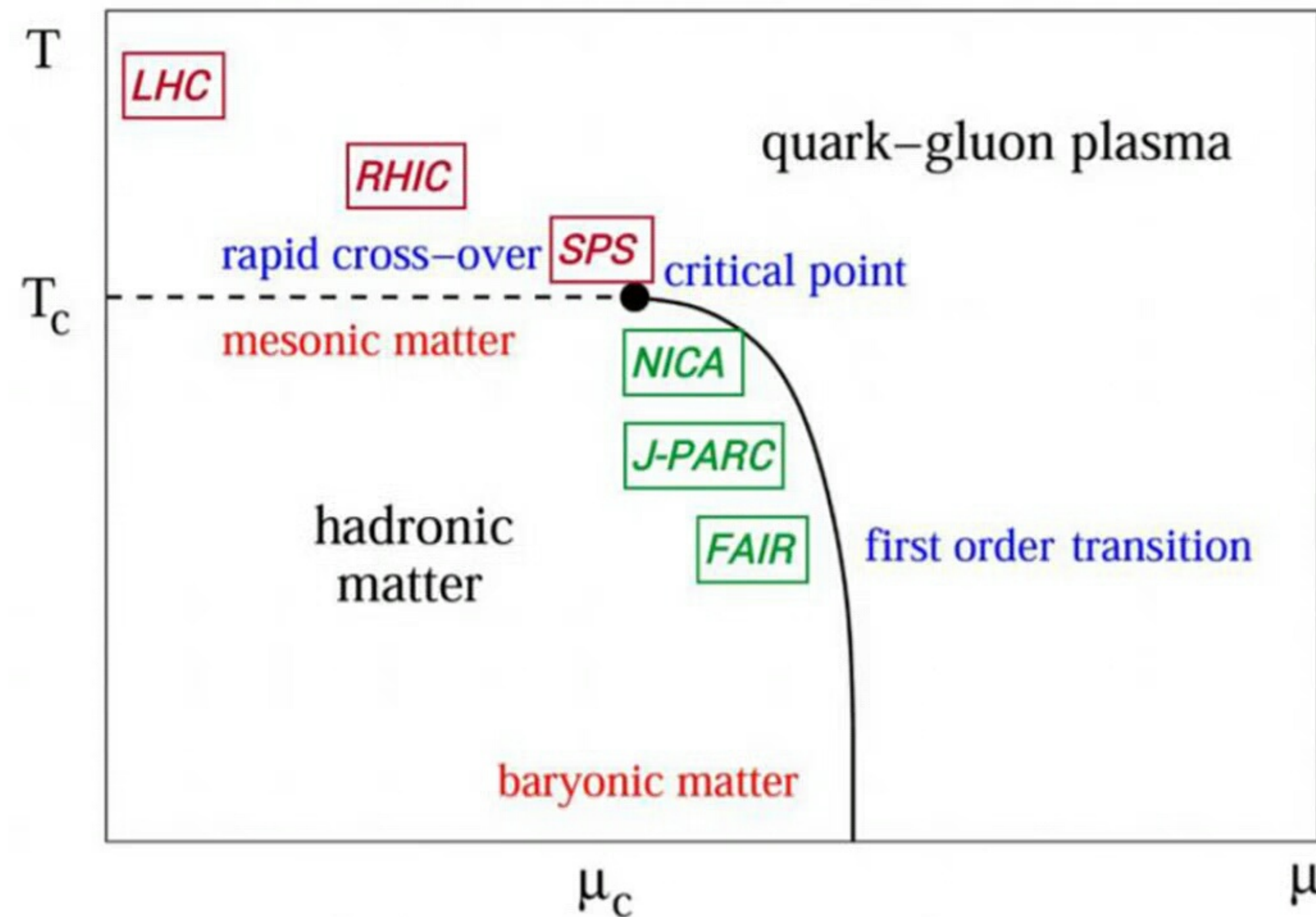
Q3: $\langle c\bar{c} \rangle$, $\langle J/\psi \rangle$ AND QGP



FORESEEN NA61/SHINE RESOLUTION IS SUFFICIENT TO ANSWER Q1, Q2 AND Q3

UNIQUENESS OF NAGI/SHINE PROGRAMME

LANDSCAPE OF PRESENT AND FUTURE HEAVY ION EXPERIMENTS



LHC and RHIC at high energies ($\sqrt{s_{NN}} \geq 200$ GeV):

measurements in limited phase space due to collider geometry and kinematics

RHIC BES (3 – 39 GeV):

measurement not under consideration

NICA (< 11 GeV):

under consideration during stage 2

J-PARC (< 6 GeV):

maybe possible after 2025

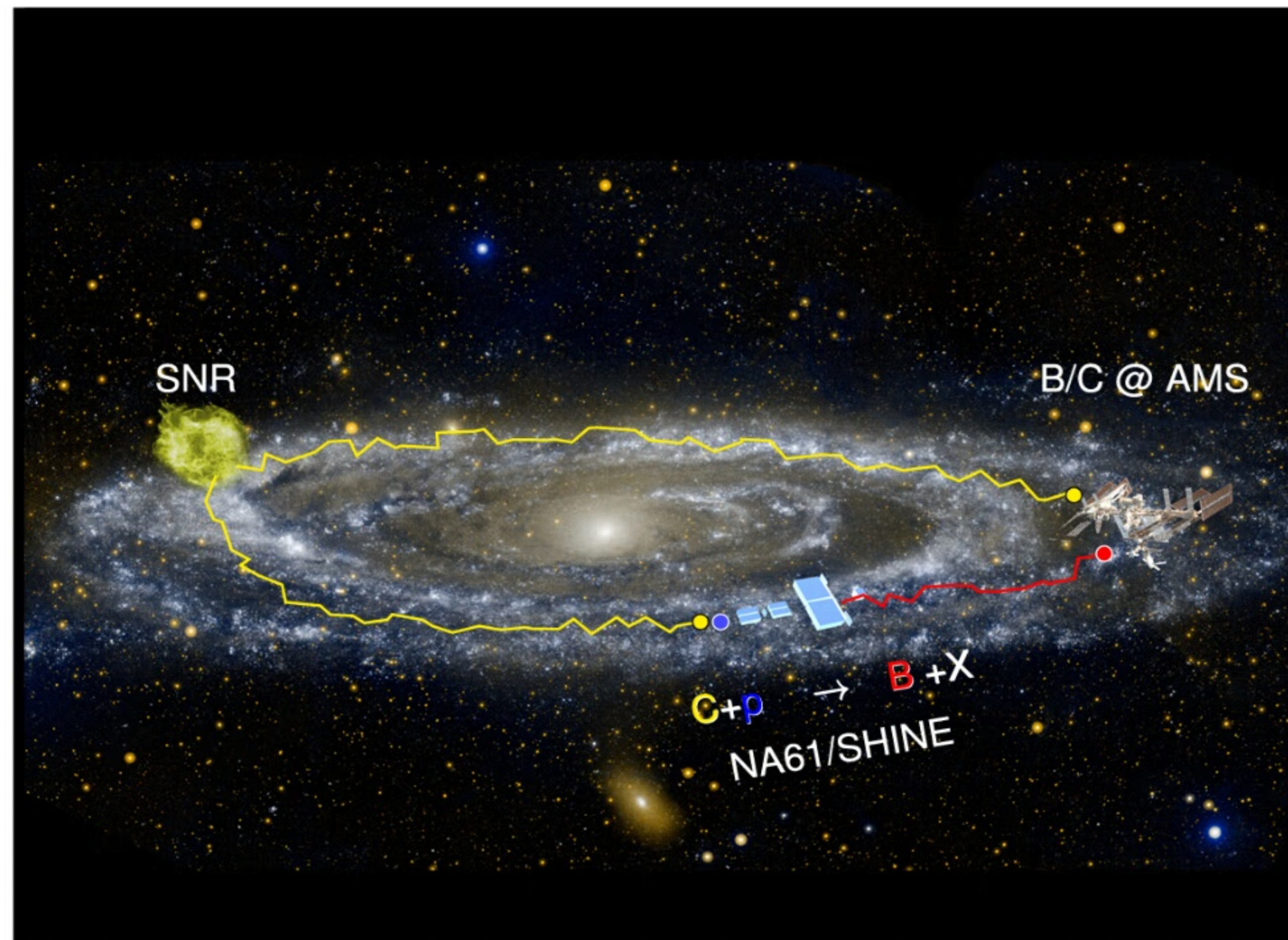
FAIR SIS-100 (< 5 GeV):

not possible at SIS-100,
planned at SIS-300 (< 7 GeV)

ONLY NAGI/SHINE IS ABLE TO MEASURE OPEN CHARM PRODUCTION IN HEAVY ION COLLISIONS IN FULL PHASE SPACE AND IN THE NEAR FUTURE

REFERENCE MEASUREMENTS:

NUCLEAR FRAGMENTATION CROSS SECTION FOR COSMIC RAY EXPERIMENTS

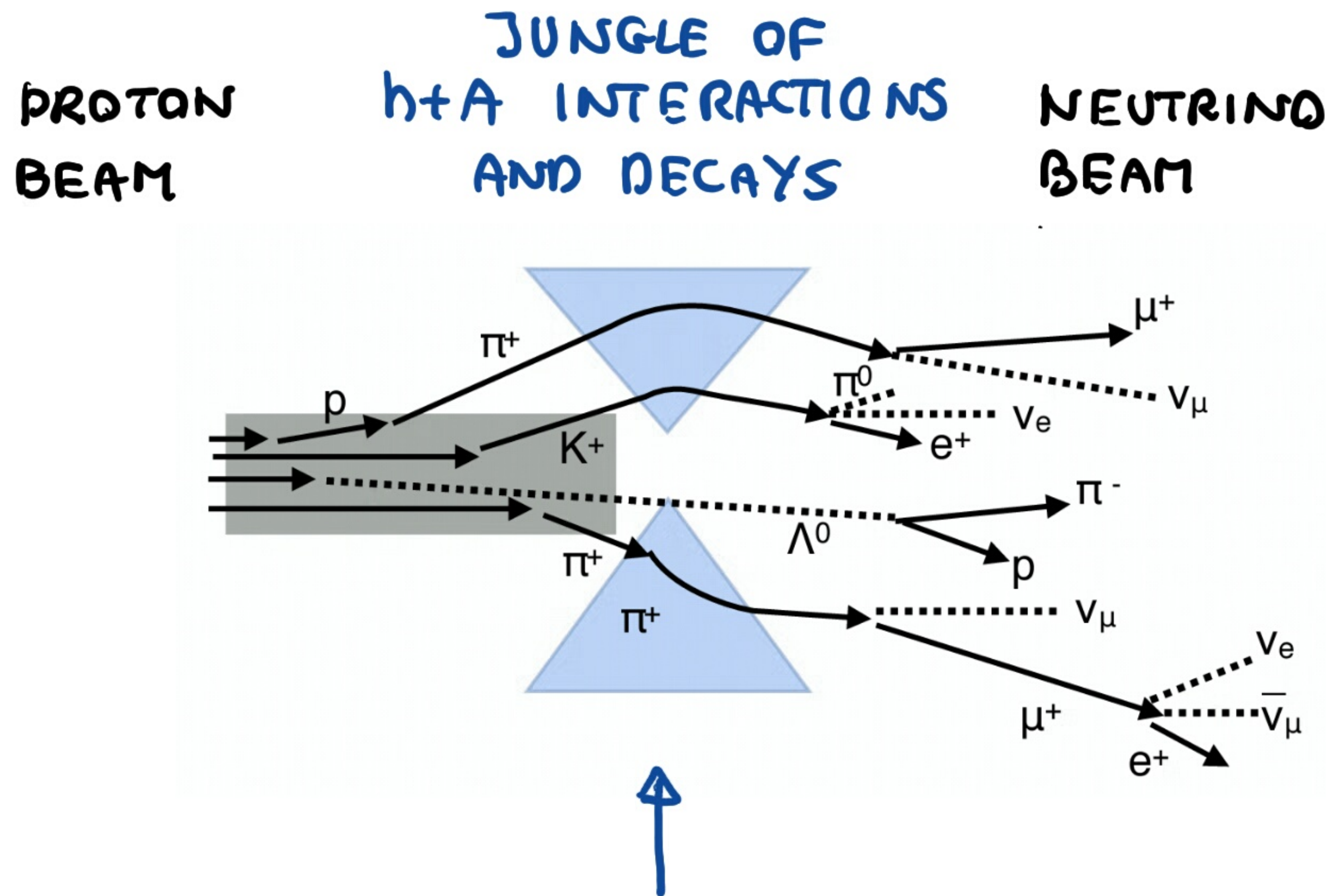


- Primary cosmic rays from supernova remnants
- Secondary cosmic rays from interactions with interstellar matter during propagation e.g.
 $^{12}\text{C} + p \xrightarrow{\text{frag.}} \text{B} + \text{X}$
 $^{12}\text{C} + p \xrightarrow{\text{frag.}} ^{11}\text{C} + p \xrightarrow{\text{decay}} \text{B} + \text{Y}$
- Primary-to-secondary ratios (e.g. B/C)
→ traversed mass density
- Unstable-to-stable ratios (e.g. $^{10}\text{Be}/^9\text{Be}$)
→ traversed distance
- Important for the understanding of origin of Galactic cosmic rays and backgrounds for DM searches

UNDERSTANDING OF COSMIC RAY PROPAGATION LIMITED BY UNCERTAINTIES OF FRAGMENTATION CROSS SECTIONS

NA61/SHINE WILL SIGNIFICANTLY REDUCE THE UNCERTAINTIES.
(FROM $\approx 20\%$ TO $\approx 0.5\%$)

REFERENCE MEASUREMENTS: HADRON PRODUCTION FOR NEUTRINO EXPERIMENTS



- Further improvement of the precision of measurements for the currently used T2K replica target,
- Measurements for a new target material (super-sialon) for T2K-II and Hyper-Kamiokande,
- Study of the possibility of measurements with beams < 12 GeV/c for improved predictions of atmospheric and accelerator ν fluxes,
- Ultimate hadron production measurements with prototypes of Hyper-Kamiokande and DUNE targets.

NAGI/SHINE WILL DECREASE SYSTEMATIC UNCERTAINTIES OF NEUTRINO FLUX (FOR T2K-II, HYPER-K FROM $\approx 10\%$ TO $\approx 3\%$)

NA61/SHINE 2020+ COLLABORATION

A. Aduszkiewicz¹⁵, E.V. Andronov²¹, T. Antičić², B. Baatar¹⁹, M. Baszczyk¹³, S. Bhosale¹⁰, A. Blondel²³, M. Bogomilov¹, A. Brandin²⁰, A. Bravar²³, W. Bryliński¹⁷, J. Brzychczyk¹², S.A. Bunyatov¹⁹, O. Busygina¹⁸, A. Bzdak¹³, H. Cherif⁶, M. Ćirković²², T. Czopowicz¹⁷, A. Damyanova²³, N. Davis¹⁰, M. Deveaux⁶, W. Dominik¹⁵, P. Dorosz¹³, J. Dumarchez³, R. Engel⁴, G.A. Feofilov²¹, L. Fields²⁴, Z. Fodor^{7,16}, A. Garibov⁰, M. Gaździcki^{6,9}, O. Golosov²⁰, M. Golubeva¹⁸, K. Grebieszko¹⁷, F. Guber¹⁸, A. Haesler²³, A.E. Hervé⁴, S.N. Igolkin²¹, S. Ilieva¹, A. Ivashkin¹⁸, S.R. Johnson²⁵, K. Kadija², E. Kaptur¹⁴, N. Kargin²⁰, E. Kashirin²⁰, M. Kiełbowicz¹⁰, V.A. Kireyeu¹⁹, V. Klochov⁶, V.I. Kolesnikov¹⁹, D. Kolev¹, A. Korzenev²³, V.N. Kovalenko²¹, K. Kowalik¹¹, S. Kowalski¹⁴, M. Koziel⁶, A. Krasnoperov¹⁹, W. Kucewicz¹³, M. Kuich¹⁵, A. Kurepin¹⁸, D. Larsen¹², A. László⁷, T.V. Lazareva²¹, M. Lewicki¹⁶, K. Łojek¹², B. Łysakowski¹⁴, V.V. Lyubushkin¹⁹, M. Maćkowiak-Pawłowska¹⁷, Z. Majka¹², B. Maksiak¹⁷, A.I. Malakhov¹⁹, D. Manić²², A. Marchionni²⁴, A. Marcinek¹⁰, A.D. Marino²⁵, K. Marton⁷, H.-J. Mathes⁴, T. Matulewicz¹⁵, V. Matveev¹⁹, G.L. Melkumov¹⁹, A.O. Merzlaya¹², B. Messerly²⁶, Ł. Mik¹³, S. Morozov^{18,20}, S. Mrówczyński⁹, Y. Nagai²⁵, M. Naskręt¹⁶, V. Ozvenchuk¹⁰, V. Paolone²⁶, M. Pavin^{3,2}, O. Petukhov¹⁸, R. Płaneta¹², P. Podlaski¹⁵, B.A. Popov^{19,3}, M. Posiadała¹⁵, S. Puławski¹⁴, J. Puzović²², W. Rauch⁵, M. Ravonel²³, R. Renfordt⁶, E. Richter-Wąs¹², D. Röhrich⁸, E. Rondio¹¹, M. Roth⁴, B.T. Rumberger²⁵, A. Rustamov^{0,6}, M. Rybczynski⁹, A. Rybicki¹⁰, A. Sadovsky¹⁸, K. Schmidt¹⁴, I. Selyuzhenkov²⁰, A.Yu. Seryakov²¹, P. Seyboth⁹, M. Słodkowski¹⁷, A. Snoch⁶, P. Staszal¹², G. Stefanek⁹, J. Stepaniak¹¹, M. Strikhanov²⁰, H. Ströbele⁶, T. Šušar², A. Taranenko²⁰, A. Tefelska¹⁷, D. Tefelski¹⁷, V. Tereshchenko¹⁹, A. Toia⁶, R. Tsenov¹, L. Turko¹⁶, R. Ulrich⁴, M. Unger⁴, F.F. Valiev²¹, D. Veberič⁴, V.V. Vechernin²¹, A. Wickremasinghe²⁶, Z. Włodarczyk⁹, A. Wojtaszek-Szwarc⁹, O. Wyszzyński¹², L. Zambelli³, E.D. Zimmerman²⁵, R. Zwaska²⁴

- Present NA61/SHINE Collaboration:
138 physicists from 27 institutions and 12 countries

- Addendum 10 co-authored by

The CERN Team:

N. Benekos (EP-NU), S. Bordoni (EP-NU), N. Charitonidis (EN-EA)¹, R. Fernandez (BE-OP), U. Kose (EP-NU), P. Martinengo (EP-DT), A. de Roeck (EP-NU), D. Sgalaberna (EP-NU), A. Weber (EP-NU), L. Whitehead (EP-NU)

- Two limited membership institutes will apply for funding for the future NA61/SHINE neutrino and cosmic ray measurements:
 - ▶ KEK, Japan
 - ▶ University of Manoa, Hawaii

REQUESTED BEAMS

2021: 6 WEEKS FOR DETECTOR COMMISSIONING

5 WEEKS OF PROTON BEAM AT 31 GEV/C FOR
DATA TAKING FOR NEUTRINO PHYSICS

4 WEEKS OF Pb BEAM AT 150A GEV/C FOR
OPEN CHARM MEASUREMENT

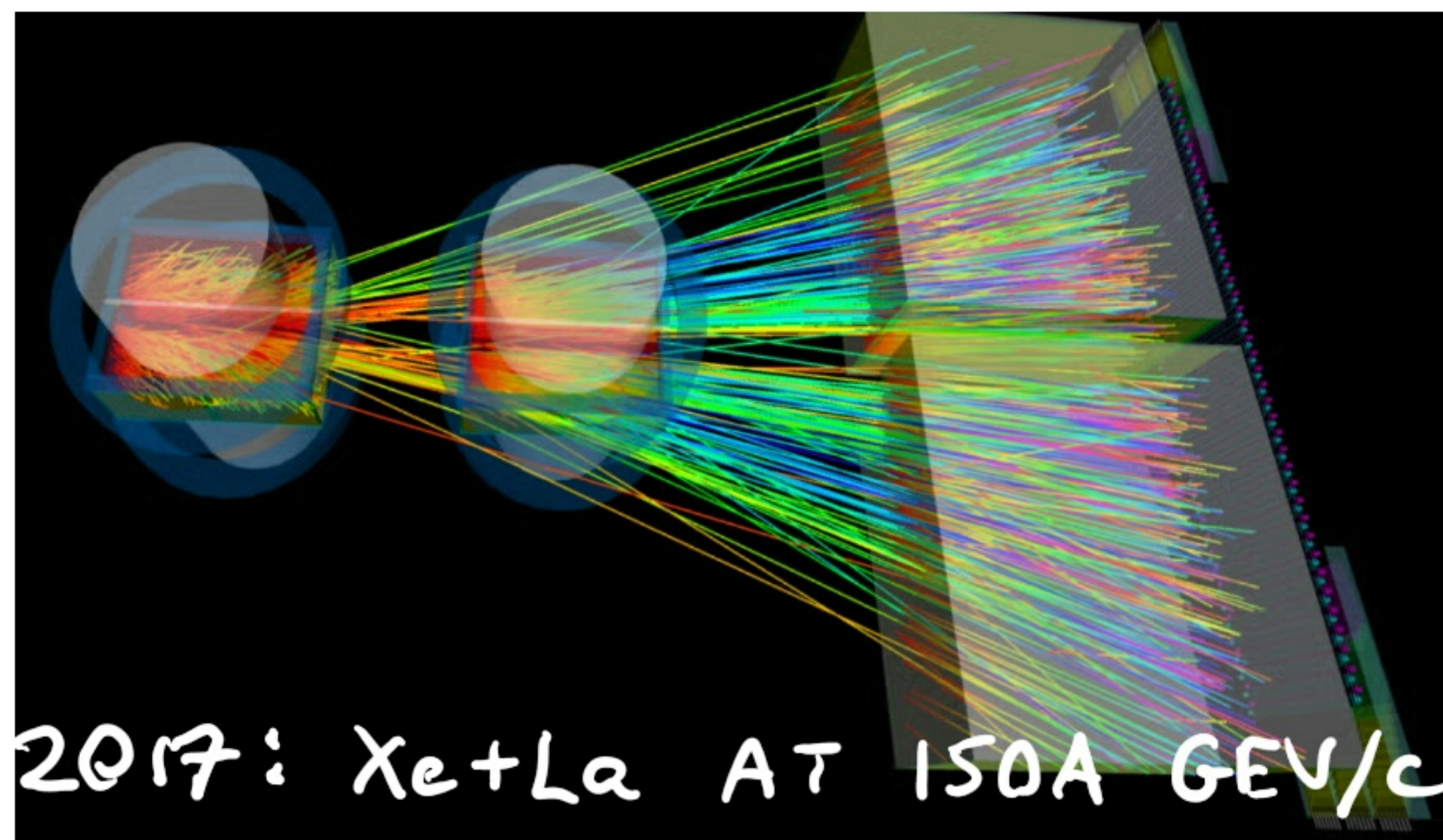
RECOMMENDED
BY SPSC

2022-24: HADRON, LIGHT ION (SECONDARY) AND Pb BEAMS
IN ACCORDANCE TO THE PROPOSED PHYSICS PROGRAM

PBC → ESPP → SPSC

SUMMARY

- NAGI/SHINE PLANS FUNDAMENTAL OPEN CHARM MEASUREMENTS IN Pb+Pb COLLISIONS AT SPS AS WELL AS NEW REFERENCE MEASUREMENTS FOR COSMIC RAY AND NEUTRINO EXPERIMENTS
 - DATA TAKING IN 2021 IS RECOMMENDED BY SPSC ON JUNE 8
 - DATA TAKING IN 2022-2024 | ← SPSC ← ESPP ← PBC
 - WORK ON DETECTOR UPGRADES HAS STARTED ON CRITICAL ISSUE: FINANCIAL RESOURCES (≈ 1 MCHF) FOR HARDWARE
-



"NAGI" Xe - THE MOST POPULAR ION AT CERN IN 2017, 2018:

NAGI/SHINE
GAMMA FACTORY
LHC

DETECTOR UPGRADE SCHEDULE / COST IN CHF

	2018			2019				2020			
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
TPC	5k	10k	10k	376k	180k	30k					
VD						.. 70k ..					
PSD			24k.....							
BPD						50k (SCiFi?)					
TDAQ	10k			16.5k+				34.5k			18k
			187.5k.....							
DRS4	30k		50k.....		.. 21k ..		40k			
Total:	15k+30k	10k	10k	487k+37k	274k+37k	101k	71k	75k			18k

GREEN - ALREADY EXISTING RESOURCES

BLACK - TO BE ACQUIRED

IN TOTAL: 854K CHF (HARDWARE ONLY)

MODERATE COSTS THANKS TO COLLABORATION WITH ALICE (TPC, VD), CBM (PSD), (MPD (MRPC))