UNIVERSITY OF ILLINOIS URBANA-CHAMPAIGN

muses

smash

Illinois Center for Advanced Studies of the Universe

37th WWND

Puerto Vallarta, Mexico

Influence of heavy resonances in SMASH

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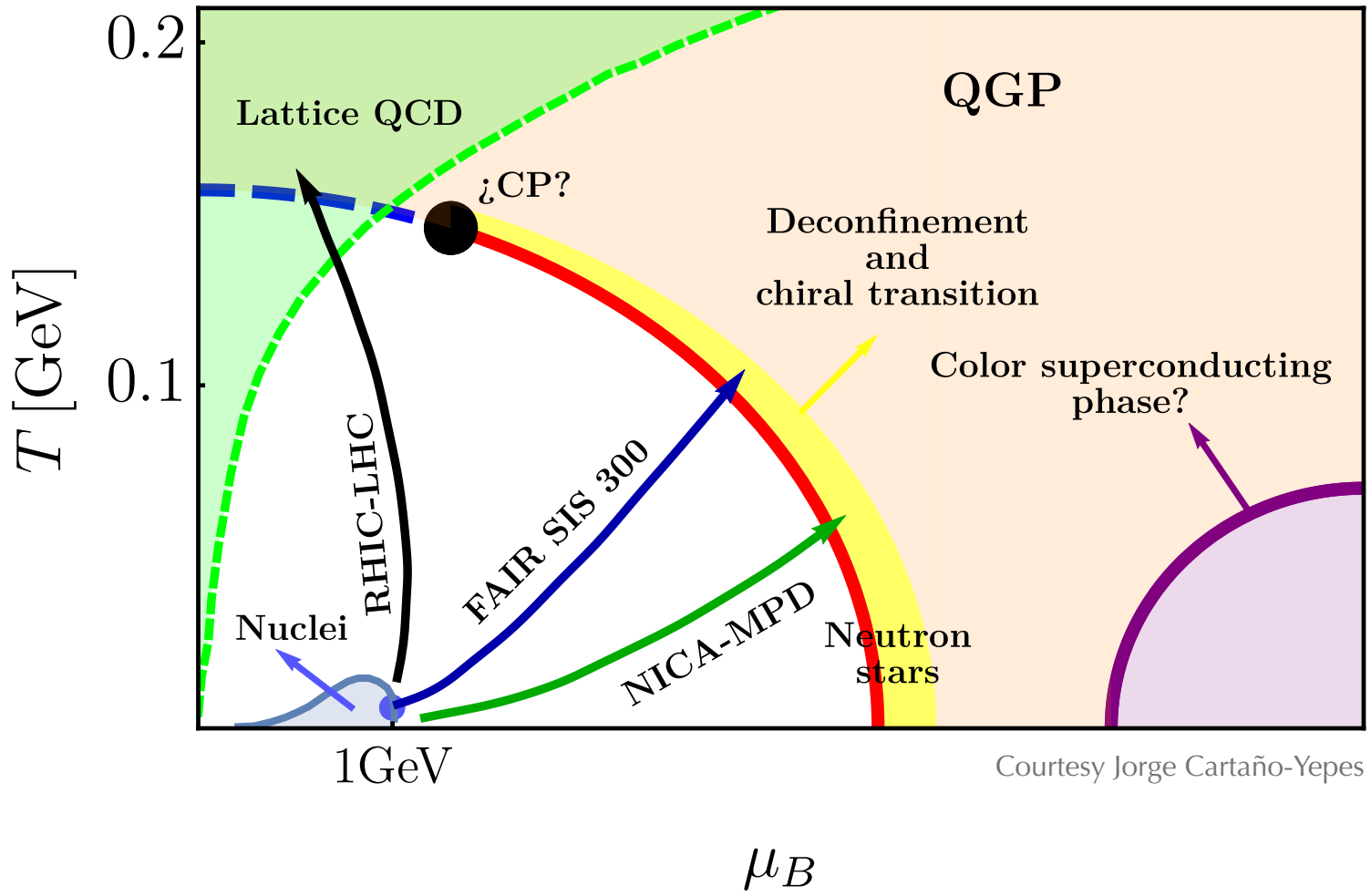
In collaboration with: J. Noronha-Hostler, H. Elfner, J. Hammelmann, R. Noboyuki Hirayama, P. Parotto, MUSES Collaboraton

Probing the QCD phase diagram

- HICs are instrumental in probing the phase diagram
- An equation of state is necessary for hydro simulations
- A complete description of a HIC encompasses several steps



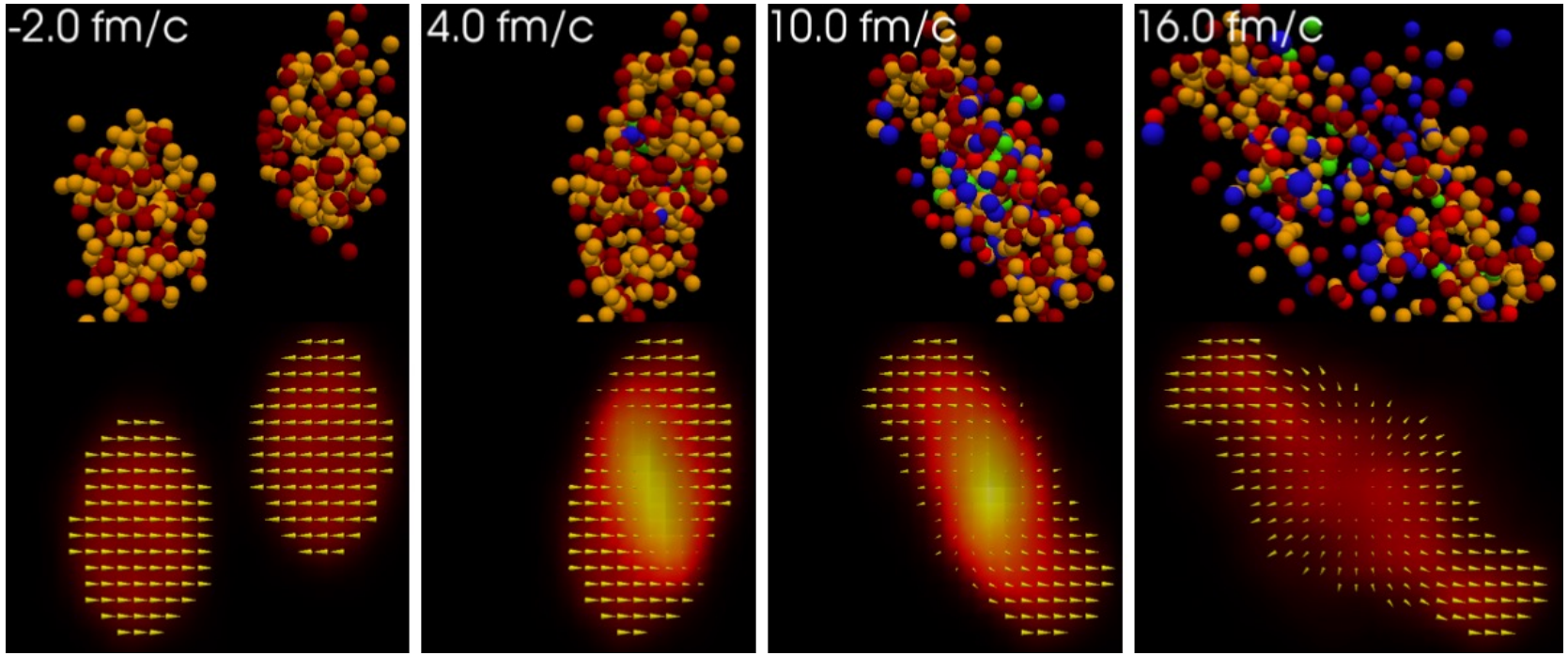
Courtesy Jorge Cartaño-Yepes

Outline

- Introduce SMASH and its relevance
- + number of resonances = good?
- PDG21+ list
- Implementation of the PDG21+ on SMASH
- Effects of resonances in cross-sections

Transport codes and SMASH

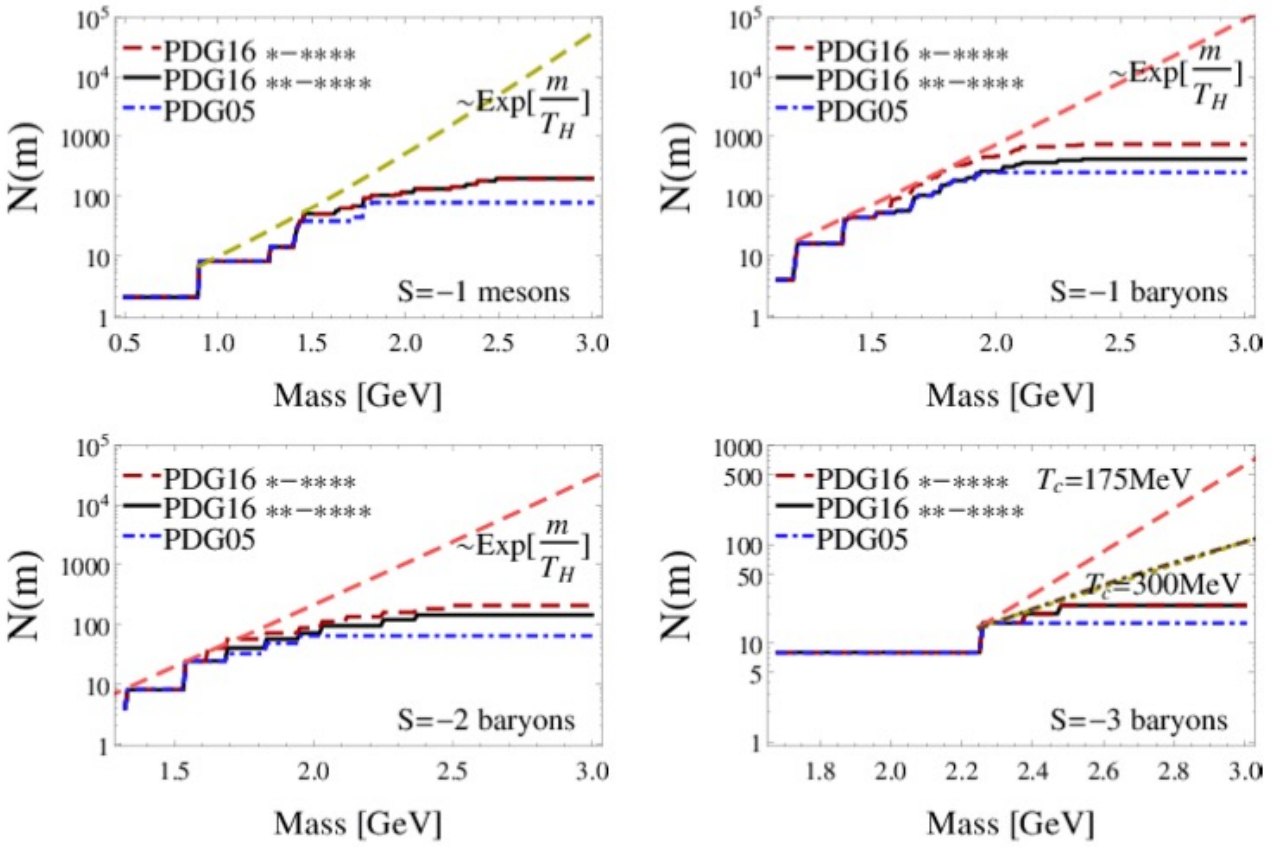
J. Weil *et al.*, PRC 94 (2016) 054905
D. Oliinychenko *et al.*, SMASH-transport (2021), https://doi.org/10.5281/zenodo.5796168



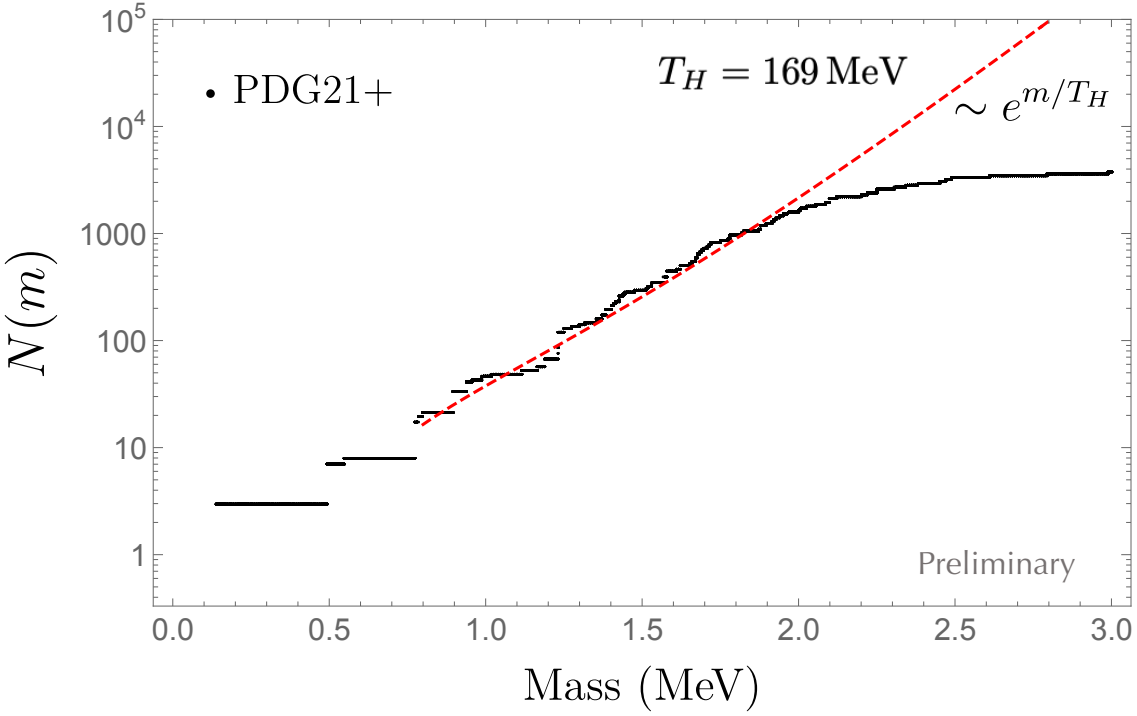
- First transport code written in C++
- Open-source
- Monte-Carlo solver of relativistic Boltzmann eq.
- Based on both BUU and QMD approaches
- Geometrical collision criteria (same as UrQMD)

Influence of resonances in HRG (Mass Spectrum)

$$N(m) = \sum_i d_i \theta(m - m_i)$$



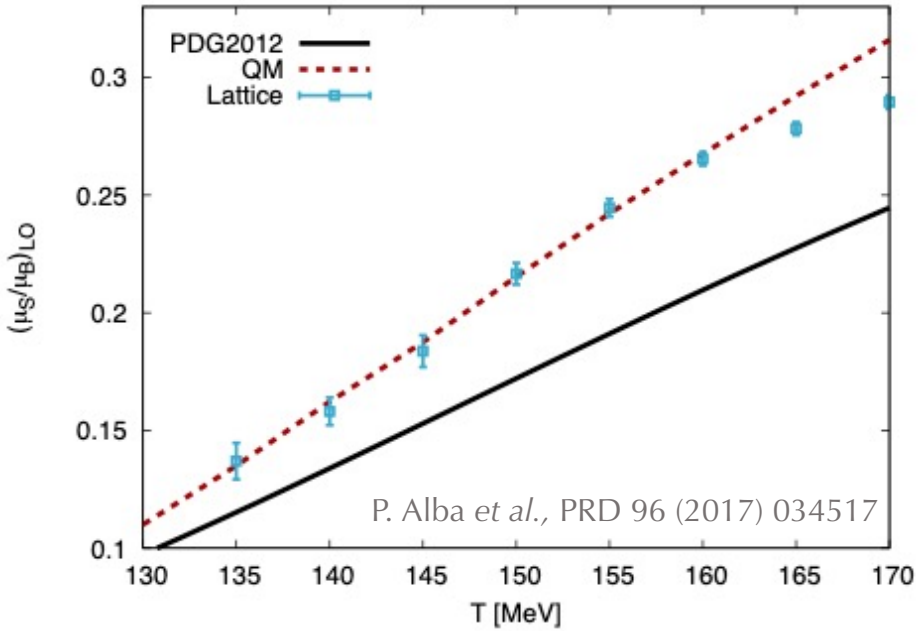
J. Noronha-Hostler, arXiv:1612.07765

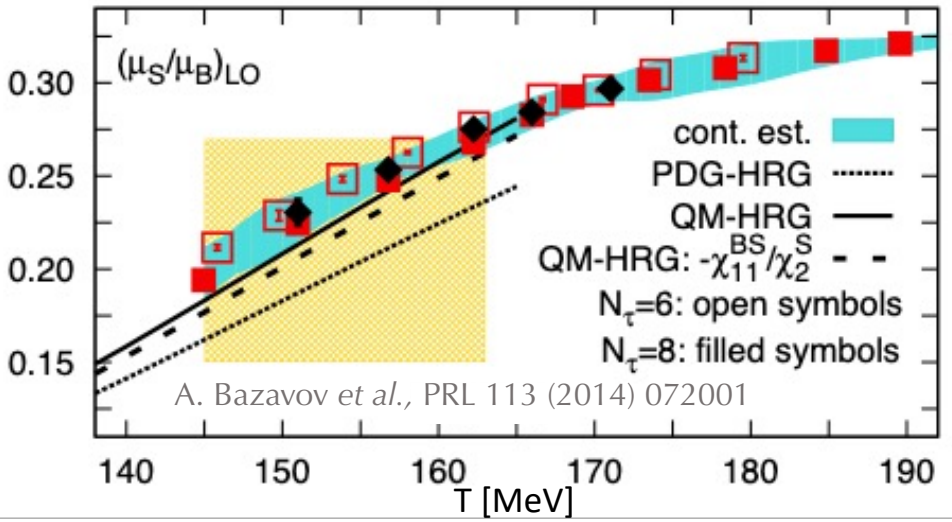


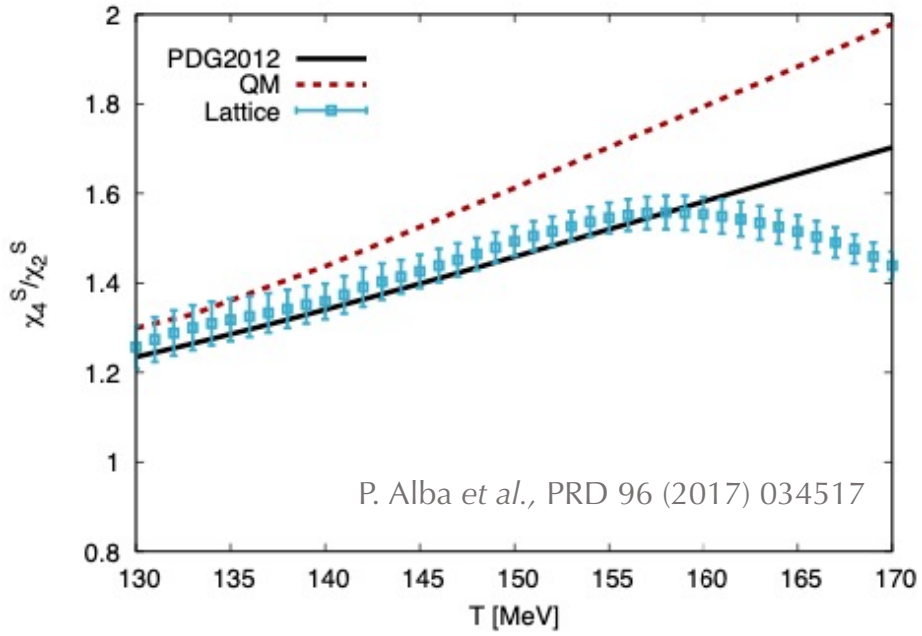
J. Salinas San Martin + MUSES Collaboration, to appear soon

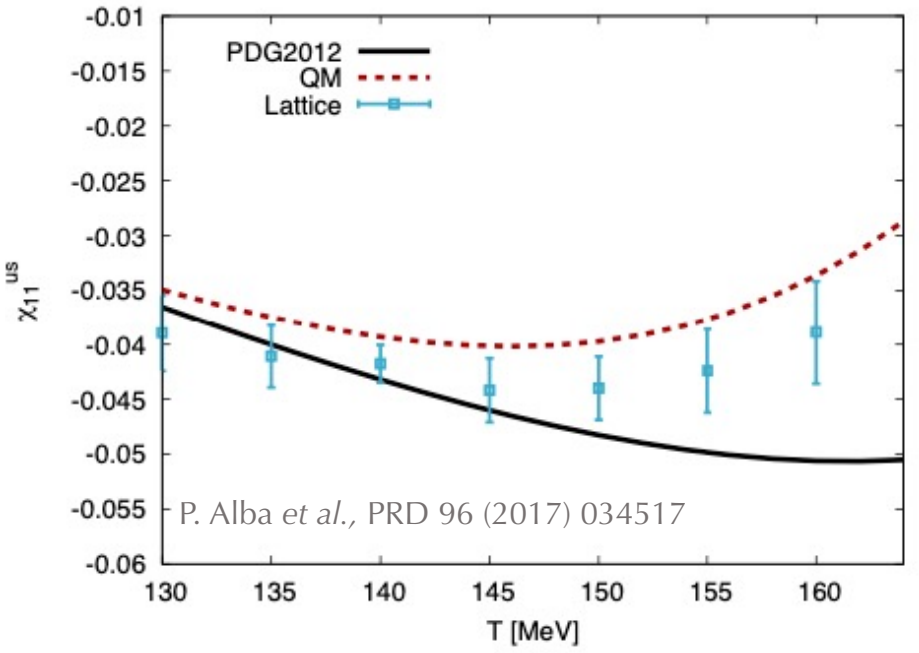
Influence of resonances

- Lattice hints at missing strange hadrons, especially $|S|=1$

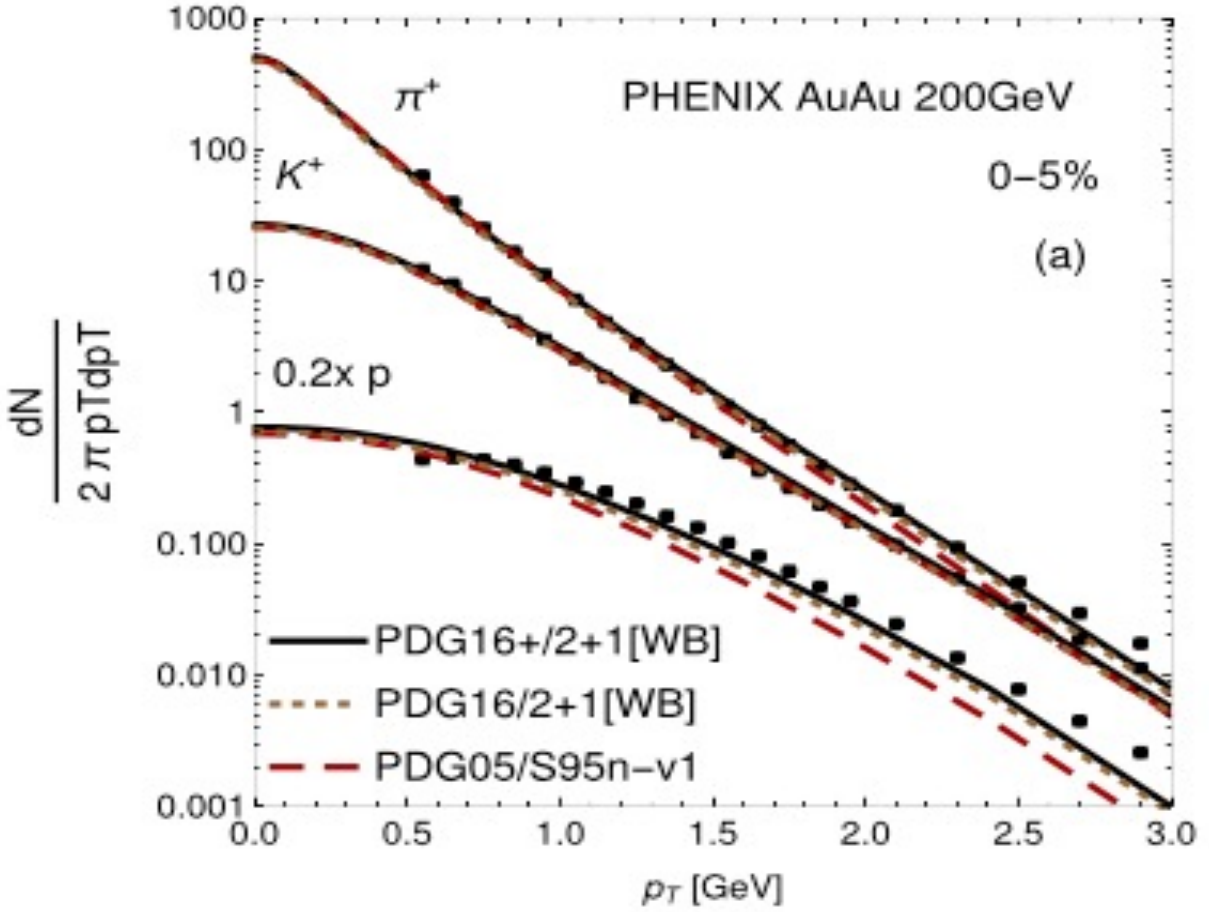








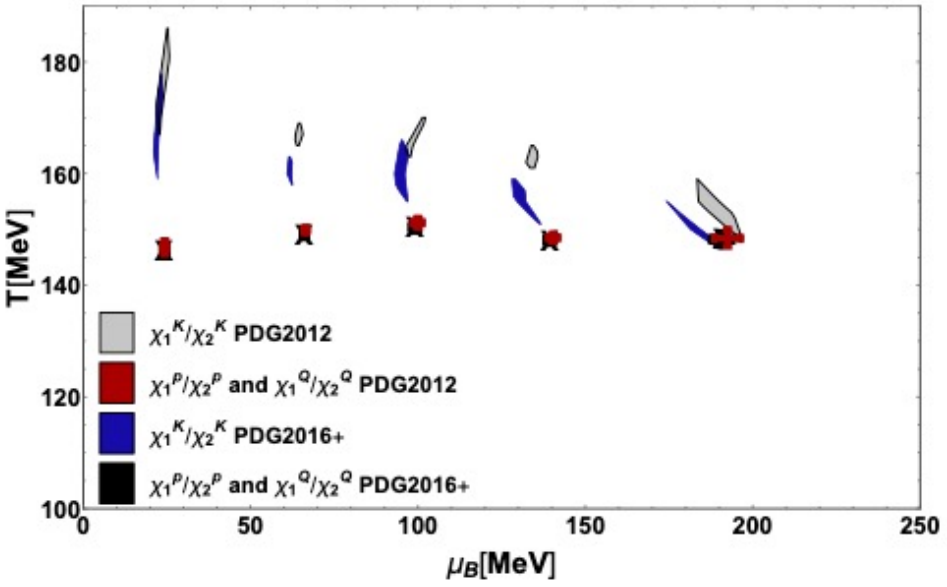
Influence of resonances in HRG ($\langle p_T \rangle$)



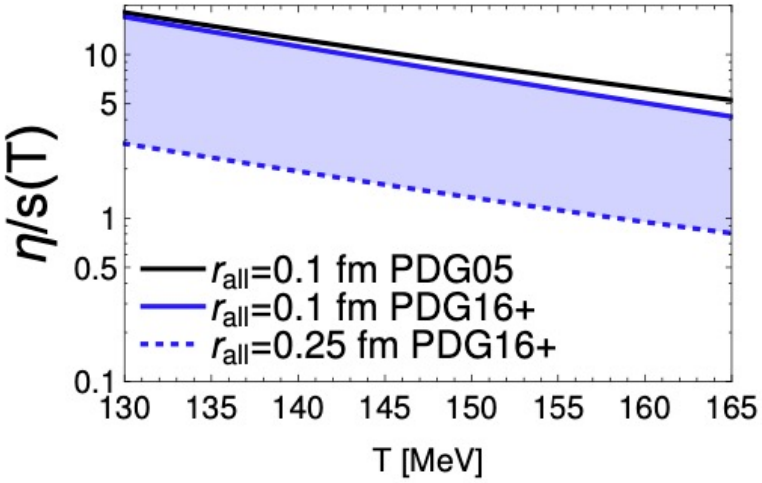
- Proton, pion, and kaon particle spectra are enhanced when including more resonances
- Larger $\langle p_T \rangle$ expected

P. Alba *et al.*, PRC 98 (2018) 034909
S. Borsanyi *et al.*, PLB 730 (2014) 99
S. Borsanyi *et al.*, Nature 539 (2016) 69

Influence of resonances in HRG



- Shear viscosity

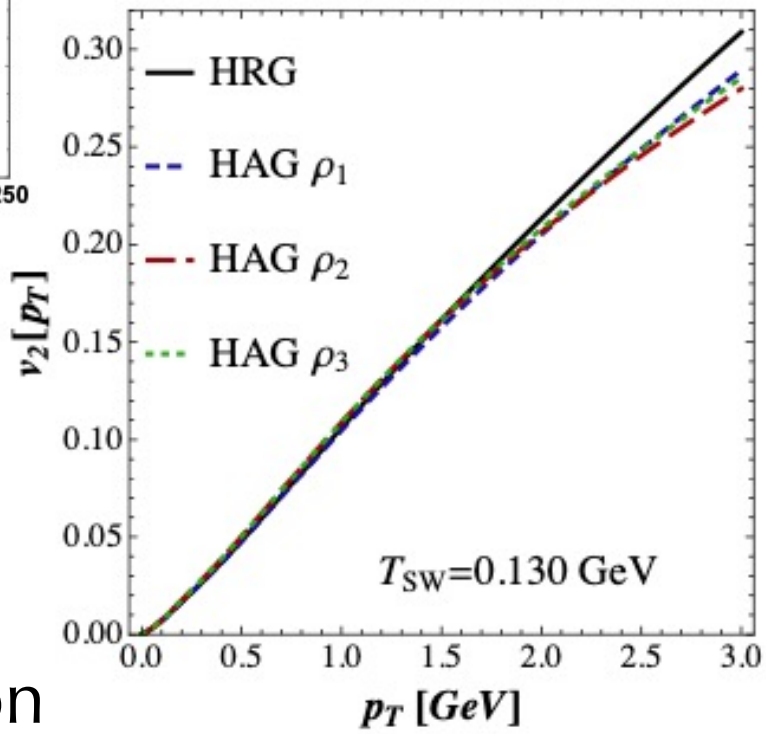


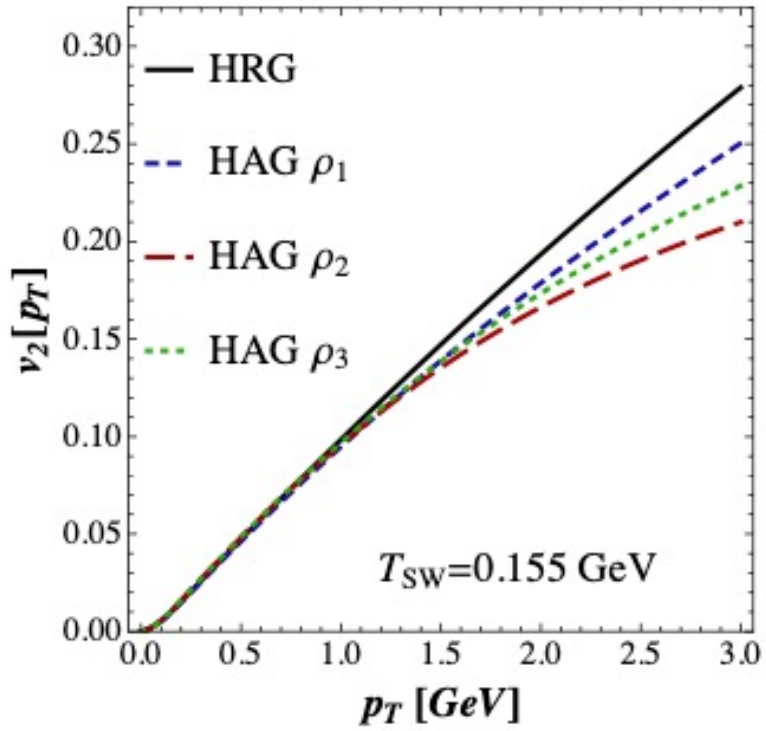
E. McLaughlin *et al.*, PRC 105 (2022) 024903

- Freeze-out params.

J. Noronha-Hostler, arXiv:1612.07765
J. Noronha-Hostler *et al.*, PRL 103 (2009) 172302
J. Noronha-Hostler *et al.*, PRC 89 (2014) 054904
P. Alba *et al.*, PRC 101 (2020) 054905
P. Alba *et al.*, PLB 738 (2014) 305

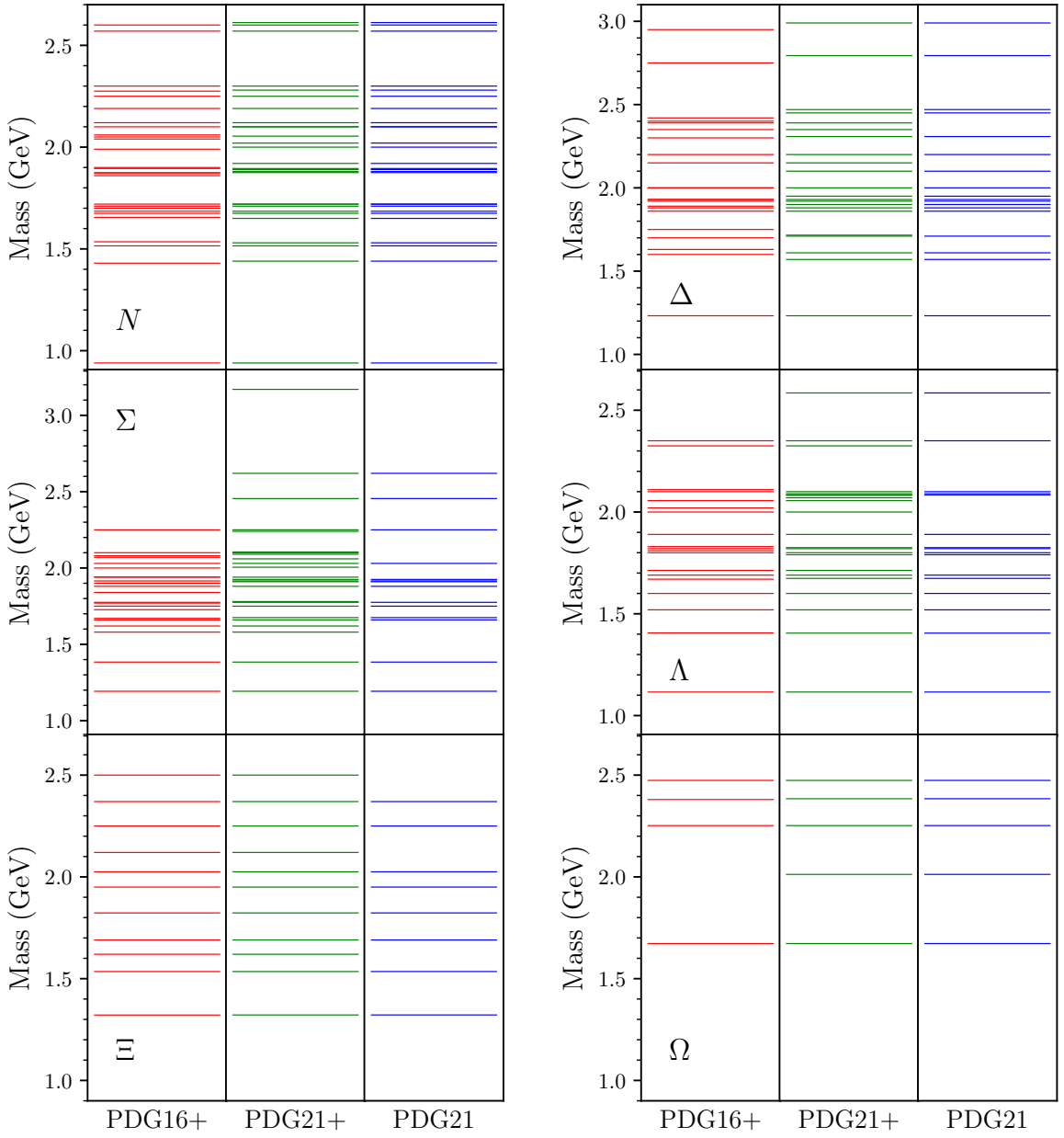
- v_2 supression





The PDG21+ list

- 760 particles
- Updated branching ratios
- Contains *–**** particles
- Automatically generates Thermal FIST inputs (results soon)



J. Salinas San Martín + MUSES Collaboration, to appear soon

The PDG21+ list vs PDG16+

Strange!

- Added 16 new particles, including:

$$\Sigma(2010), \Sigma(2160), \Sigma(2230), \Lambda(2070), \Lambda(2080), \Omega(2012)$$

- Deleted some states that were taken out of the PDG or merged with others, like:

$$a_1(1420), X(1840), a_6(2460), \Sigma(1940)^{\pm}$$

- Added several decay channels, along with updated branching ratios, witdths, and quantum numbers

The PDG21+ list vs SMASH

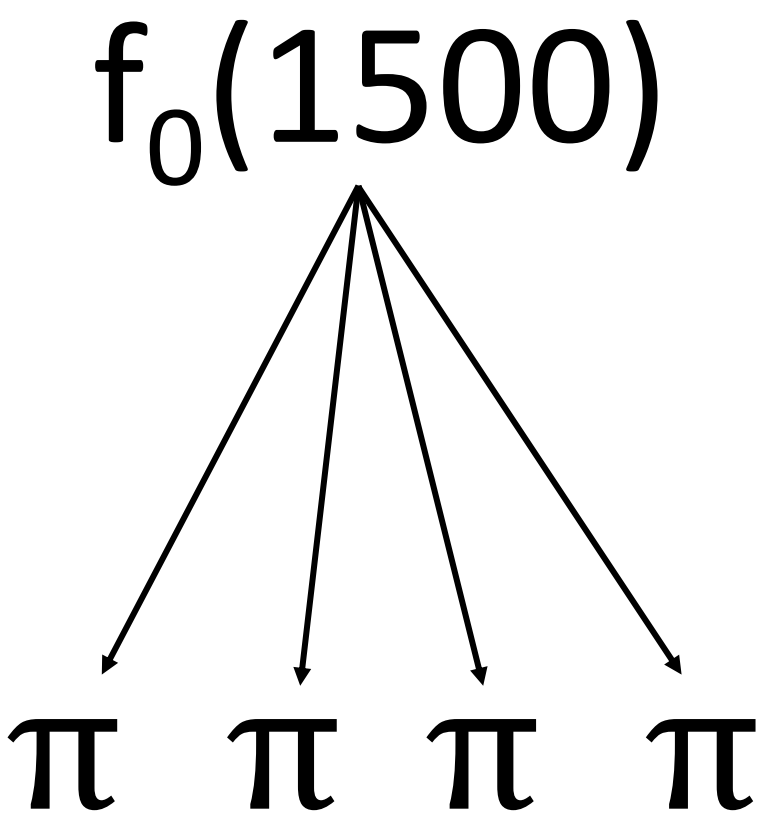
- Added 189 particles
- Added 299 decay channels
- Updated N branching ratios

  (N >> 1)

Implementation of the list on SMASH

J. Weil *et al.*, PRC 94 (2016) 054905
D. Oliinychenko *et al.*, SMASH-transport (2021), https://doi.org/10.5281/zenodo.5796168

- 1 –> 2 decays needed for SMASH



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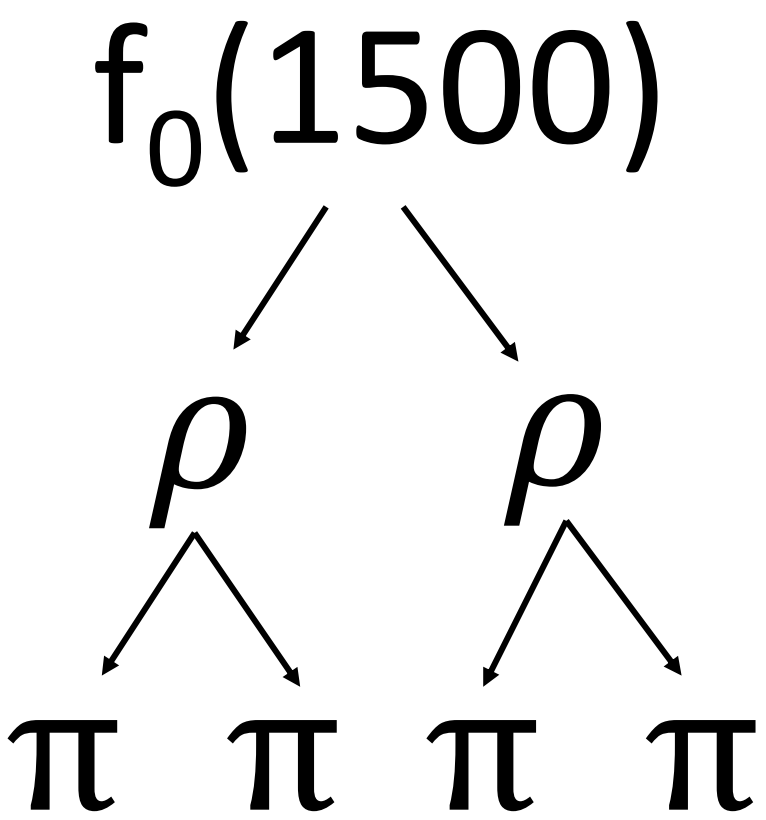
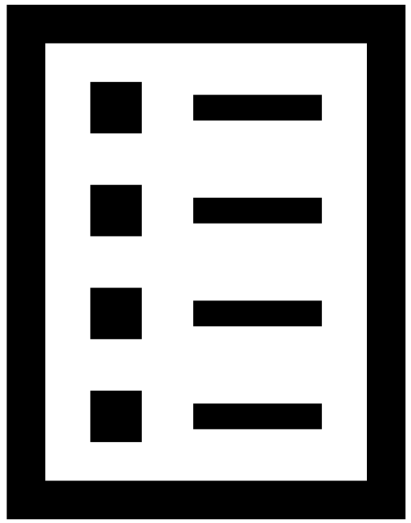
- 1 –> 2 decays needed for SMASH
- Model 3 and 4-body decays with intermediate states

SMASH input:
1. Particle list
2. Decay modes



Implementation of the list on SMASH

Full decay list from PDG



Implementation of the list on SMASH

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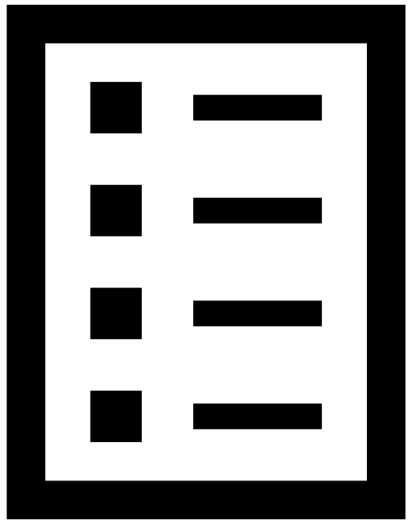


Particles with 2 decay daughters

Particles with 3 decay daughters

Particles with 4 decay daughters

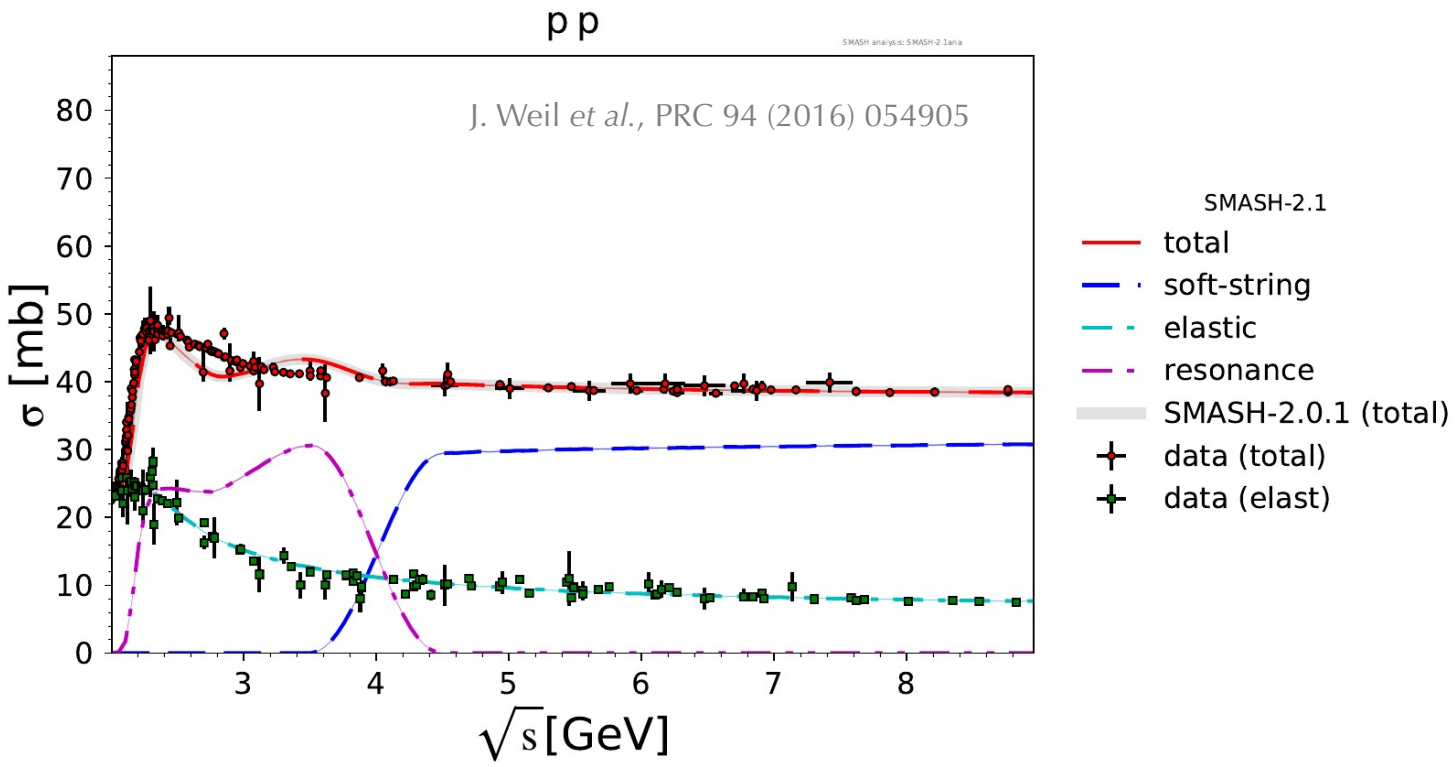
Implementation of the list on SMASH

A few examples…

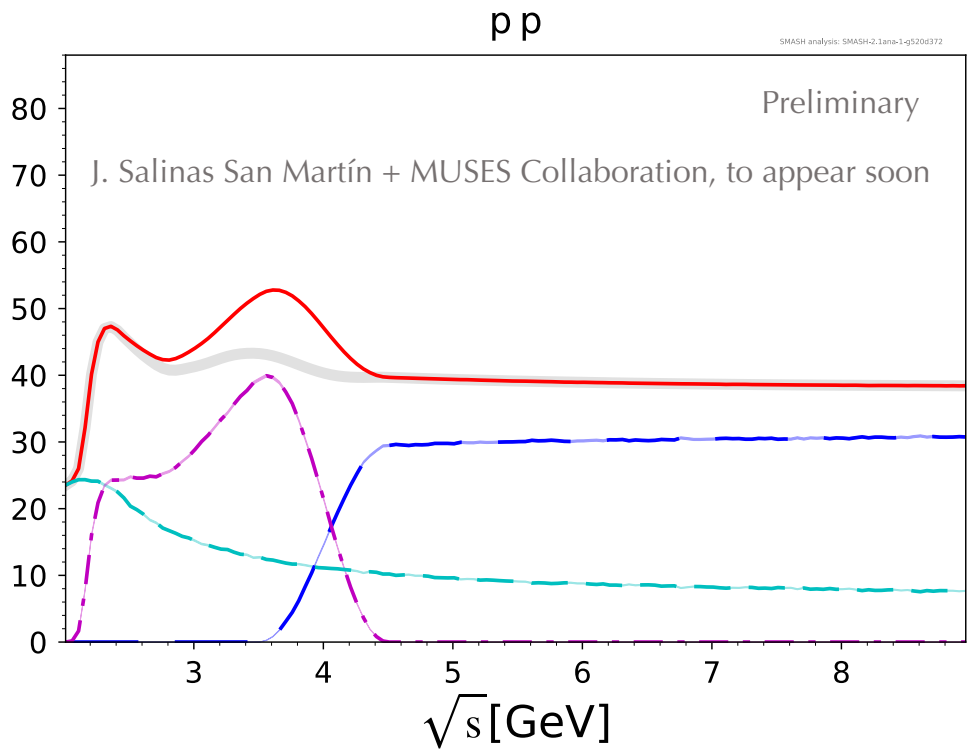
Particles with 3 decay daughters 

Mother	Daughter 1	Daughter 2	Daughter 3	1–2	1–3	2–3	Intermediate	Final
$\rho_3(1680)^0$	$\overline{K}^+$	K^+	π^0	$f_0(980)$	$\overline{K}_*^+(892)$	$K_*^+(892)$	$f_0(980)$	π^0
$\Delta(1900)^{++}$	n	π^+	π^+	$\Delta(1232)^+$	$\Delta(1232)^+$		$\Delta(1232)^+$	π^+
$\Lambda(1690)$	Σ^0	π^-	π^+	$\Sigma(1385)^-$	$\Sigma(1385)^+$	ρ^0	$\Sigma(1385)^+$	π^-
$\pi(1300)^0$	π^-	π^+	π^0	ρ^0	ρ^-	ρ^+	ρ^0	π^0
…	…	…	…	…	…	…	…	…

Resonances in SMASH: cross-sections (pp)



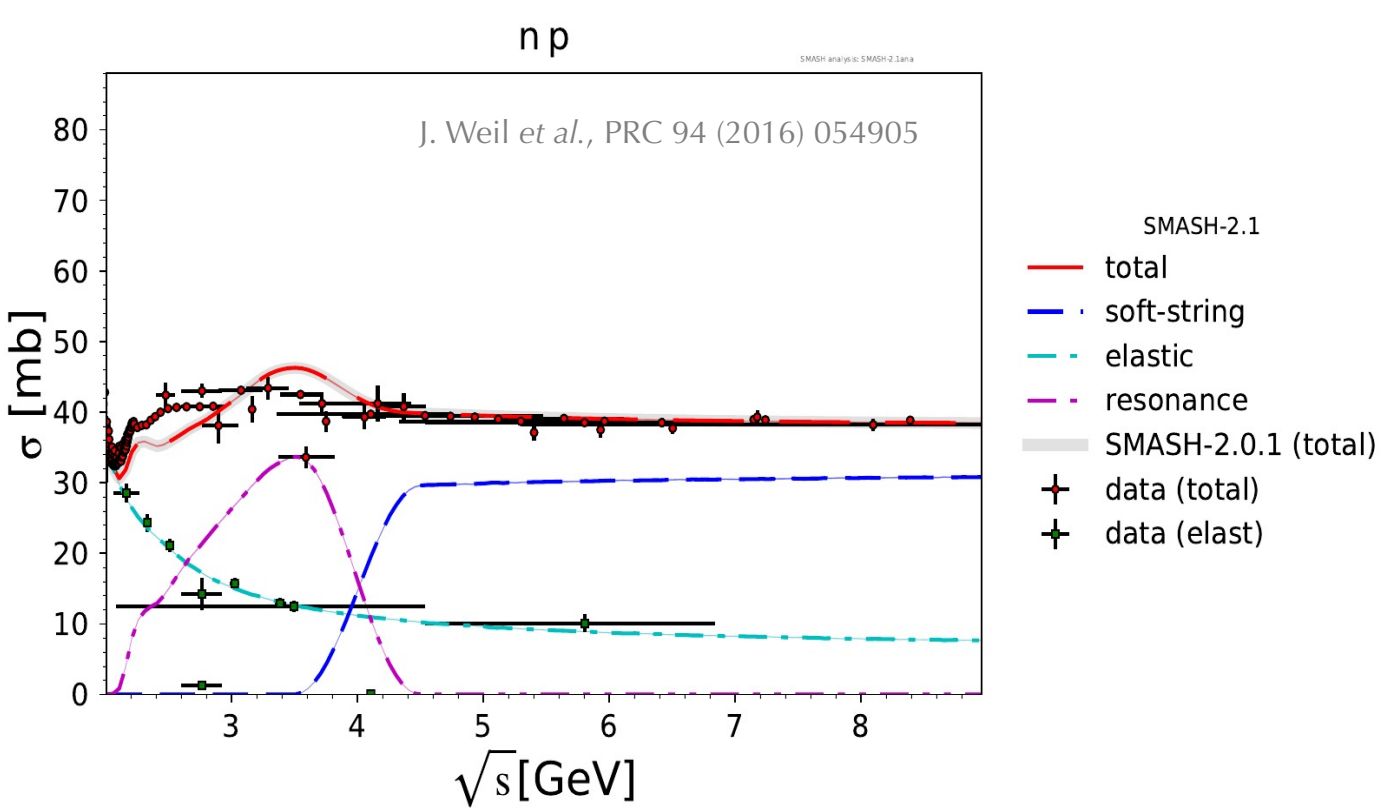
Default SMASH list



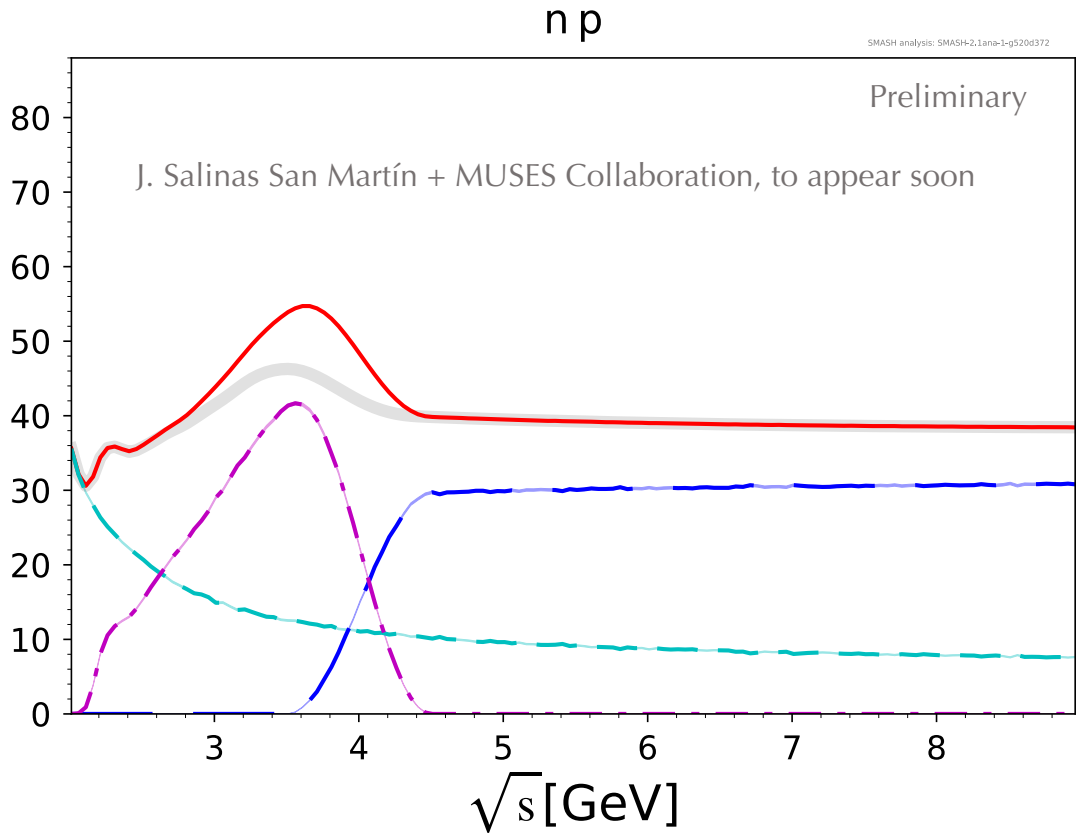
PDG21+ list

http://theory.gsi.de/~smash/analysis_suite/SMASH-2.1/index.html
D. Oliinychenko *et al.*, SMASH-transport (2021), https://doi.org/10.5281/zenodo.5796168

Resonances in SMASH: cross-sections (np)



Default SMASH list



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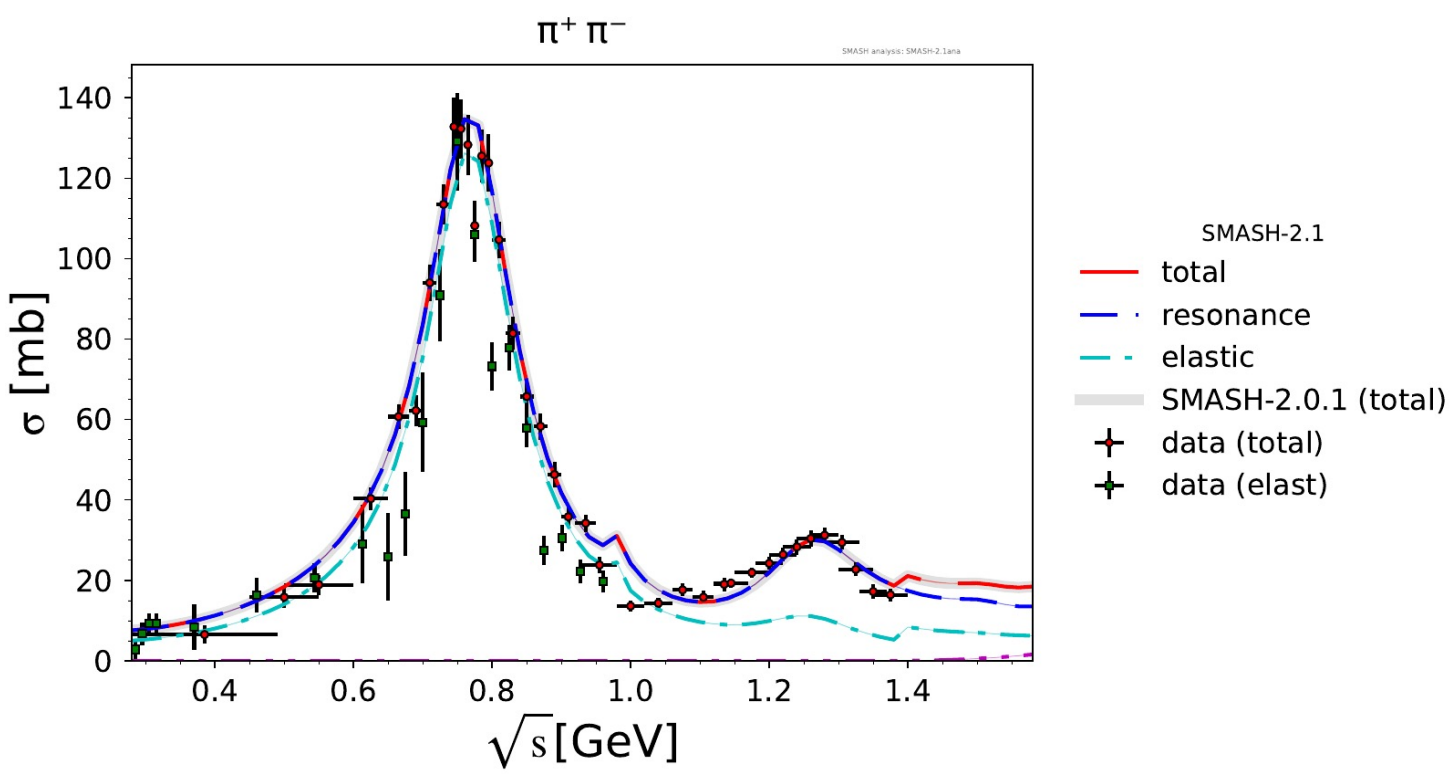
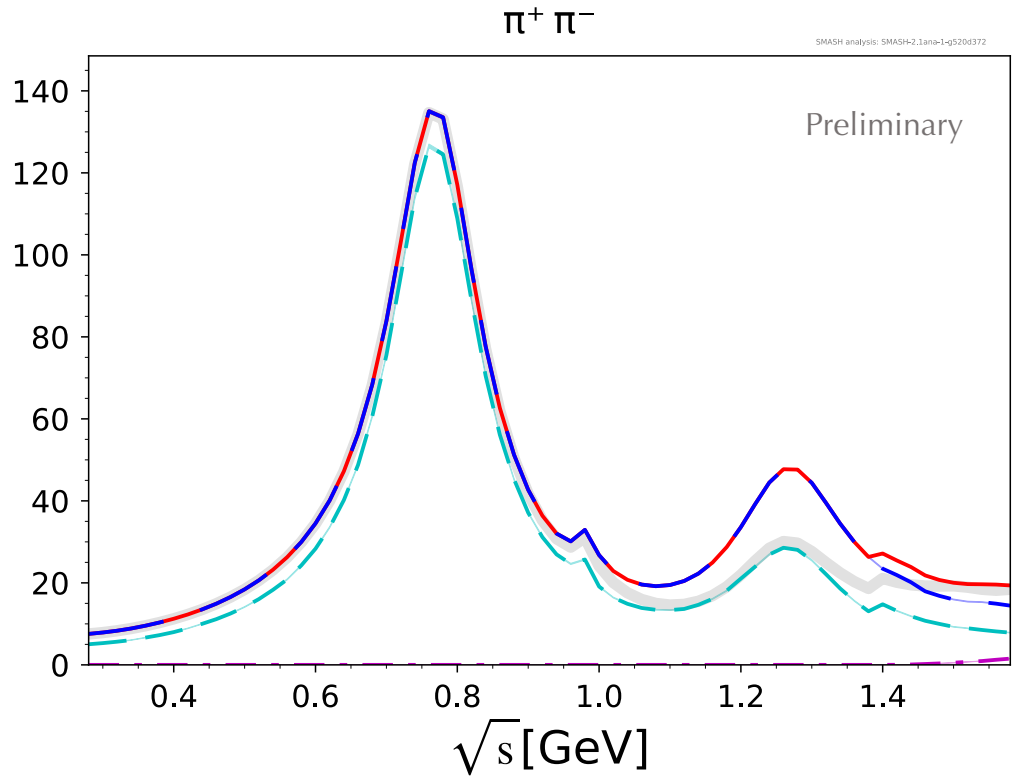
Resonances in SMASH: cross-sections ($\pi\pi$)





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Default SMASH list

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PDG21+ list

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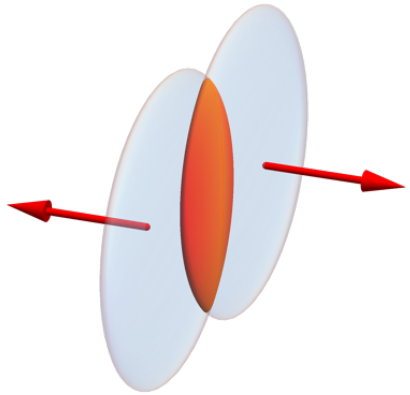
MUSES collaboration

Modular Unified Solver of the Equation of State

cyberinfrastructure



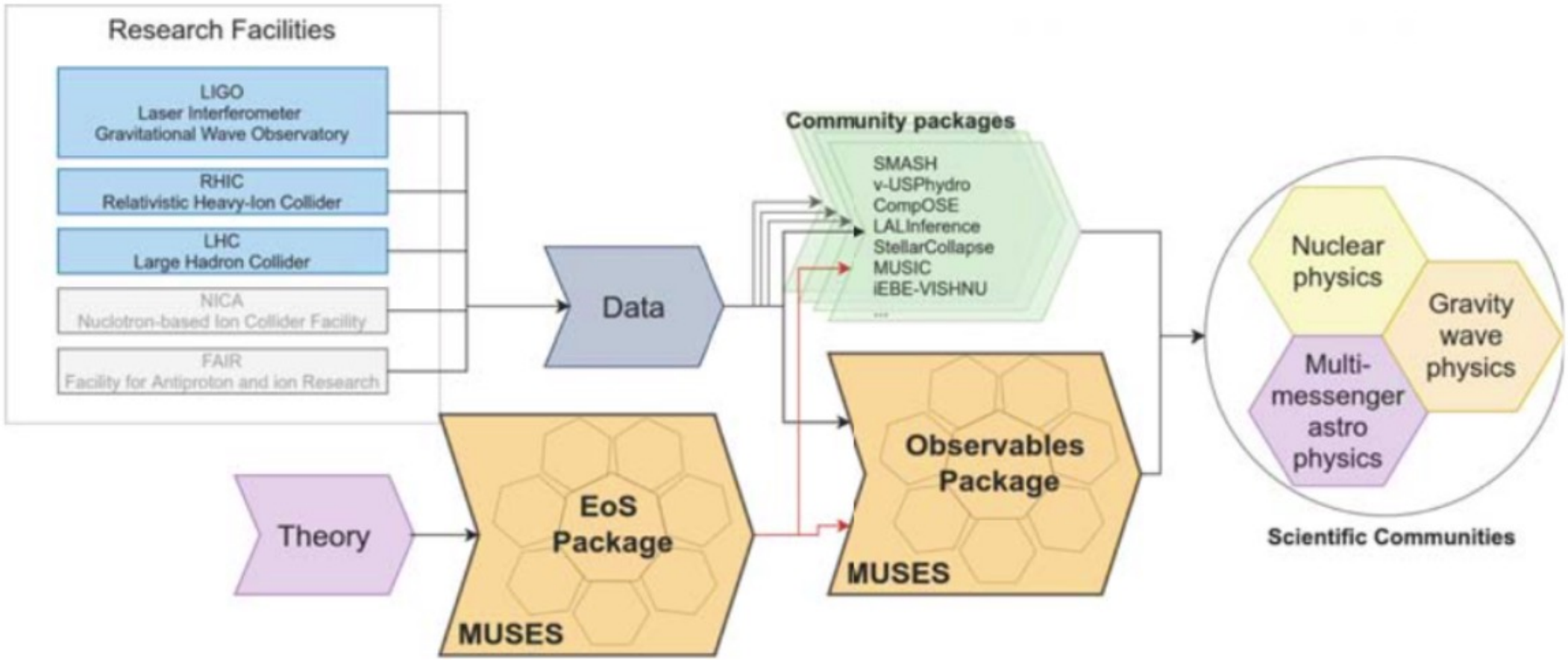
heavy-ions

neutron stars

users

MUSES collaboration

Modular Unified Solver of the Equation of State



Conclusions/Outlook

- Lattice hints at additional strange hadronic states
- Hadronic resonances have an effect on particle spectra, viscosities, freeze-out temperatures, and v_2
- A new list, PDG21+, was built with the latest experimental data available
- The list was implemented into SMASH with help of intermediate states
- Future work is directed towards building an EoS and study freeze-out (C. Ratti and students)
- KEY TAKEAWAY: If SMASH is used as an afterburner, one wants a consistent EoS-afterburner relation to be consistent with lattice → updated SMASH particle list