

# NA61/SHINE IN BRIEF

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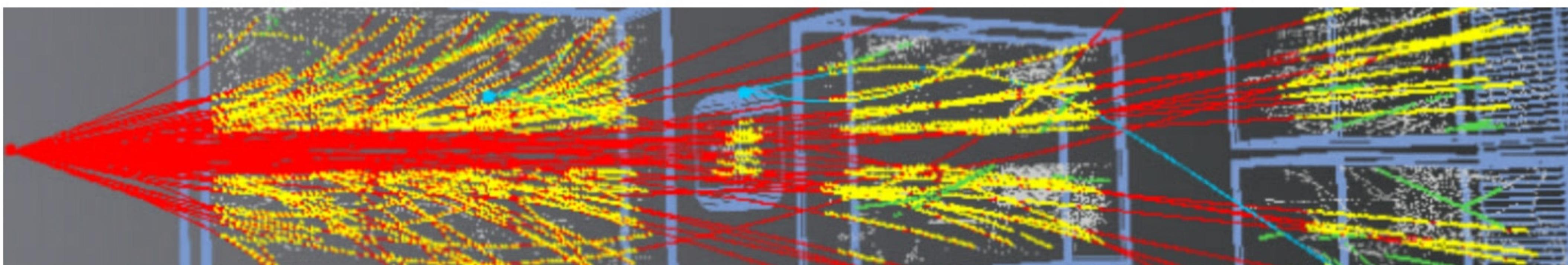
FACILITY



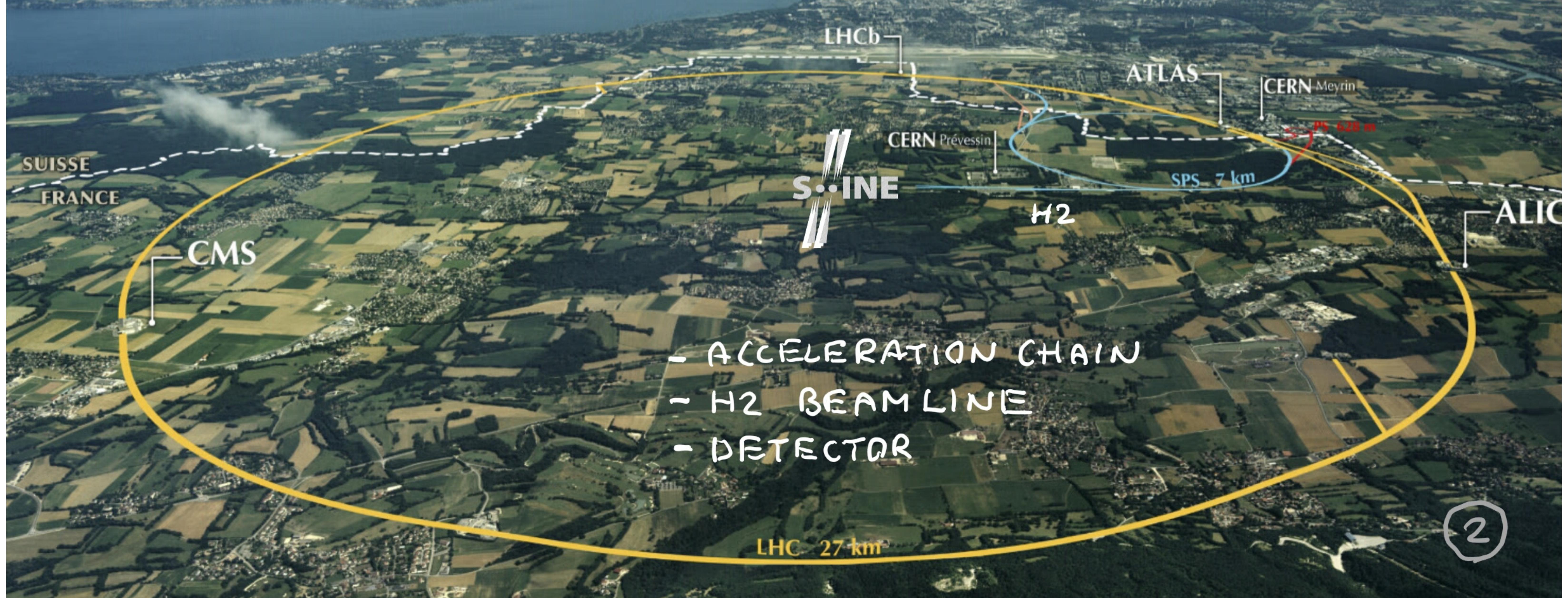
PHYSICS PROGRAMMES



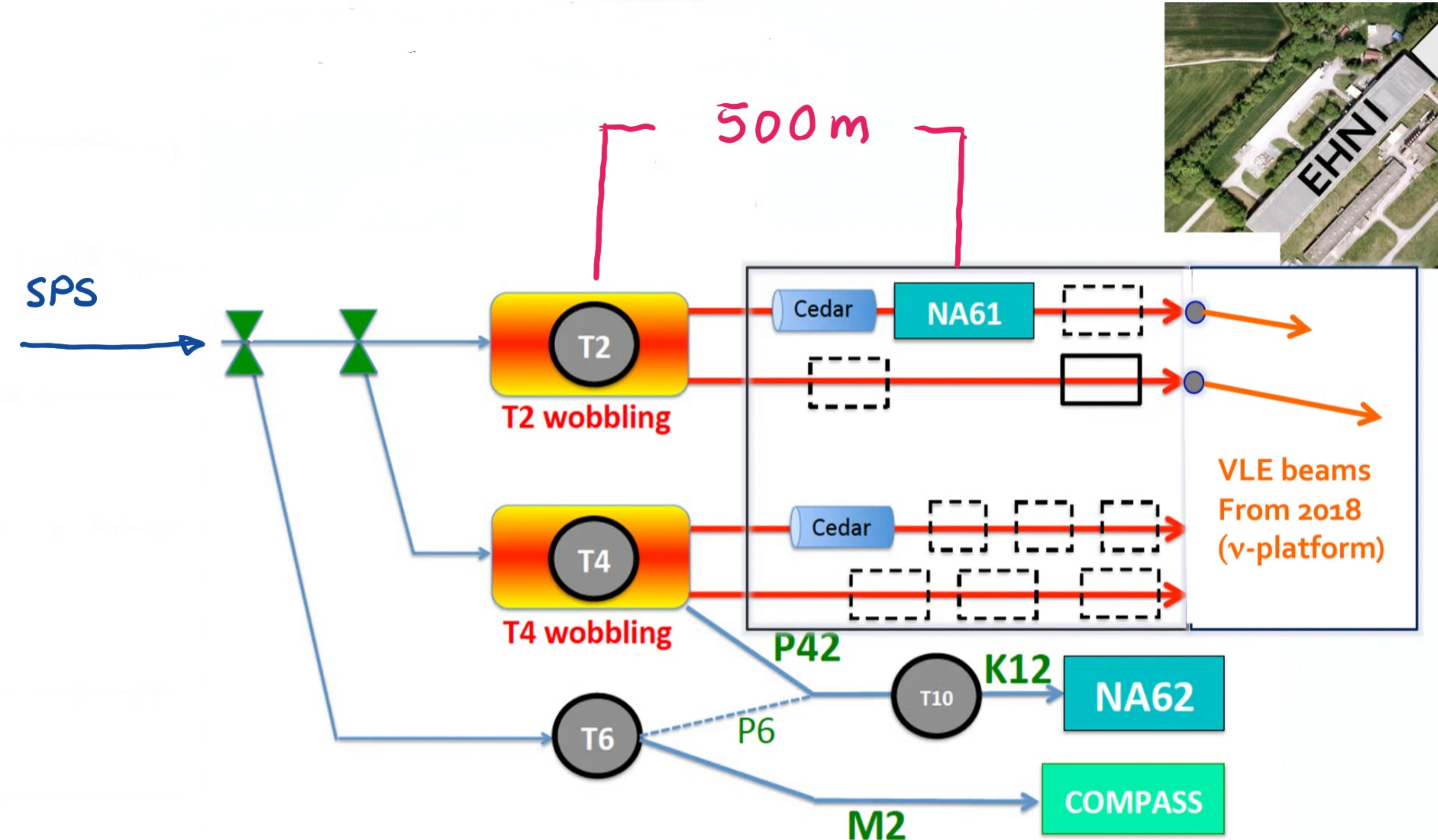
COLLABORATION



NA61/SHINE - UNIQUE MULTIPURPOSE FACILITY:  
HADRON PRODUCTION IN  $\text{h} + \text{p}$ ,  $\text{h} + \text{A}$ ,  $\text{A} + \text{A}$   
AT 13A - 150A (400) GeV/c

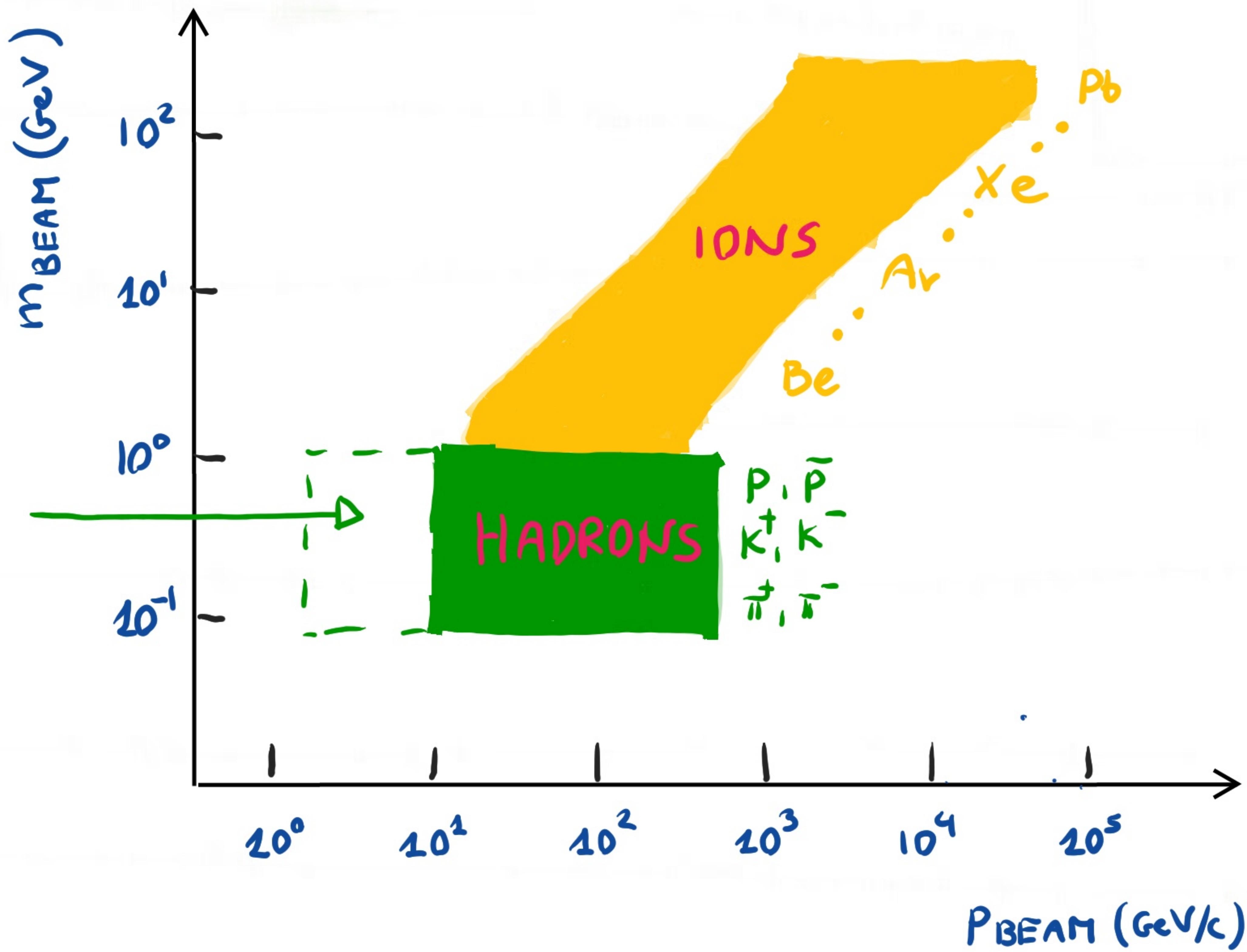


## H<sub>2</sub> BEAM LINE

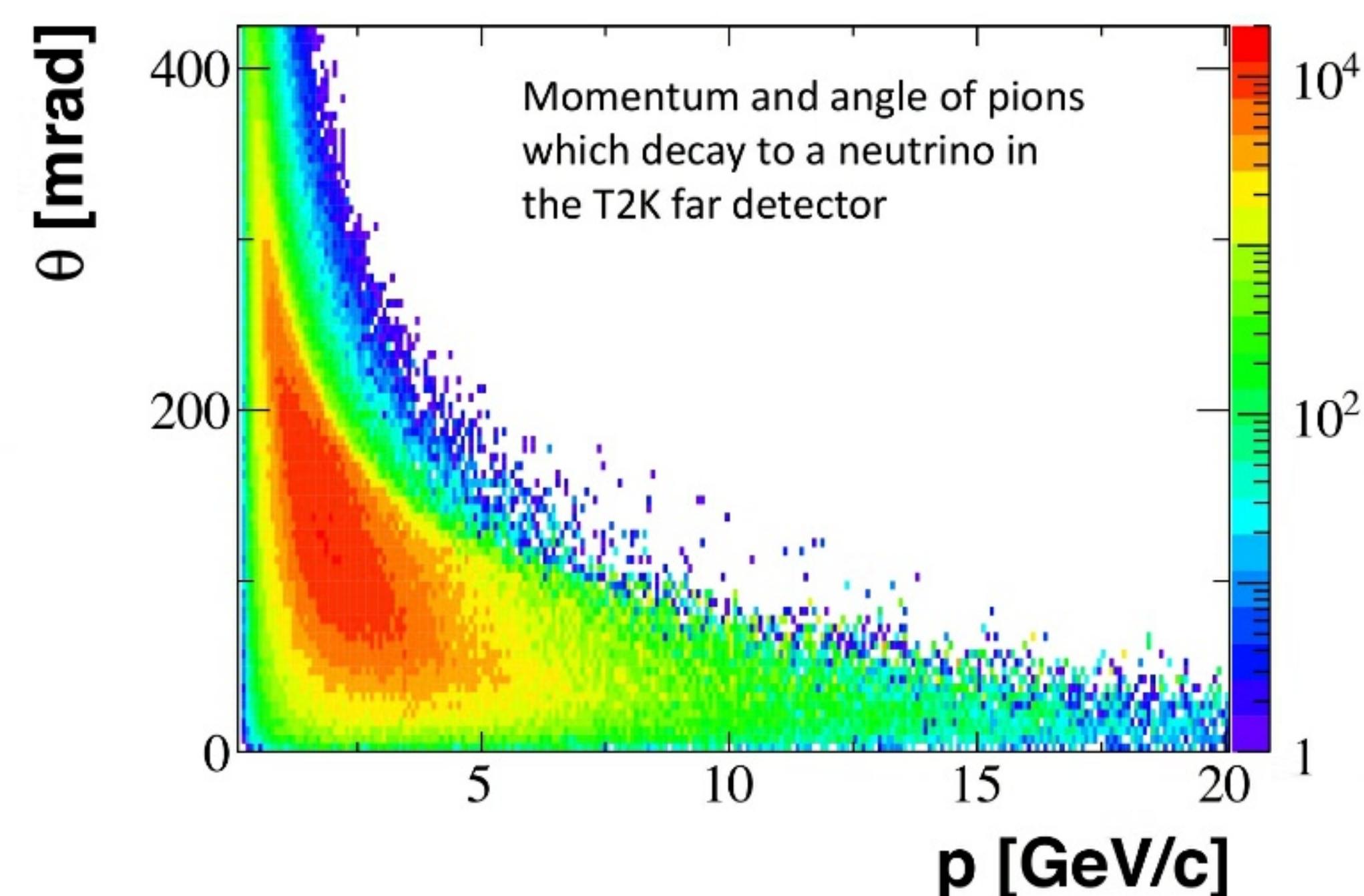
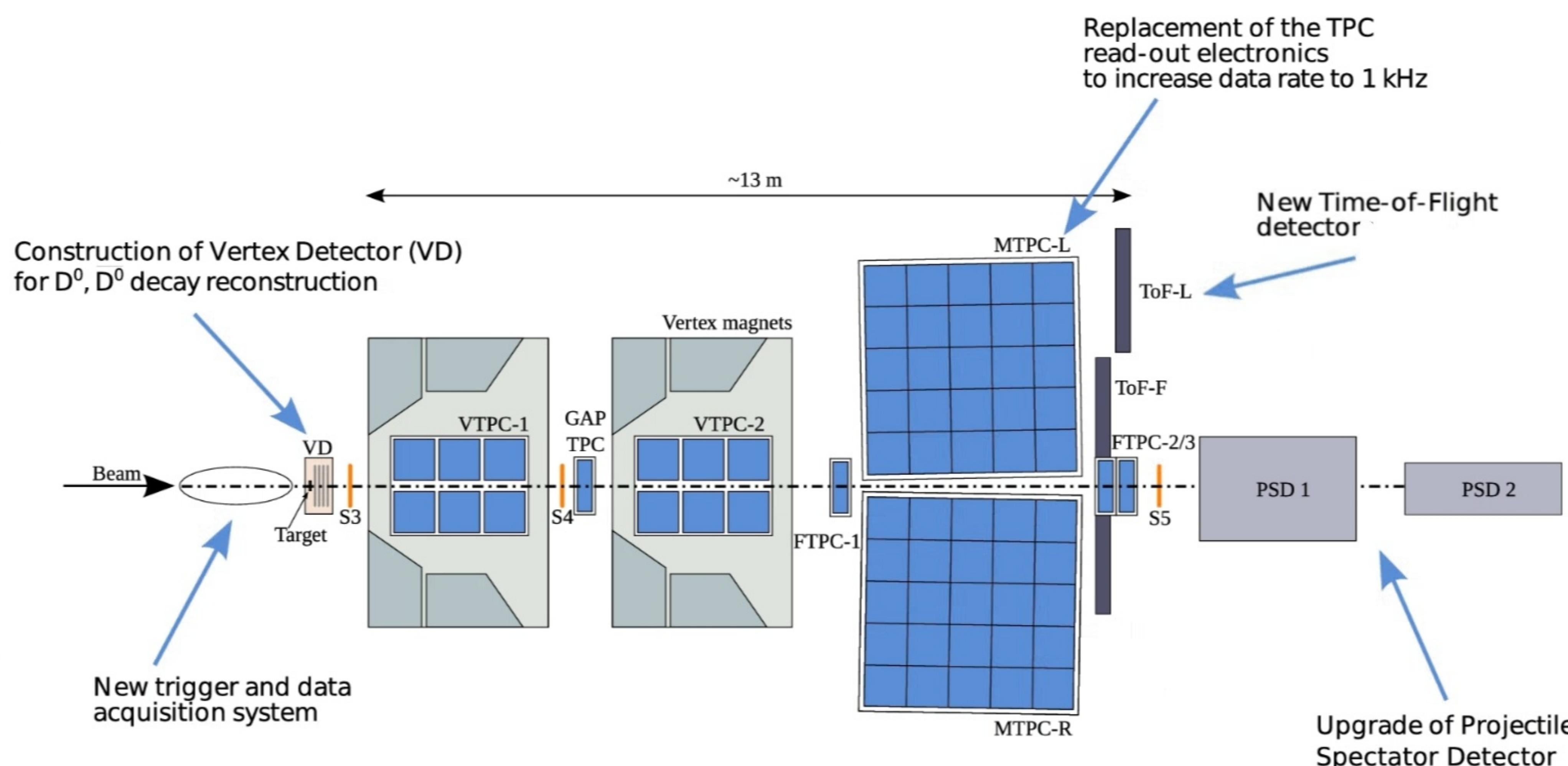


## BEAMS: UNPRECEDENTED VARIETY OF MASSES AND MOMENTA

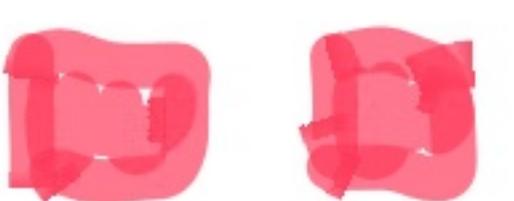
SUBJECT OF  
THIS WORKSHOP



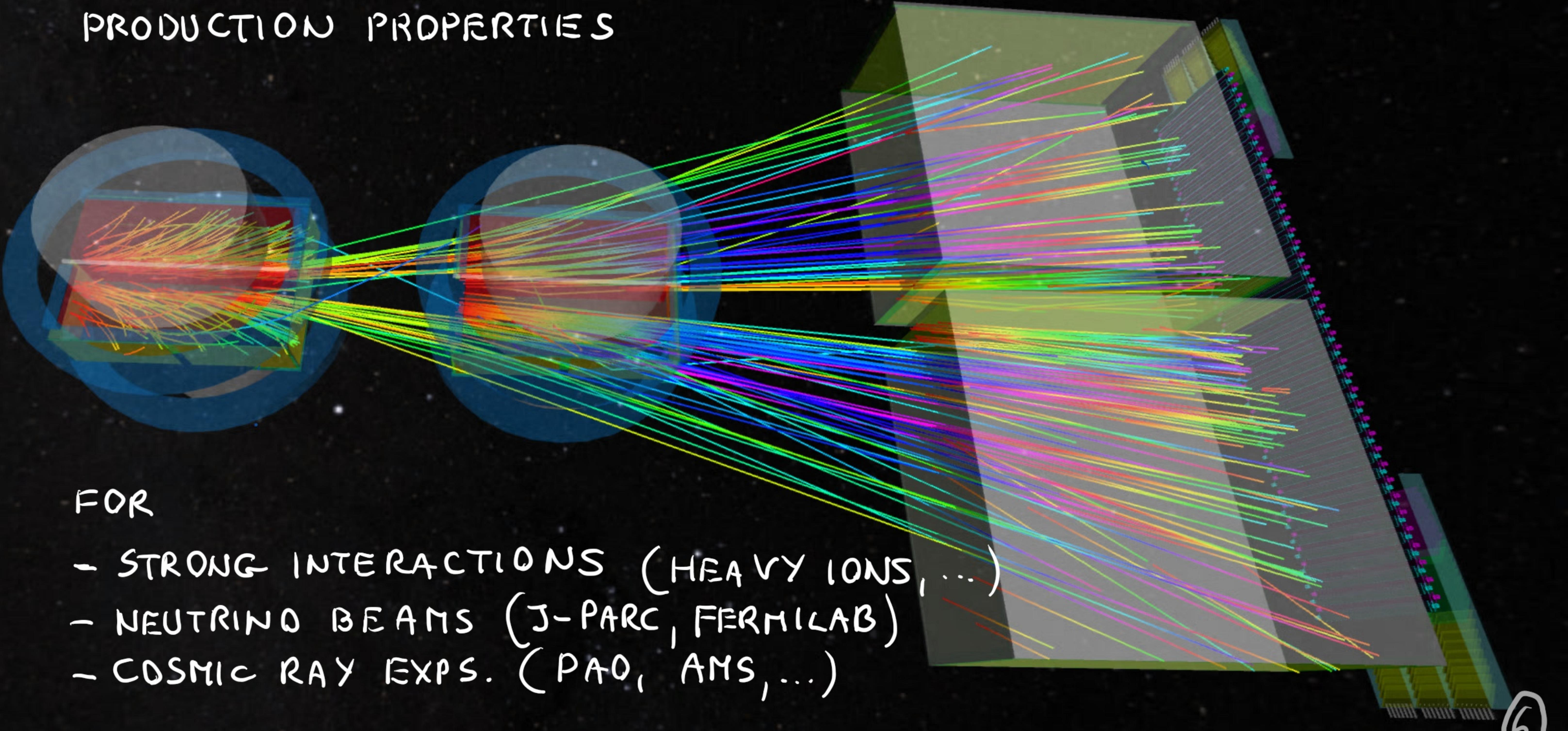
# DETECTOR AND ITS UPGRADE (2019 - 2021)



- $B \cdot L \lesssim 9 \text{ T} \cdot \text{m}$
- **LARGE ( $\approx 50\%$ ) ACCEPTANCE**
- $\sigma(x), \sigma(y) \approx 10 \mu\text{m} \text{ VD}$   
 $200 \mu\text{m} \text{ TPC}$
- $\sigma(p)/p^2 \approx 10^{-4} (\text{GeV}/c)^{-1}$
- $\sigma(dE/dx)/dE/dx \approx 4\%$
- $\sigma(\text{tof}) \lesssim 100 \text{ ps}$
- **EVENT RATE  $\approx 1 \text{ kHz}$**



### MEASUREMENTS OF HADRON PRODUCTION PROPERTIES

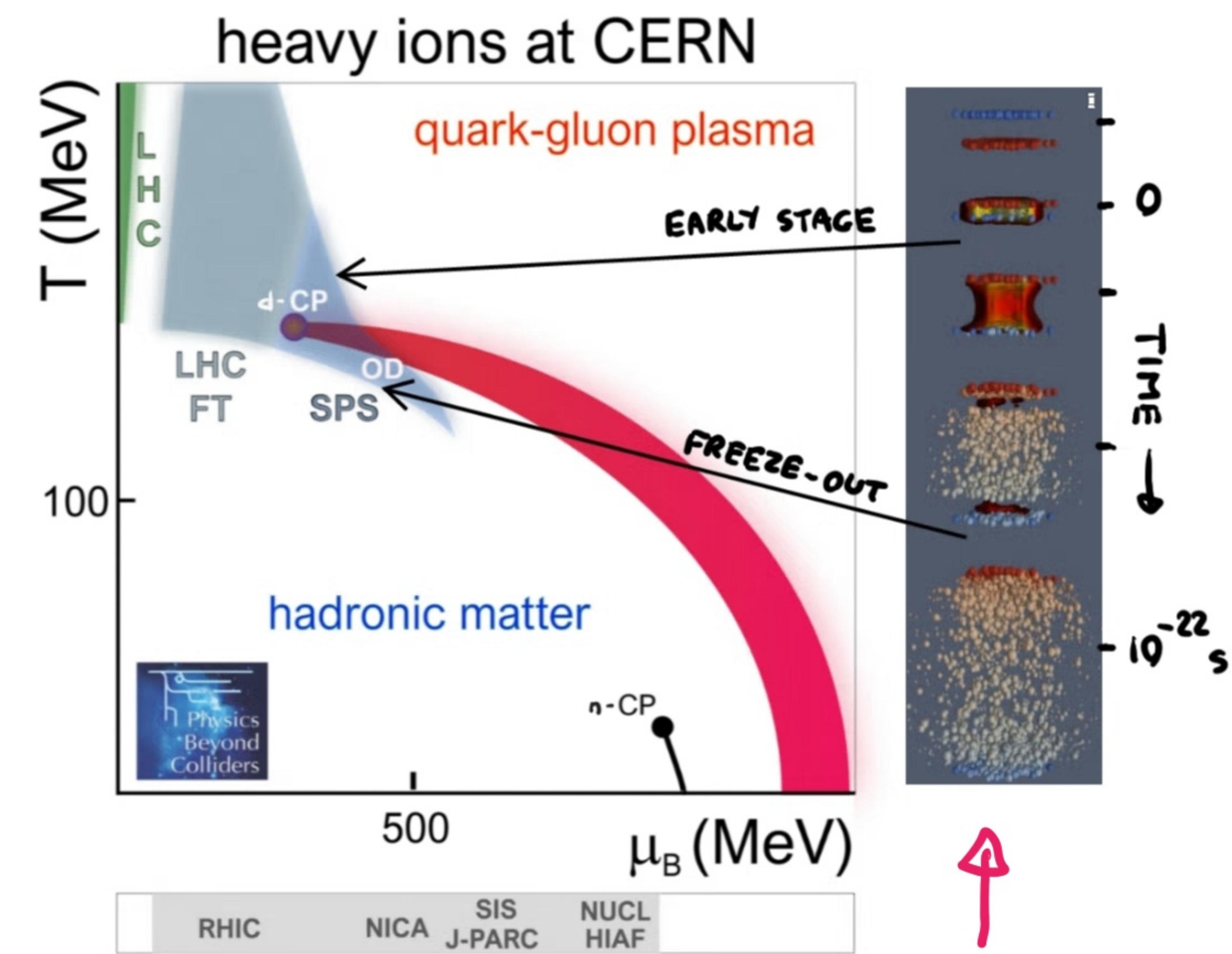
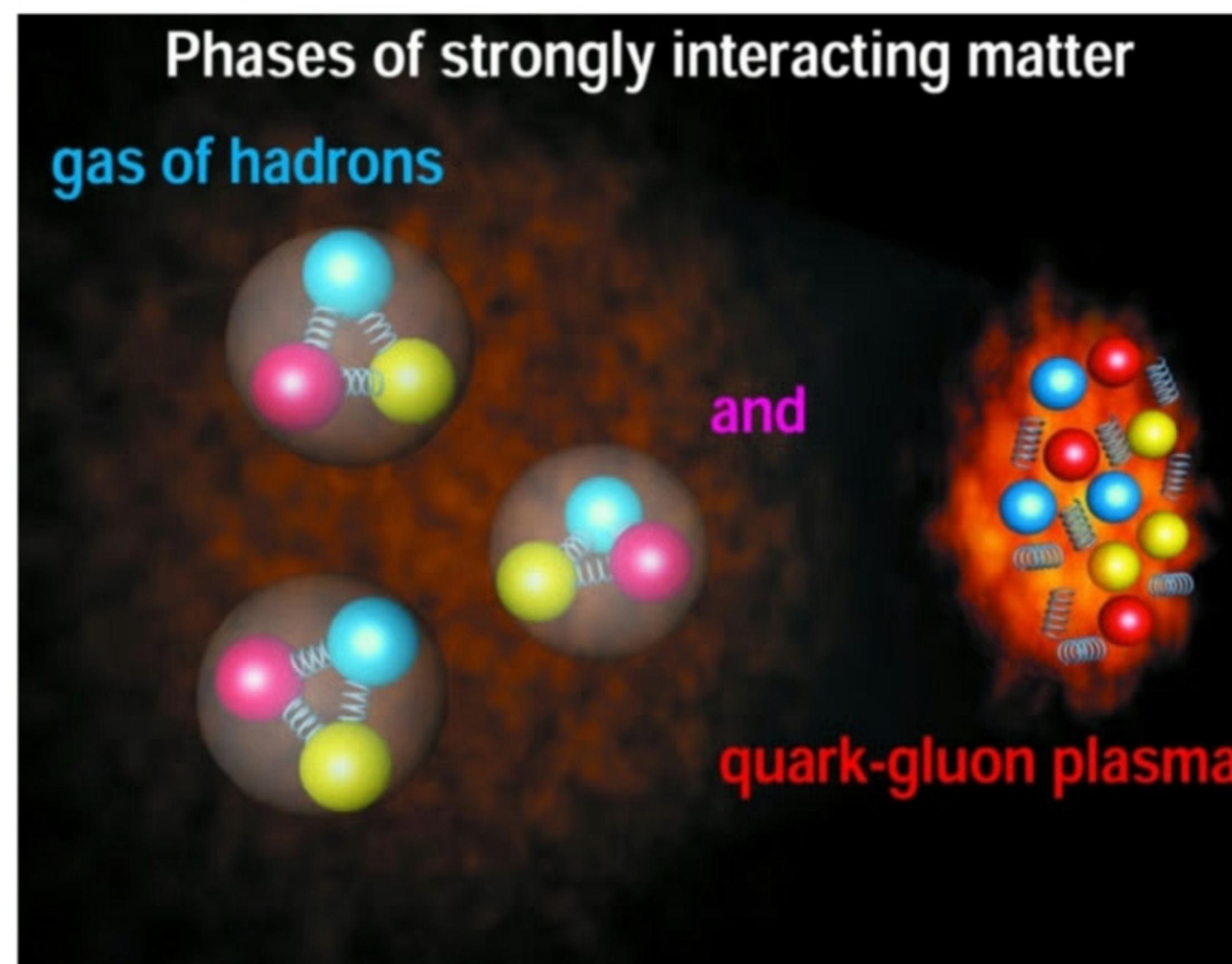


FOR

- STRONG INTERACTIONS (HEAVY IONS, ...)
- NEUTRINO BEAMS (J-PARC, FERMILAB)
- COSMIC RAY EXPS. (PAO, AMS, ...)

## STRONG INTERACTIONS

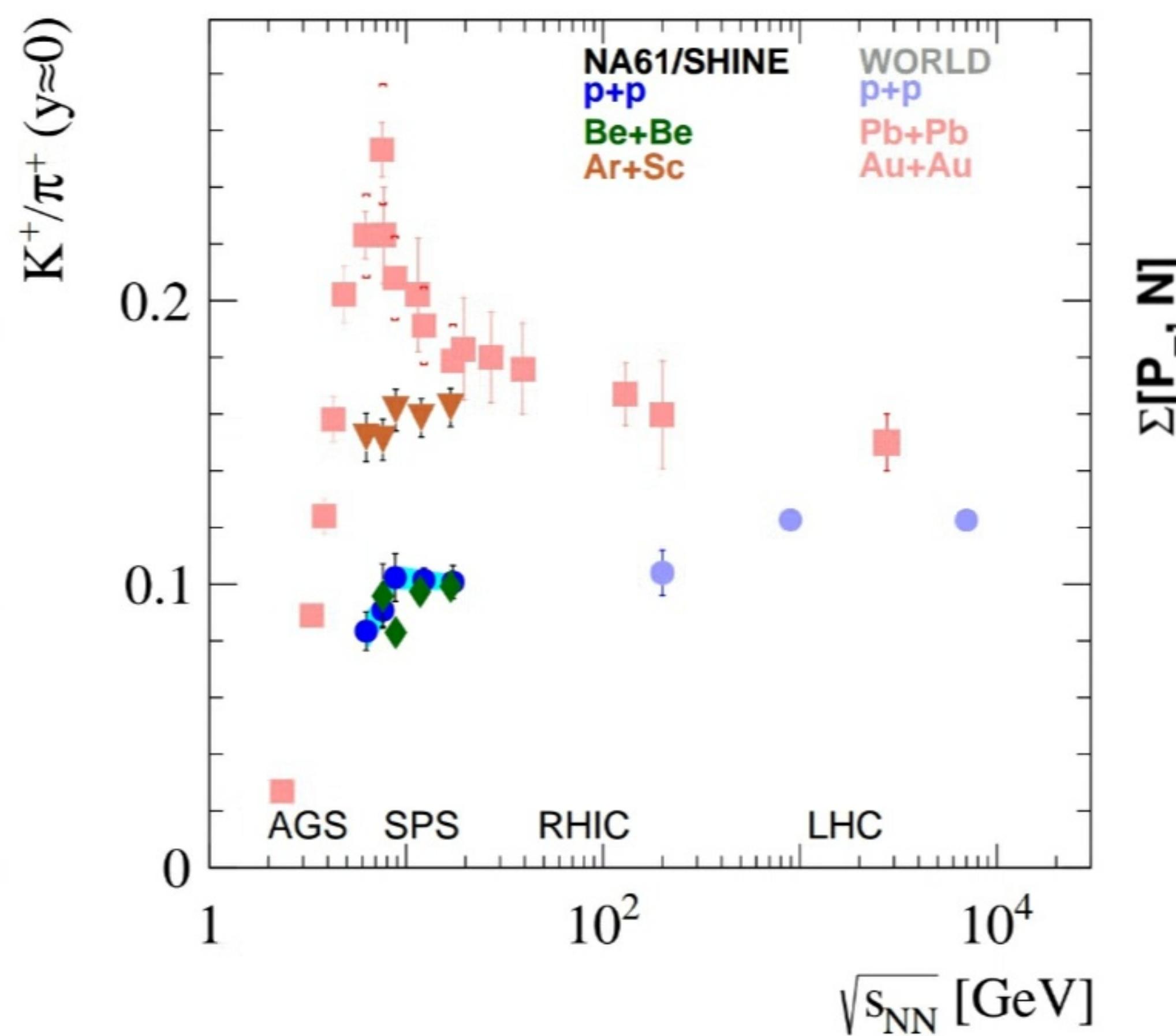
WHAT HAPPENS WHEN STRONGLY INTERACTING MATTER GETS HOTTER/DENSER AND ITS VOLUME CHANGES ?



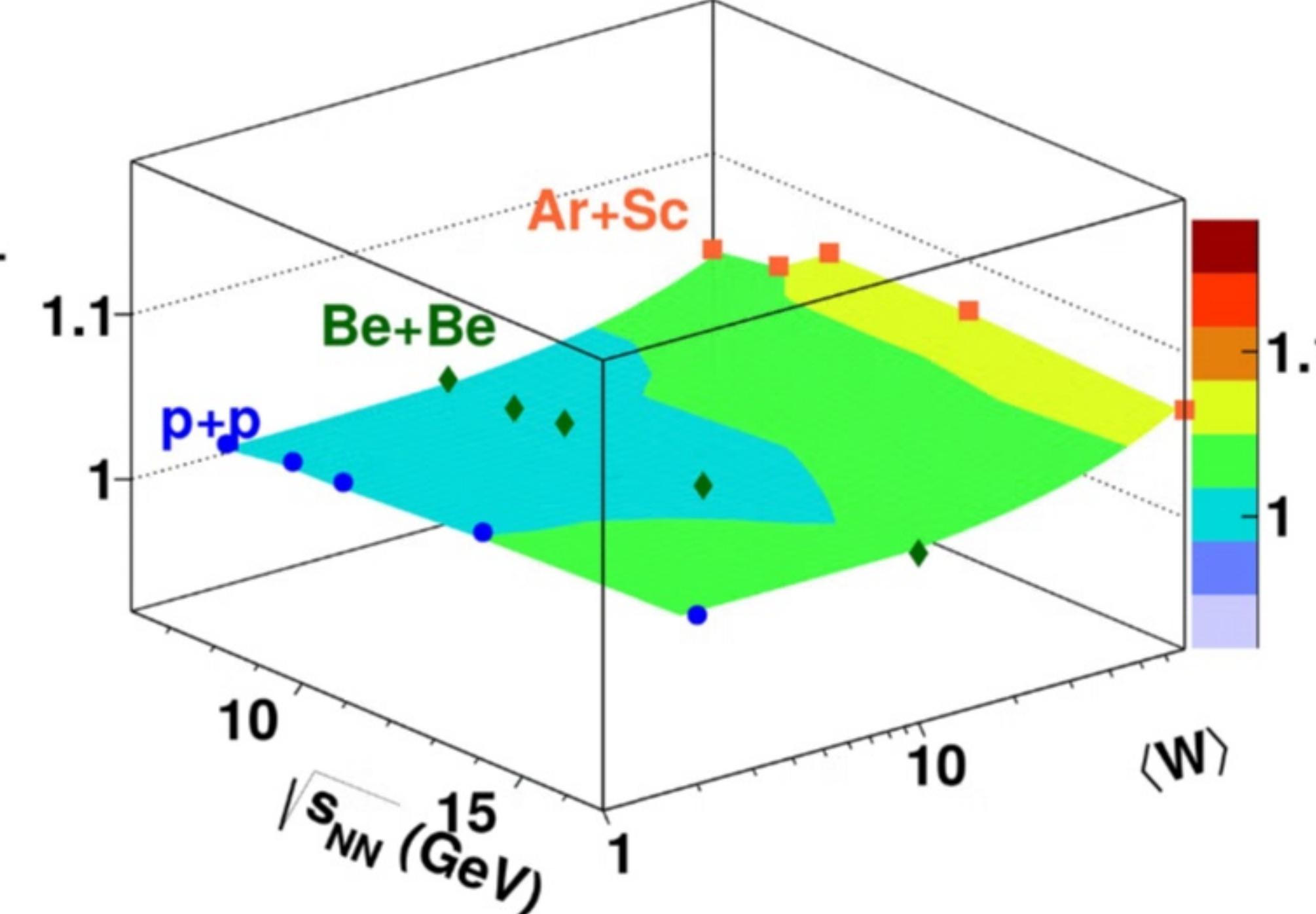
NAGI/SHINE: WHAT HAPPENS IN HEAVY ION COLLISIONS?

# STRONG INTERACTIONS: KEY RESULTS

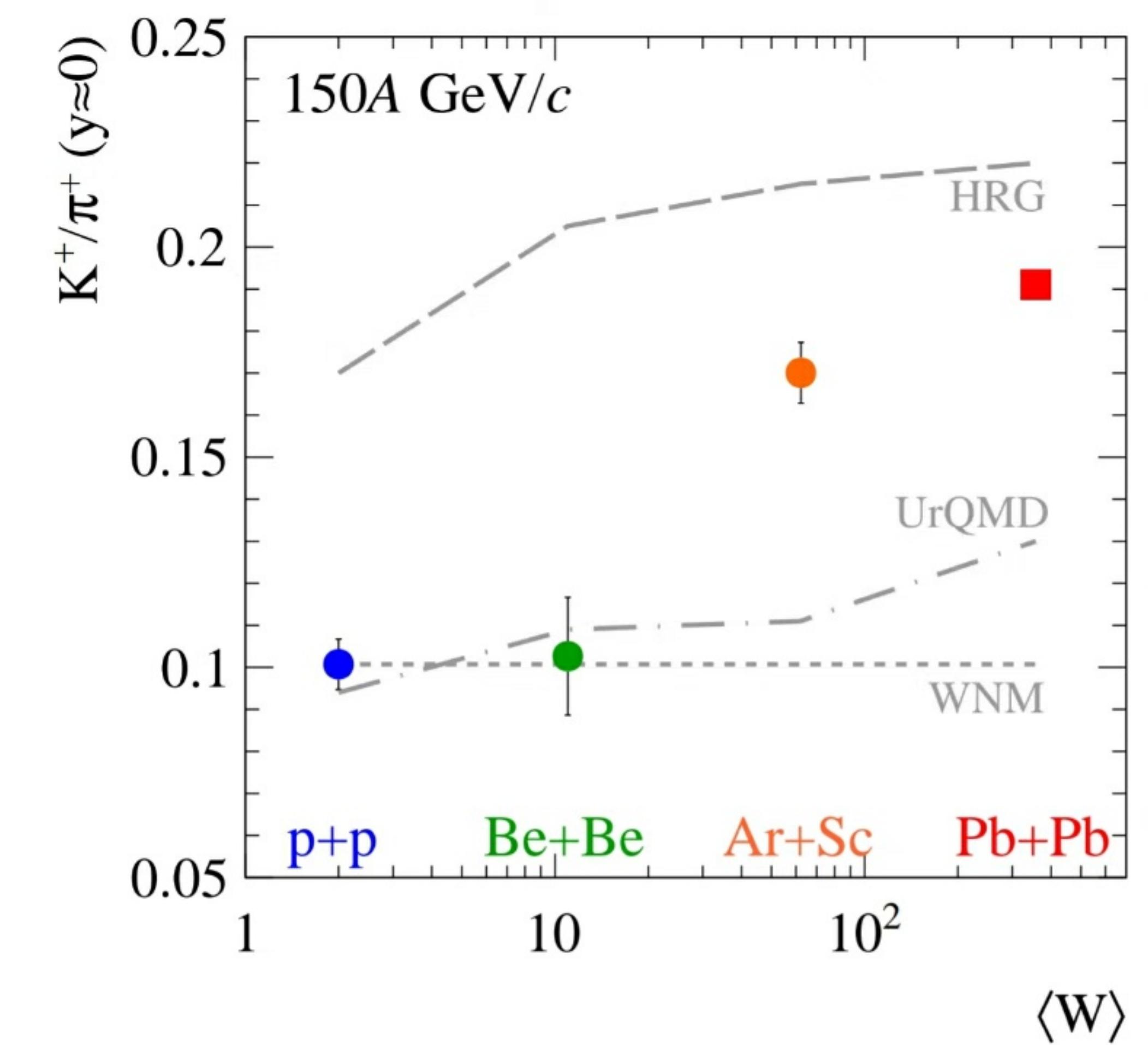
## ONSET OF DECONFINEMENT



## CRITICAL POINT



## ONSET OF FIRE BALL



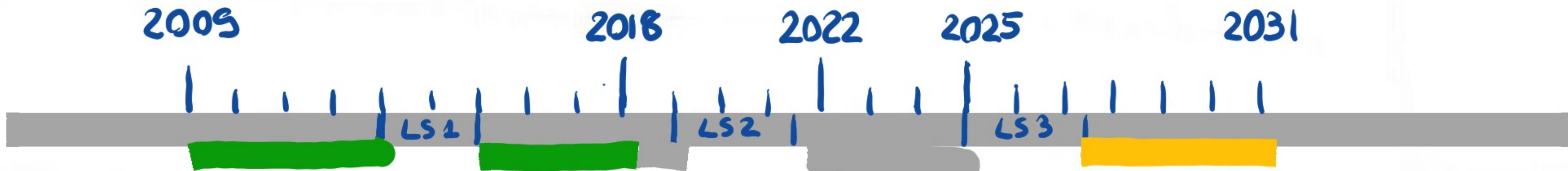
UNEXPECTED COLLISION ENERGY DEPENDENCE FOR SMALL/MEDIUM SIZE IONS

HORN → BREAK

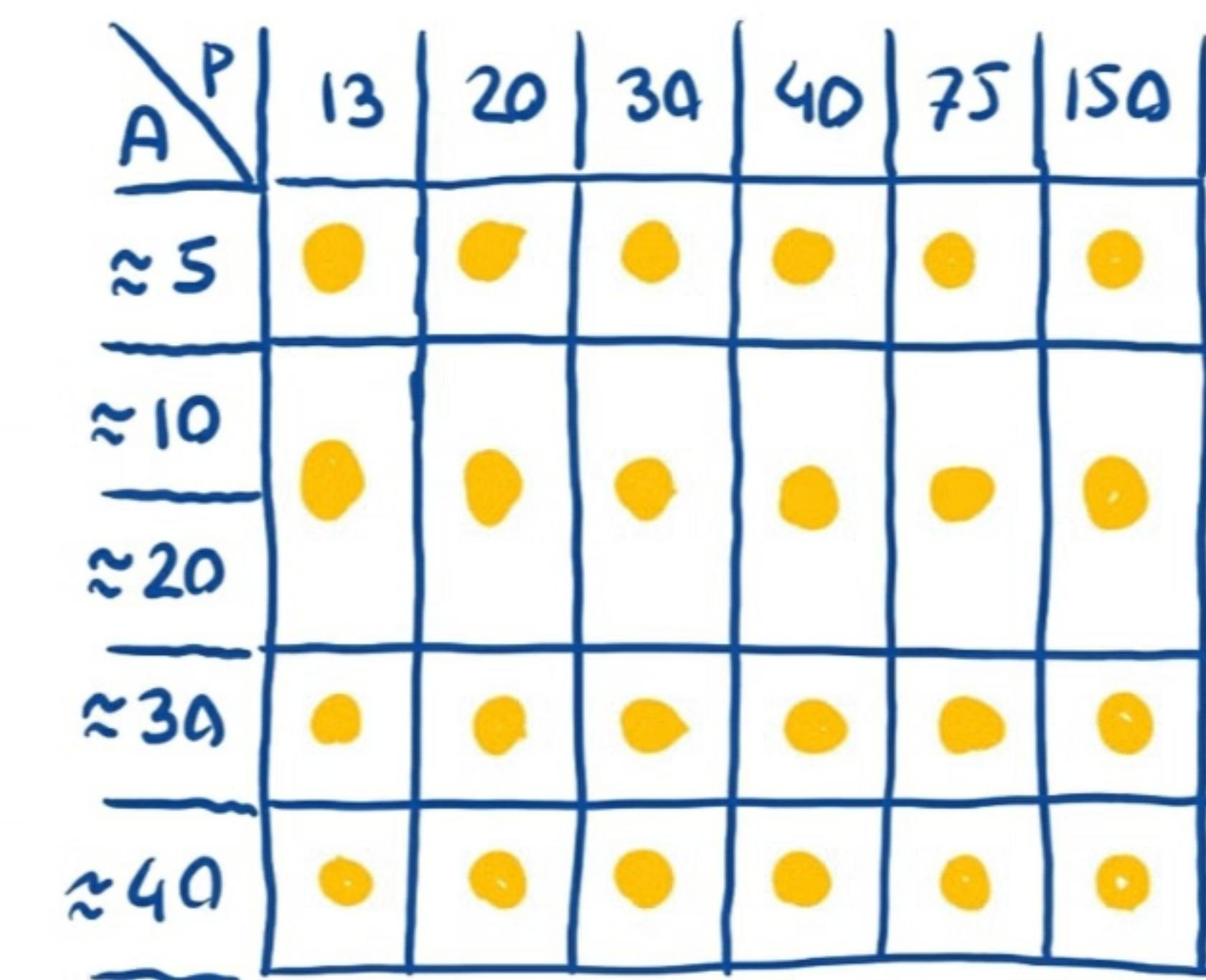
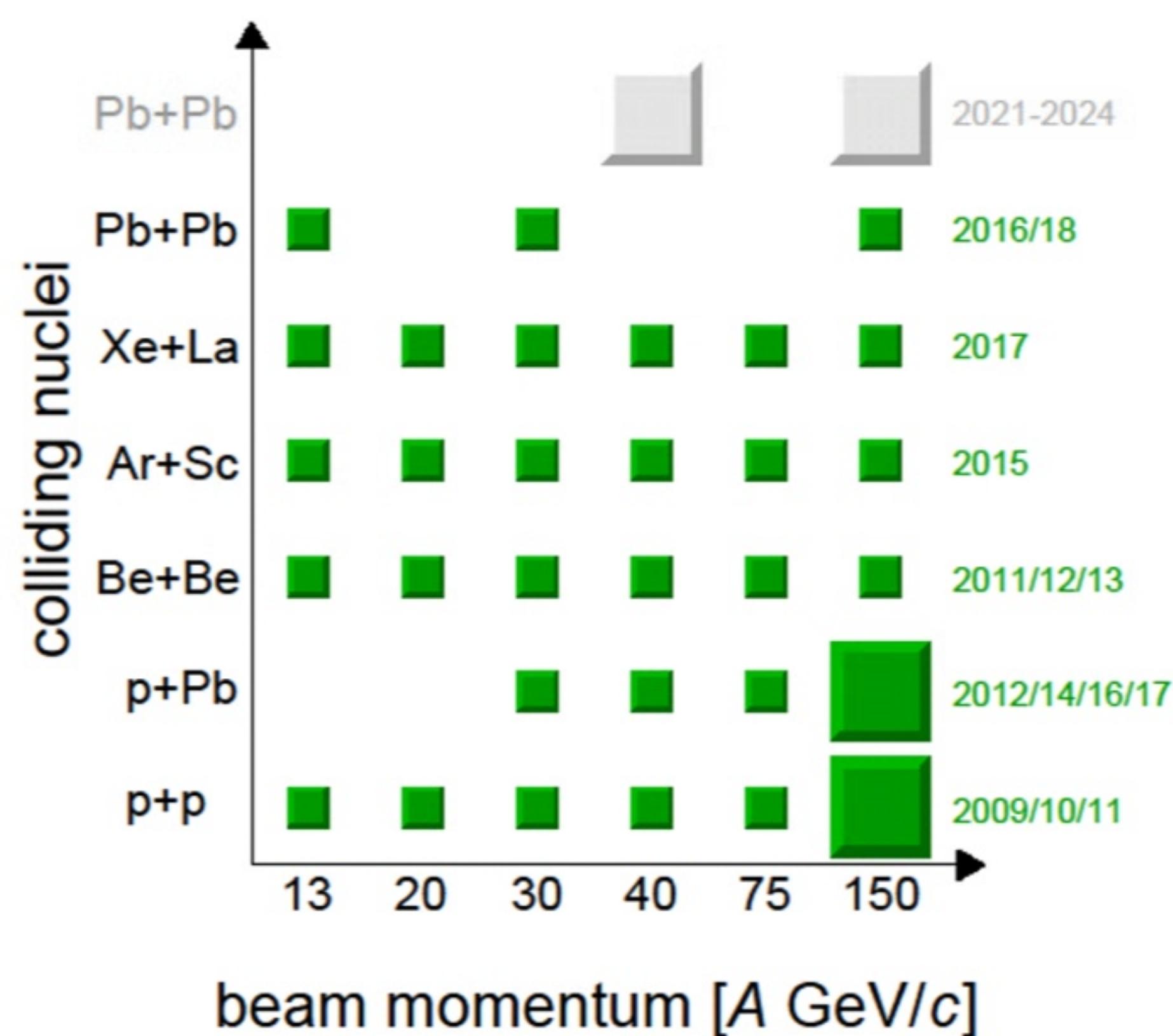
NO EVIDENCE YET

UNEXPECTED SYSTEM SIZE DEPENDENCE FOR SMALL/MEDIUM SIZE IONS

# STRONG INTERACTIONS: DATA TAKING



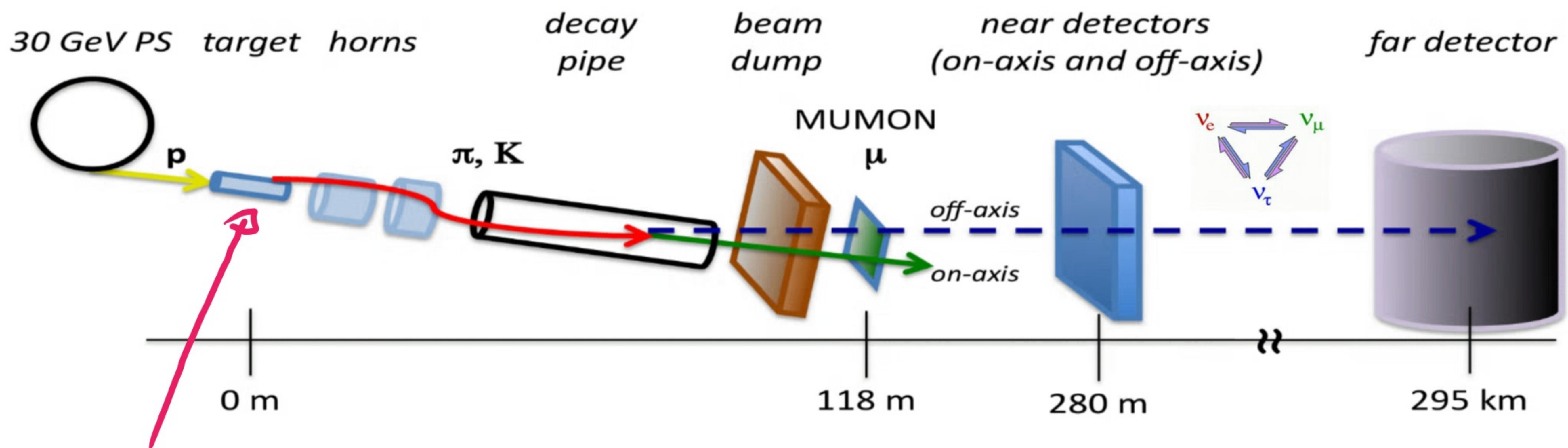
ONSET OF  
DECONFINEMENT



# NEUTRINOS

WHAT HAPPENS WITH NEUTRINOS FLYING ACROSS JAPAN AND UNITED STATES ?

## THE T2K LONG-BASELINE NEUTRINO OSCILLATION EXPERIMENT

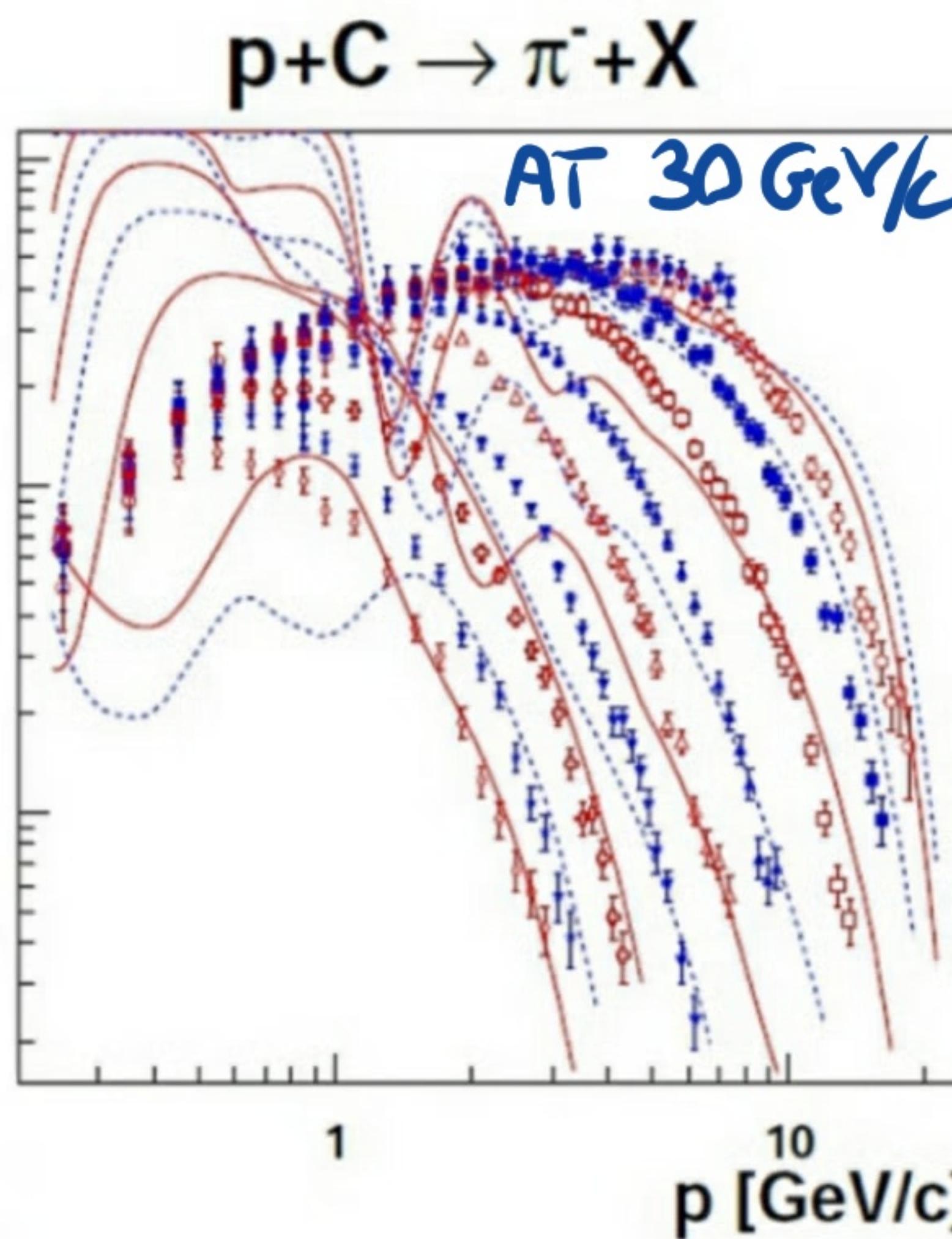


NA61/SHINE :

WHAT HAPPENS IN TARGETS OF NEUTRINO EXPERIMENTS ?

## NEUTRINOS: KEY RESULTS

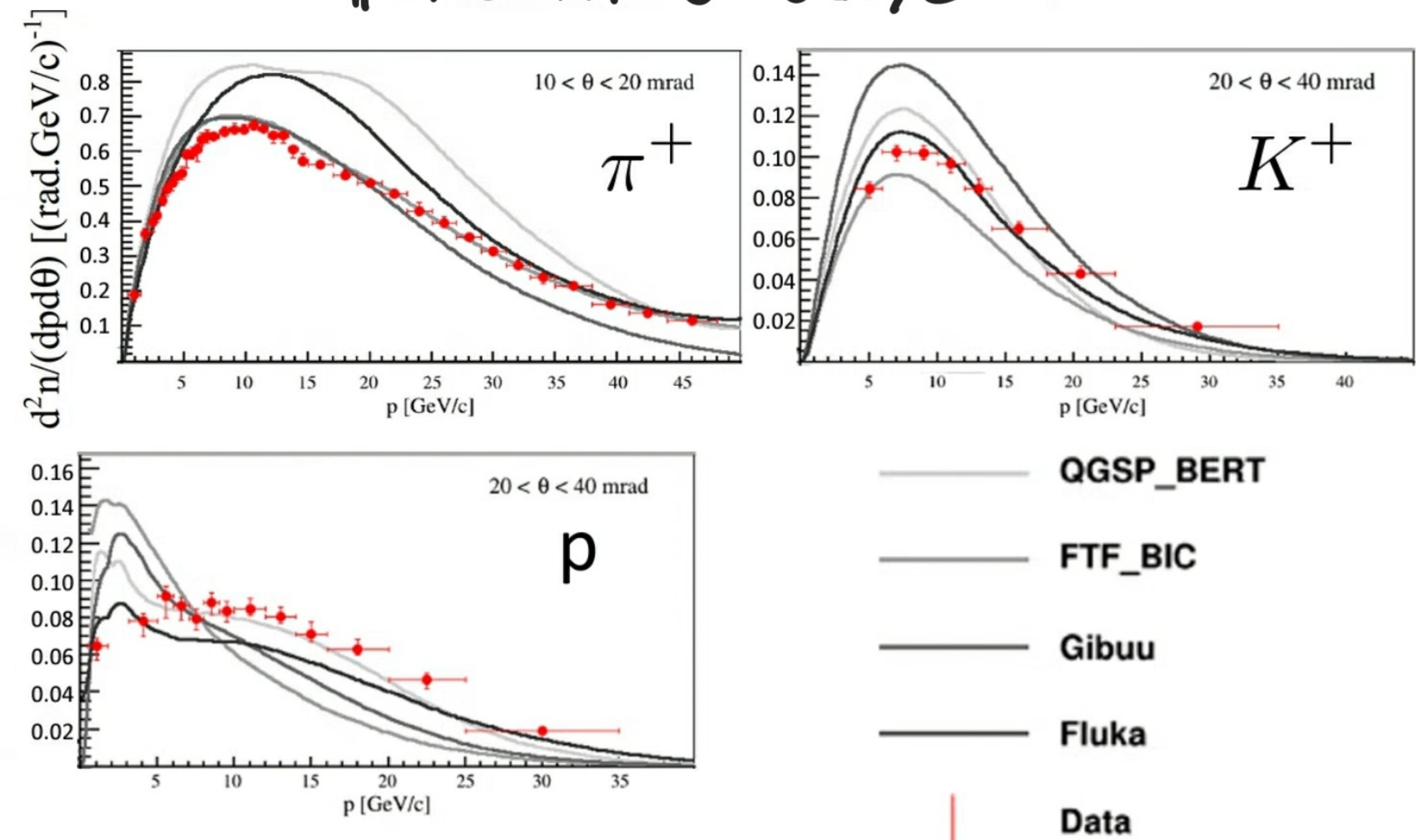
FOR J-PARC:



comparison to Gheisha2002

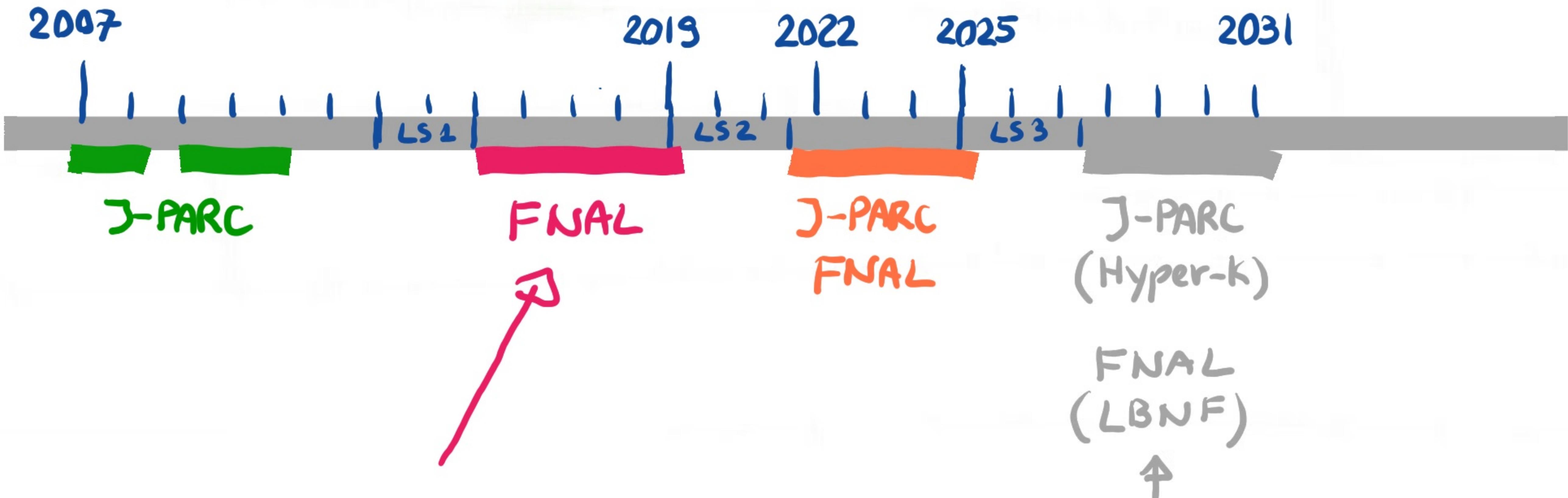
FOR FNAL:

$\pi^+ + C$  AT 60 GeV/c



NAS1/SHINE DATA REDUCE DECISIVELY  
UNCERTENTIES OF FINAL RESULTS OF NEUTRINO EXPERIMENTS

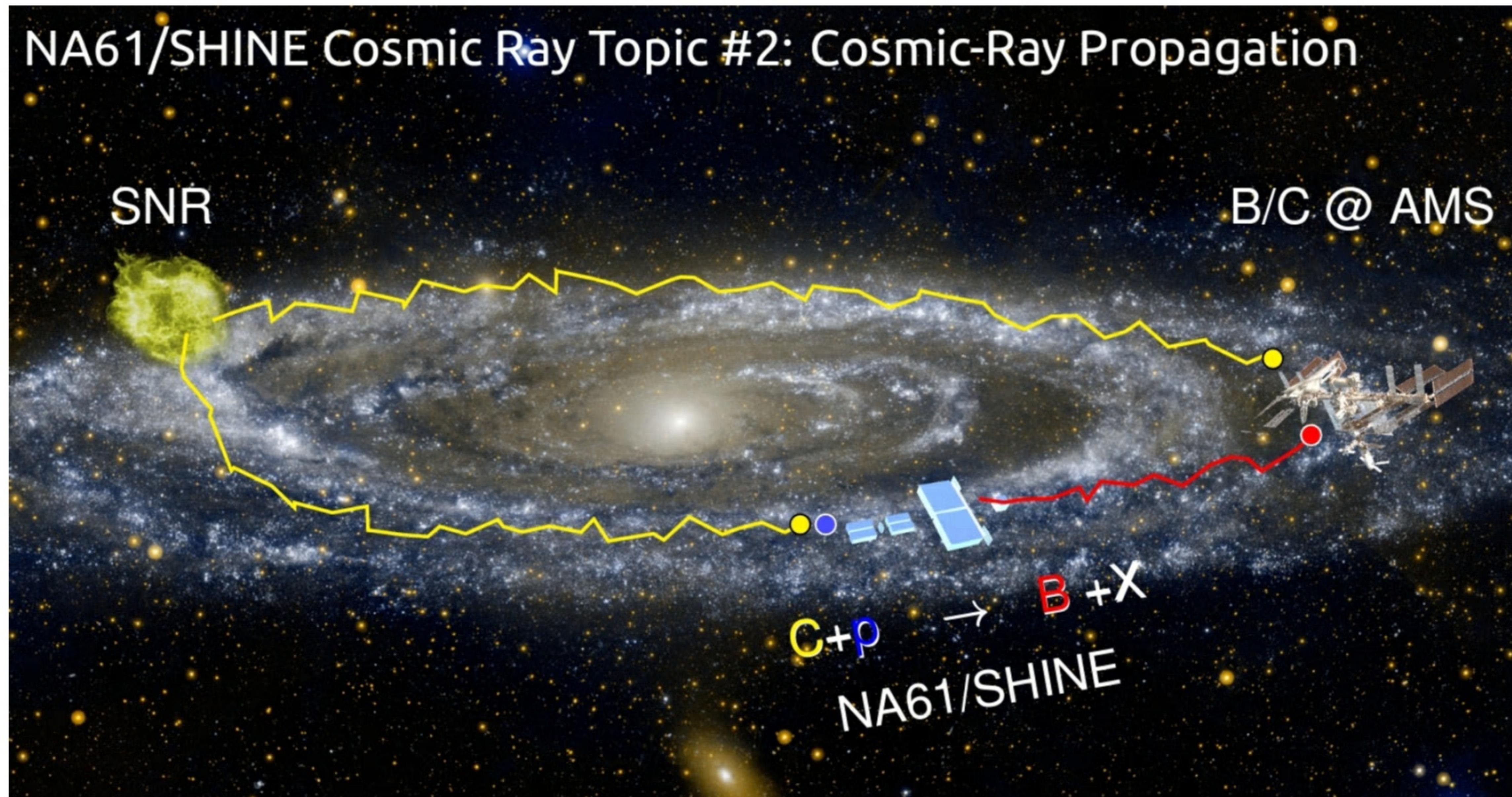
## NEUTRINOS: DATA TAKING



2016	2017
p + C @ 120 GeV/c	$\pi^+$ + Al @ 60 GeV/c
p + Be @ 120 GeV/c	$\pi^+$ + C @ 30 GeV/c
p + C @ 60 GeV/c	$\pi^-$ + C @ 60 GeV/c
p + Al @ 60 GeV/c	p + C @ 120 GeV/c (w FTPCs)
p + Be @ 60 GeV/c	p + Be @ 120 GeV/c (w FTPCs)
$\pi^+$ + C @ 60 GeV/c	p + C @ 90 GeV/c (w FTPCs)
$\pi^+$ + Be @ 60 GeV/c	

## COSMIC-RAYS

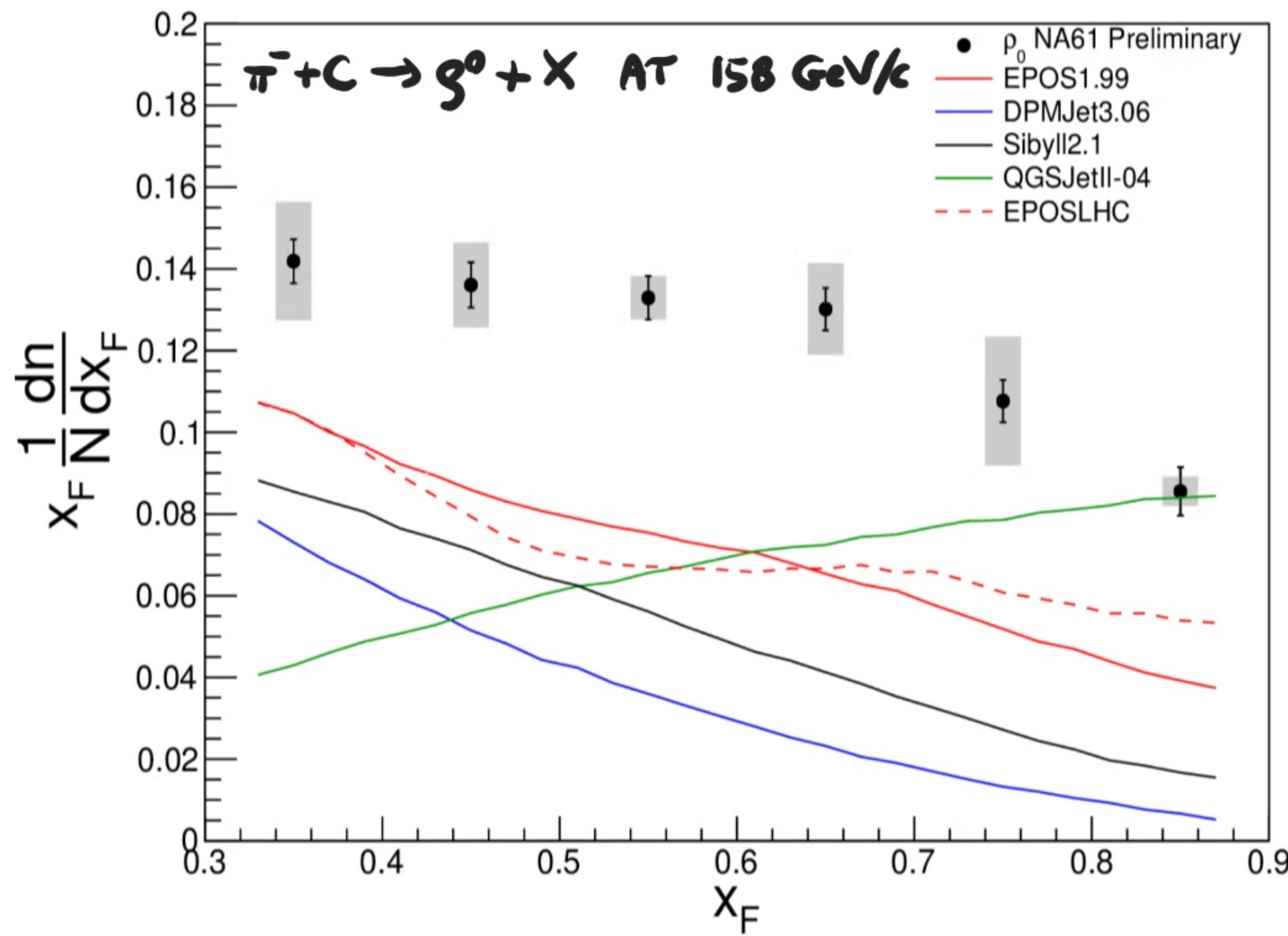
WHAT IS THE ORIGIN OF VERY HIGH ENERGY COSMIC-RAYS ?



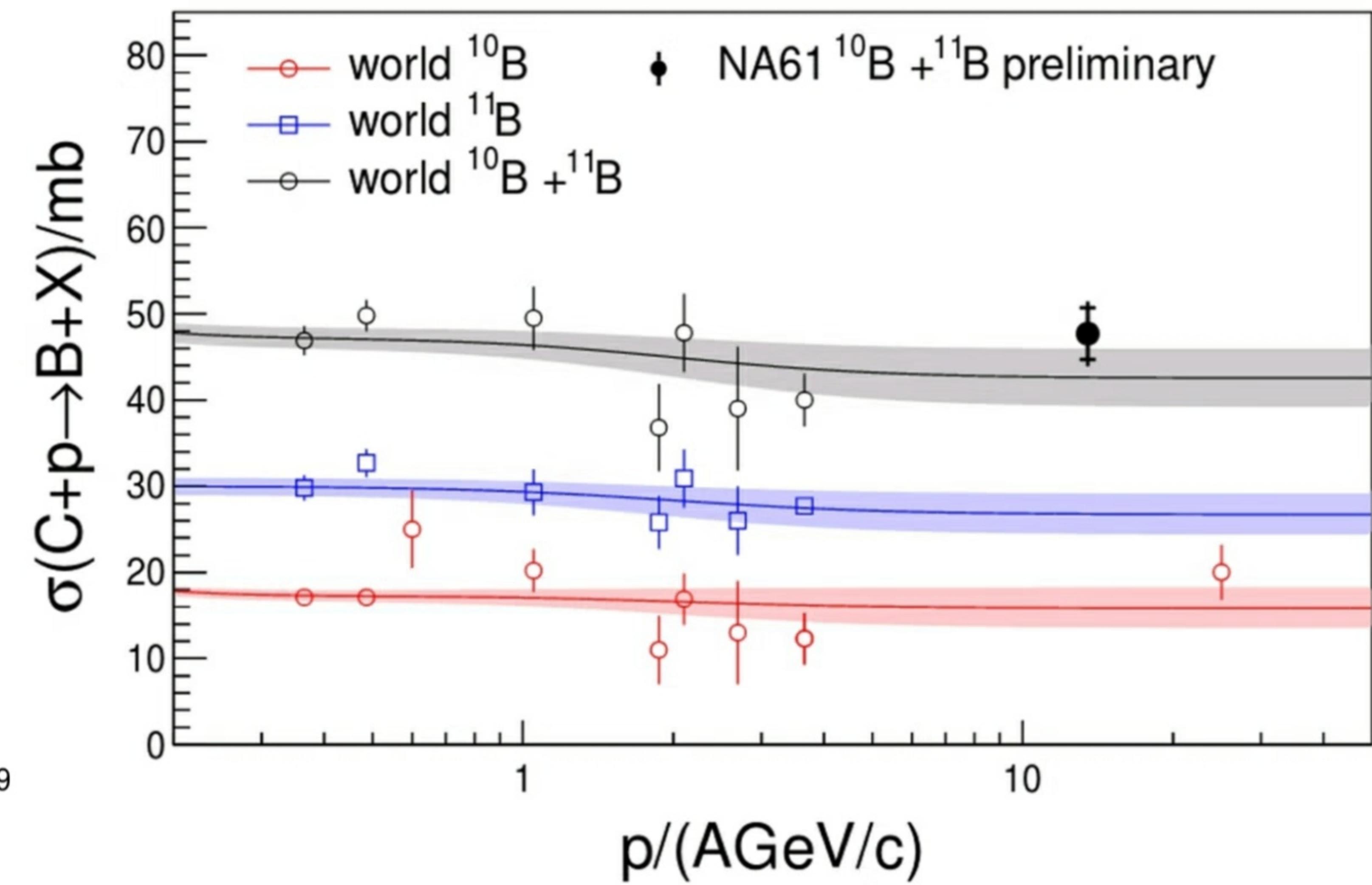
NA61/SHINE: WHAT HAPPENS WITH COSMIC RAYS  
IN INTERSTELLAR MEDIUM?

## COSMIC-RAYS: KEY RESULTS

### EXTENSIVE AIR SHOWERS:

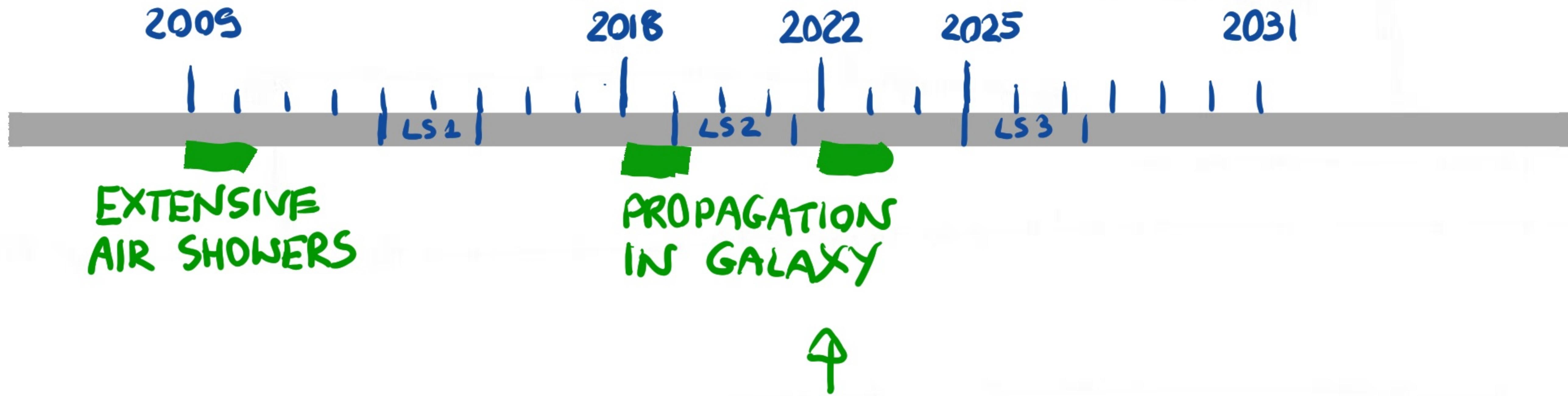


### PROPAGATION IN GALAXY:



UNIQUE RESULTS WHICH CONSTRAIN MODELS  
NEEDED TO INTERPRET HIGH PRECISION  
DATA ON COSMIC RAYS

## COSMIC-RAYS: DATA TAKING



reaction	$N_{\text{inter}}$	$A/Z$
$^{16}\text{O} + \text{H}$	250k	2
$^{12}\text{C} + \text{H}$	150k	2
$^{16}\text{O} + \text{He}$	100k	2
$^{14}\text{N} + \text{H}$	40k	2
$^{10}\text{B} + \text{H}$	5k	2
$^{11}\text{B} + \text{H}$	5k	2
$^{12}\text{C} + \text{He}$	5k	2
$^{13}\text{C} + \text{H}$	5k	11/5
$^{15}\text{N} + \text{H}$	5k	13/6
$^{20}\text{Ne} + \text{H}$	5k	15/7
$^{24}\text{Mg} + \text{H}$	5k	2
$^{28}\text{Si} + \text{H}$	5k	2
$^7\text{Li} + \text{H}$	5k	7/3
$\Sigma = 0.6\text{M}$		

## Measurements of Cross Sections and Charged Pion Spectra in Proton-Carbon Interactions at 31 GeV/c #1

NA61/SHINE Collaboration • N. Abgrall (Geneva U.) et al. (Feb 6, 2011)

Published in: *Phys.Rev.C* 84 (2011) 034604 • e-Print: 1102.0983 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[269 citations](#)

## Measurement of Production Properties of Positively Charged Kaons in Proton-Carbon Interactions at 31 GeV/c #2

NA61/SHINE Collaboration • N. Abgrall (Geneva U.) et al. (Dec 1, 2011)

Published in: *Phys.Rev.C* 85 (2012) 035210 • e-Print: 1112.0150 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[158 citations](#)

## Measurement of negatively charged pion spectra in inelastic p+p interactions at $p_{lab} = 20, 31, 40, 80$ and $158$ GeV/c #3

NA61/SHINE Collaboration • N. Abgrall (Geneva U.) et al. (Oct 9, 2013)

Published in: *Eur.Phys.J.C* 74 (2014) 3, 2794 • e-Print: 1310.2417 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[93 citations](#)

## Measurements of $\pi^\pm, K^\pm, K_S^0, \Lambda$ and proton production in proton–carbon interactions at 31 GeV/c with the NA61/SHINE spectrometer at the CERN SPS #4

NA61/SHINE Collaboration • N. Abgrall (Geneva U.) et al. (Oct 9, 2015)

Published in: *Eur.Phys.J.C* 76 (2016) 2, 84 • e-Print: 1510.02703 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[92 citations](#)

## Pion emission from the T2K replica target: method, results and application #5

NA61/SHINE Collaboration • N. Abgrall (Geneva U.) et al. (Jul 9, 2012)

Published in: *Nucl.Instrum.Meth.A* 701 (2013) 99-114 • e-Print: 1207.2114 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[70 citations](#)

## Measurements of $\pi^\pm, K^\pm, p$ and $\bar{p}$ spectra in proton-proton interactions at 20, 31, 40, 80 and 158 GeV/c with the NA61/SHINE spectrometer at the CERN SPS #6

NA61/SHINE Collaboration • A. Aduszkiewicz (Warsaw U.) et al. (May 6, 2017)

Published in: *Eur.Phys.J.C* 77 (2017) 10, 671 • e-Print: 1705.02467 [nucl-ex]

[pdf](#) [DOI](#) [cite](#)

[66 citations](#)

## Multiplicity and transverse momentum fluctuations in inelastic proton–proton interactions at the CERN Super Proton Synchrotron #7

NA61/SHINE Collaboration • A. Aduszkiewicz (Warsaw U.) et al. (Oct 1, 2015)

Published in: *Eur.Phys.J.C* 76 (2016) 11, 635 • e-Print: 1510.00163 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[57 citations](#)

## Measurements of production properties of $K_S^0$ mesons and $\Lambda$ hyperons in proton–carbon interactions at 31 GeV/c #8

NA61/SHINE Collaboration • N. Abgrall (U. Geneva (main)) et al. (Sep 8, 2013)

Published in: *Phys.Rev.C* 89 (2014) 2, 025205 • e-Print: 1309.1997 [physics.acc-ph]

[pdf](#) [DOI](#) [cite](#)

[34 citations](#)

# SELECTED PUBLICATIONS



## Measurements of $\pi^\pm$ differential yields from the surface of the T2K replica target for incoming 31 GeV/c protons with the NA61/SHINE spectrometer at the CERN SPS #9

NA61/SHINE Collaboration • N. Abgrall (Geneva U.) et al. (Mar 22, 2016)

Published in: *Eur.Phys.J.C* 76 (2016) 11, 617 • e-Print: 1603.06774 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[34 citations](#)

## Ion Program of Na61/Shine at the CERN SPS #10

NA61/SHINE Collaboration • Marek Gazdzicki (Frankfurt U., Inst. Kernphys. and Jan Kochanowski U.) for the collaboration. (Dec 23, 2008)

Published in: *J.Phys.G* 36 (2009) 064039 • Contribution to: SQM 2008 • e-Print: 0812.4415 [nucl-ex]

[pdf](#) [DOI](#) [cite](#)

[28 citations](#)

## Production of $\Lambda$ -hyperons in inelastic p+p interactions at 158 GeV/c #11

NA61/SHINE Collaboration • A. Aduszkiewicz (Warsaw U.) et al. (Oct 13, 2015)

Published in: *Eur.Phys.J.C* 76 (2016) 4, 198 • e-Print: 1510.03720 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[21 citations](#)

## Measurements of $\pi^\pm, K^\pm$ and proton double differential yields from the surface of the T2K replica target for incoming 31 GeV/c protons with the NA61/SHINE spectrometer at the CERN SPS #12

NA61/SHINE Collaboration • N. Abgrall (Geneva U.) et al. (Aug 14, 2018)

Published in: *Eur.Phys.J.C* 78 (2018) 1000 • e-Print: 1805.04546 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[20 citations](#)

## Measurement of meson resonance production in $\pi^- + C$ interactions at SPS energies #13

NA61/SHINE Collaboration • A. Aduszkiewicz (Warsaw U.) et al. (May 23, 2017)

Published in: *Eur.Phys.J.C* 77 (2017) 9, 626 • e-Print: 1705.08206 [nucl-ex]

[pdf](#) [DOI](#) [cite](#)

[18 citations](#)

## Measurements of total production cross sections for $\pi^+ + C$ , $\pi^+ + Al$ , $K^+ + C$ , and $K^+ + Al$ at 60 GeV/c and $\pi^+ + C$ and $\pi^+ + Al$ at 31 GeV/c #14

NA61/SHINE Collaboration • A. Aduszkiewicz (Warsaw U.) et al. (May 11, 2018)

Published in: *Phys.Rev.D* 98 (2018) 5, 052001 • e-Print: 1805.04546 [hep-ex]

[pdf](#) [DOI](#) [cite](#)

[10 citations](#)

## Two-particle correlations in azimuthal angle and pseudorapidity in inelastic p + p interactions at the CERN Super Proton Synchrotron #15

NA61/SHINE Collaboration • A. Aduszkiewicz (Warsaw U. (main)) et al. (Oct 3, 2016)

Published in: *Eur.Phys.J.C* 77 (2017) 2, 59 • e-Print: 1610.00482 [nucl-ex]

[pdf](#) [DOI](#) [cite](#)

[9 citations](#)

## Proton-Proton Interactions and Onset of Deconfinement #16

NA61/SHINE Collaboration • A. Aduszkiewicz (Warsaw U. (main)) et al. (Dec 23, 2019)

Published in: *Phys.Rev.C* 102 (2020) 1, 011901 • e-Print: 1912.10871 [hep-ex]

[pdf](#) [links](#) [DOI](#) [cite](#)

[9 citations](#)

# COLLABORATIONS





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## MORE ON NACI/SHINE

### WEBSITE:

<https://shine.web.cern.ch>

### PUBLICATIONS:

<https://inspirehep.net/literature?sort=mostrecent&size=25&page=1&q=find%20cn%3Ana61/shine%20and%20tc%20p>

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