Understanding results of box calculation Hw3: production of pion-like particles

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Based on

- Homework 3 results by homework participants
- Discussions with Jun Xu
- Discussions with participants of Week 1 of the ICNT program
- Discussions with homework participants

Progress of Homework 3

Homework 3 (Pion Box Homework) just started half a year ago.

- Phase I: sent out on November 4, 2016; due on January 27, 2017.
- Phase II and Phase III: sent out on January 30, 2017; due on March 19, 2017.
- New Phase II: sent out on March 24, 2017.

Current situation

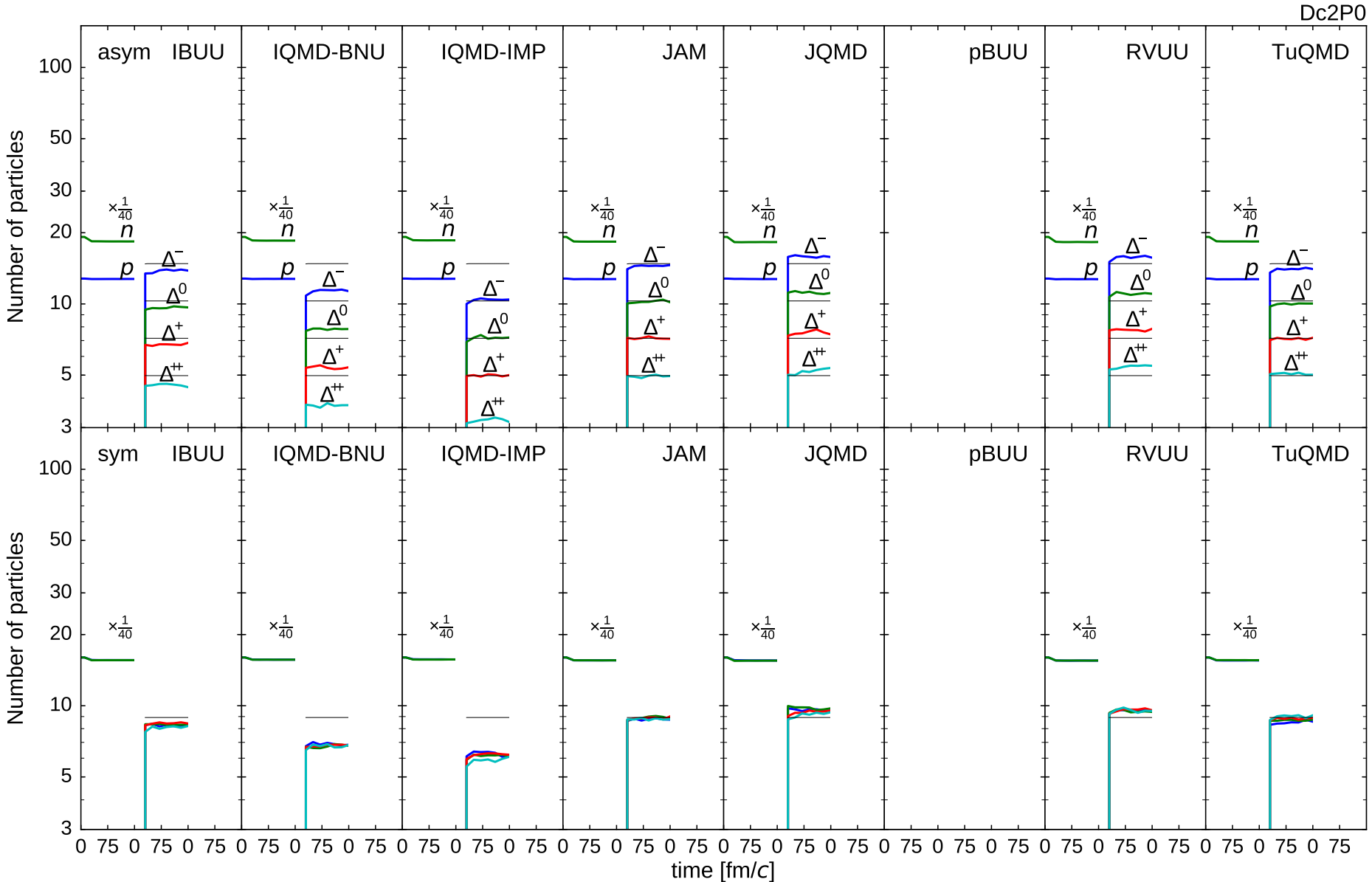
- New results are still coming up.
- The results submitted early are now relatively stable, after revisions.
- We have some deviations already at the simplest cases Dc1P0 and Dc2P0.
- From the currently available results, we can guess some sources of problems which should be confirmed in future homework.

First results and improvements – Number of particles

20170130 - Option Dc2P0 ($NN \leftrightarrow N\Delta$ with a constant Δ mass; no pions)

First results and improvements – Number of particles

20170327 - Option Dc2P0 ($NN \leftrightarrow N\Delta$ with a constant Δ mass; no pions)

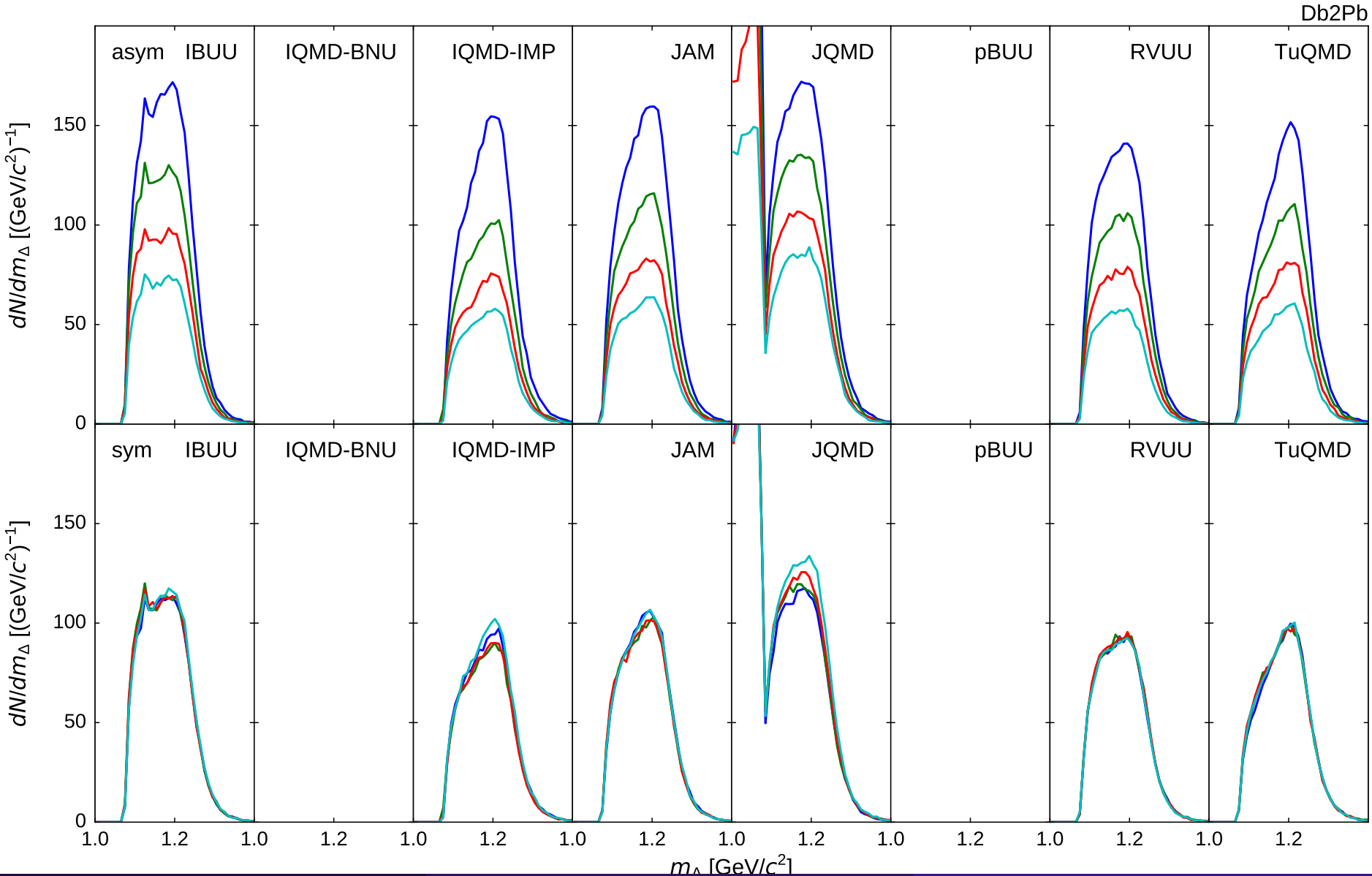


First results and improvements – Δ mass distribution

20170308 - Option Db2Pb (Breit-Wigner Δ-mass distribution, with pions)

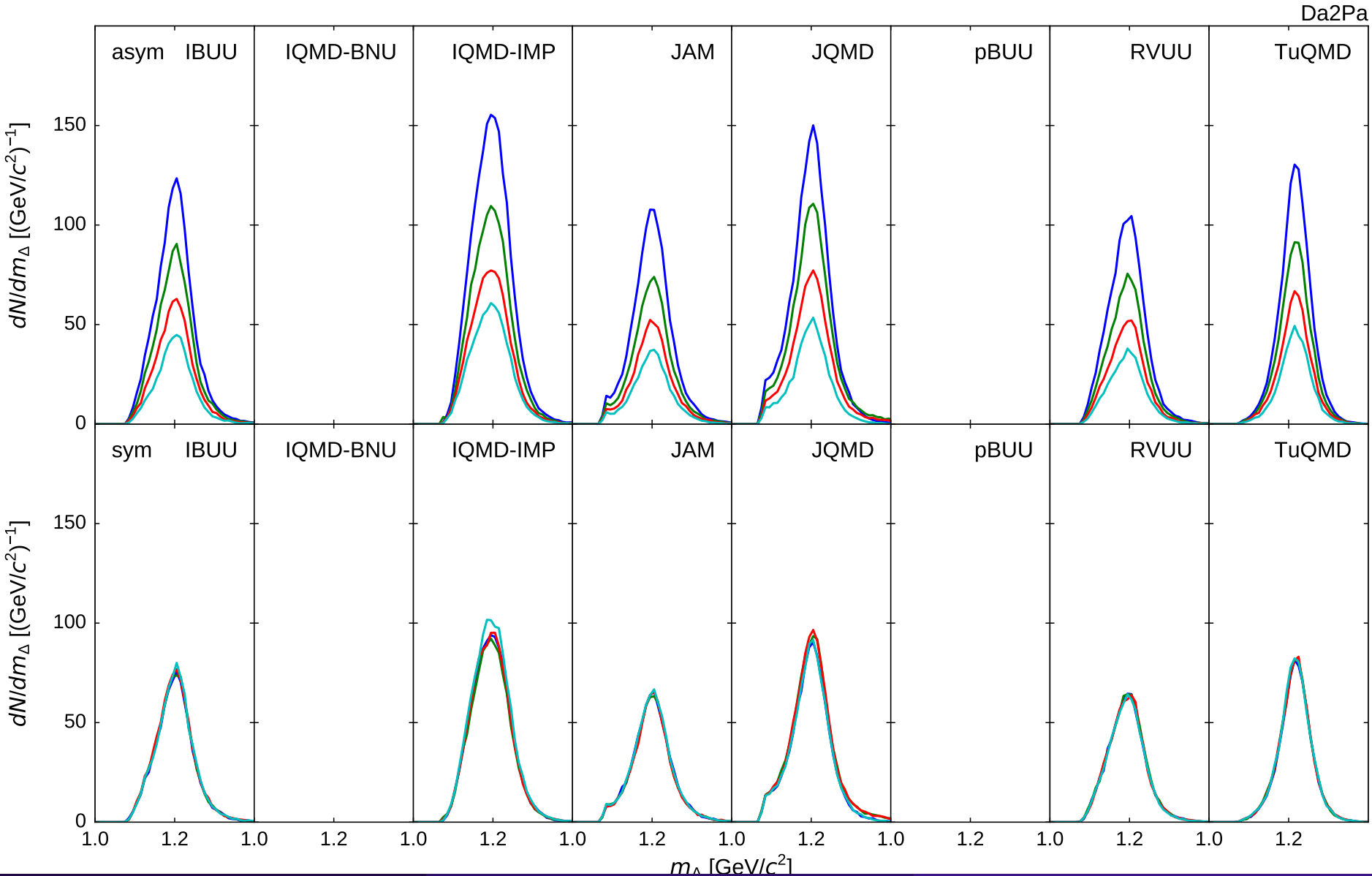
First results and improvements – Δ mass distribution

20170327 - Option Db2Pb (Breit-Wigner Δ-mass distribution, with pions)



First results and improvements – Δ mass distribution

20170327 - Option Da2Pa (suggests that errors came in by changing the codes for hw)

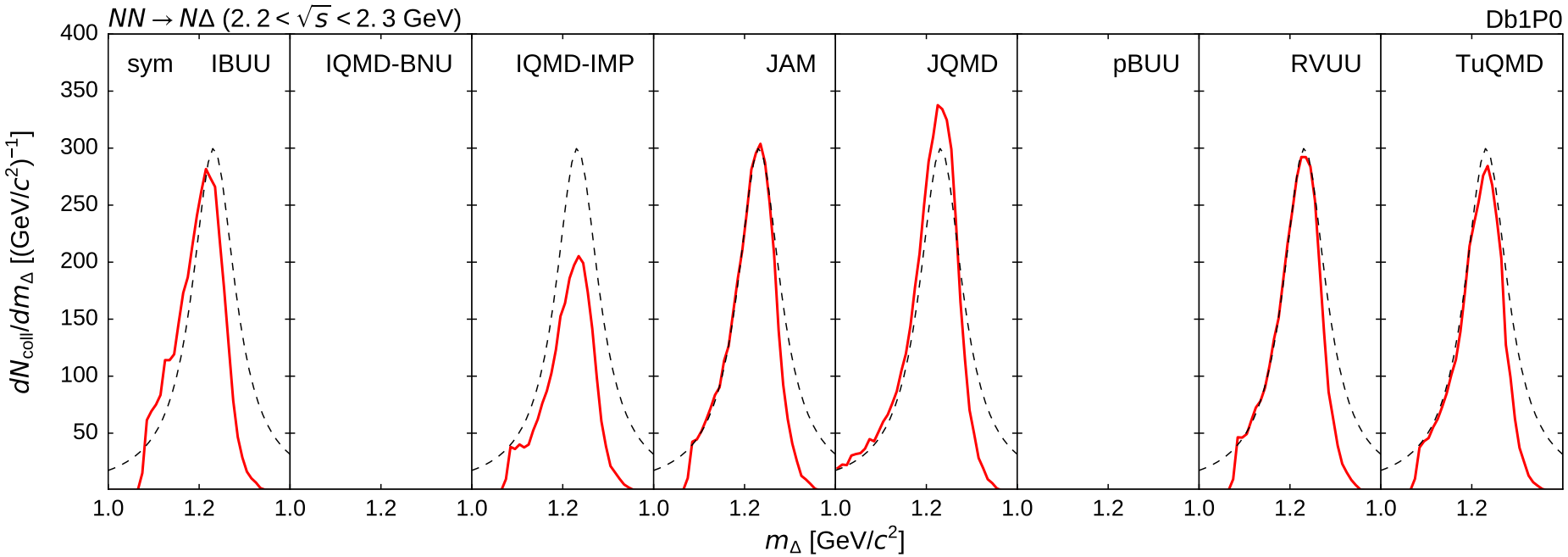


Some problems in following homework specifications

At the current stage, some disagreement between codes is expected because the homework conditions are not followed precisely by some codes.

- Initialization $\sim \exp\left[-\sqrt{m_N^2+\mathbf{p}^2}/T\right]$ with $T = 60$ MeV is not correctly done in IQMD-IMP and IQMD-BNU, so the results correspond to a lower temperature.
- Some codes don't sample m_Δ mass at $NN \to N\Delta$ as specified by hw (Db options):

$$P(m_\Delta) \propto 1\Big/\left[(m_\Delta - m_\Delta^0)^2 + \tfrac{1}{4}\Gamma^2\right] \qquad \text{for} \quad m_N + m_\pi < m_\Delta < \sqrt{s} - m_N.$$



Understanding results of box calculation Hw3...

Someone put this in the agenda much before we had any results of Box Pion Homework.

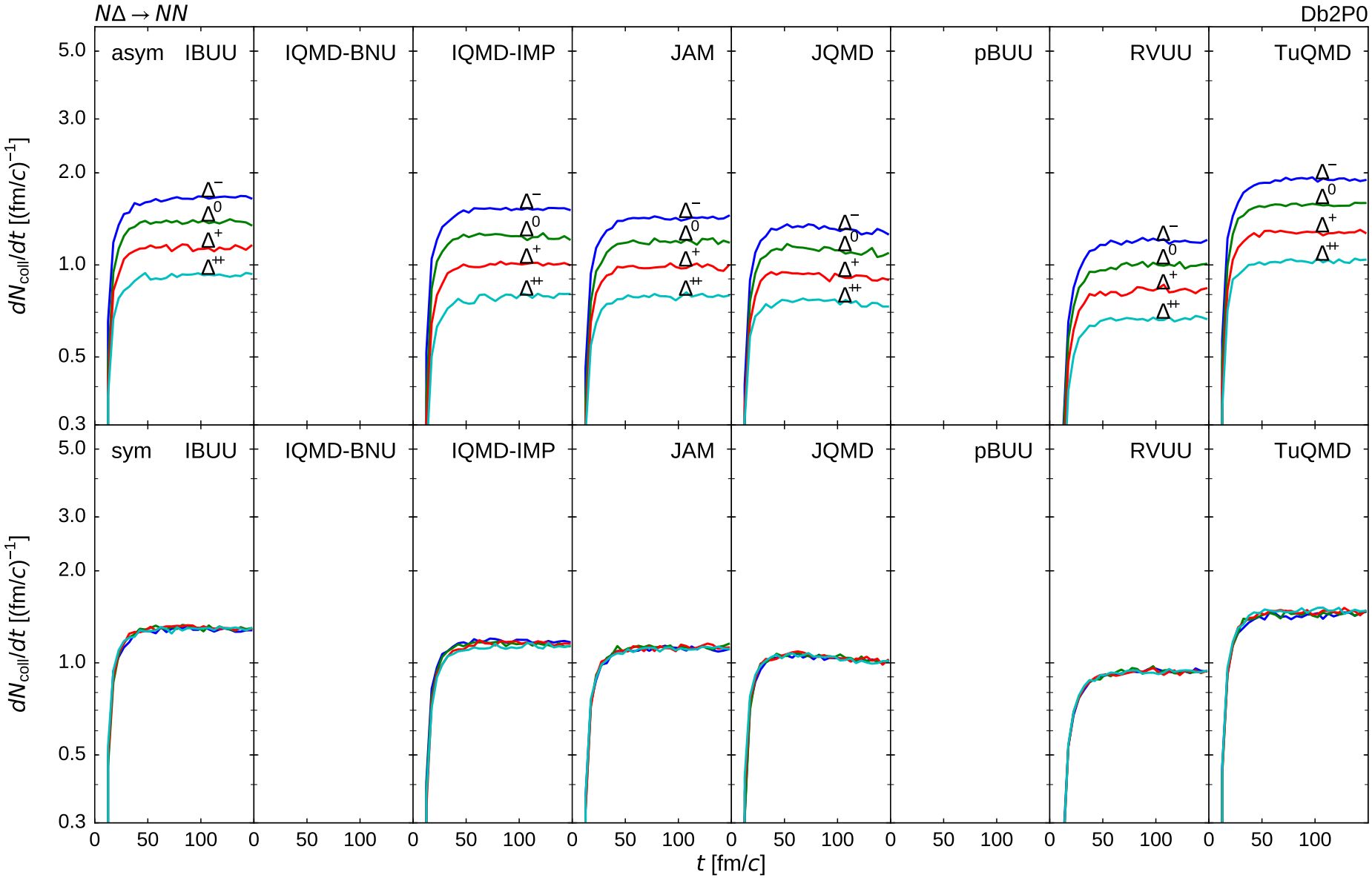
Fortunately, thanks to the discussions with the Week 1 participants of the ICNT program and with the homework participants, I have something more to talk about.

Possible sources of the differences among the codes

- Some codes do not follow the homework specification.
- The treatments are different in different codes when a new particle is produced and/or a particle can decay.
  - Strange results appear in some codes when pions are swithced on in Pb and Pa options.
  - The $N\pi \to \Delta$ cross section is large ($\sim$ 200 mb), which seems to be the reason. (pointed out by **Zhen Zhang**)
  - The results should depend on whether the decays are calculated before or after the collisions in a time step. (pointed out by **Tatsuhiko Ogawa**)

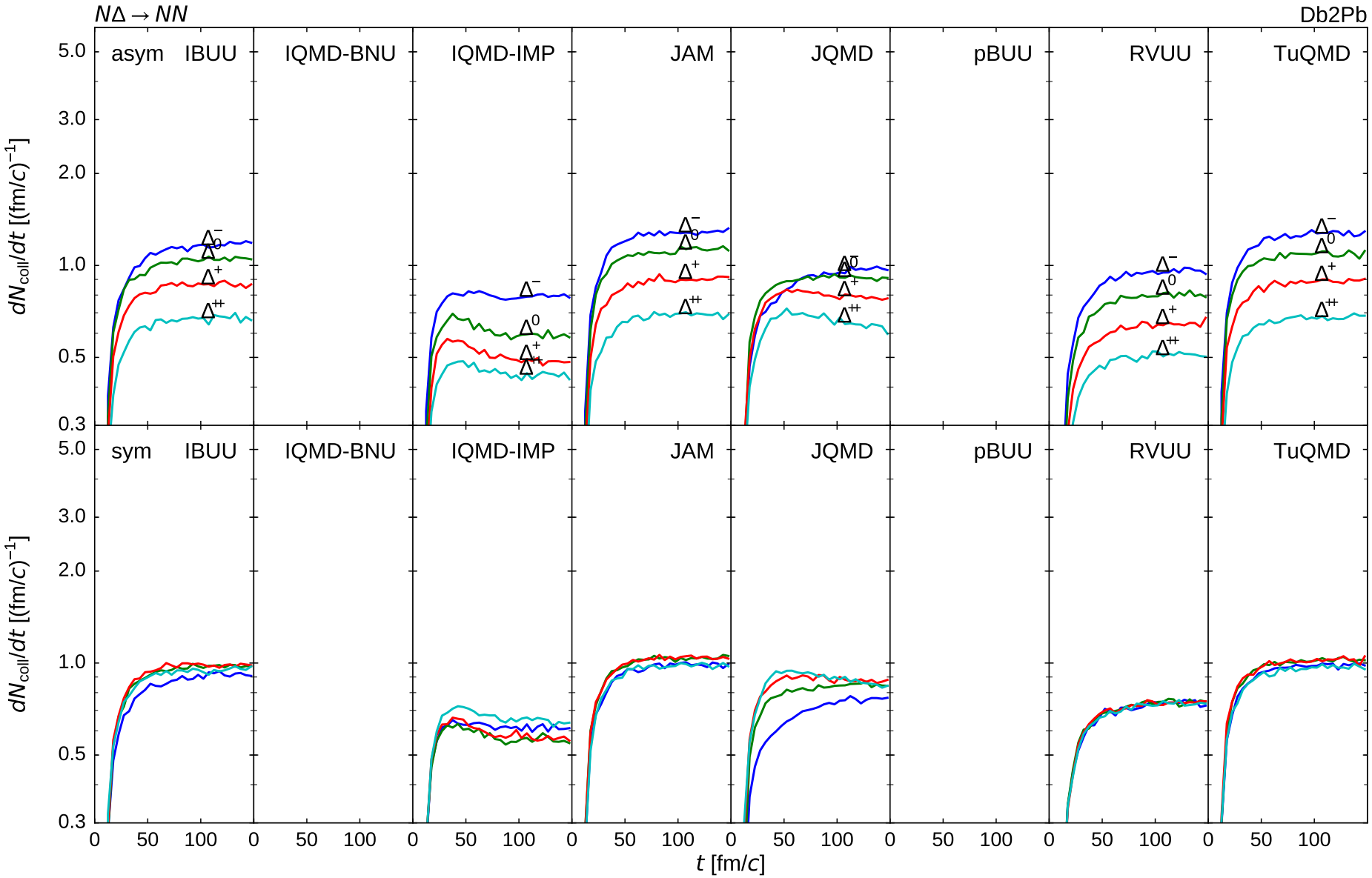
Db2P0 → Db2Pb: something strange by pions?

Db2P0 (without pions): Reaction rates for $N\Delta \to NN$



Db2P0 → Db2Pb: something strange by pions?

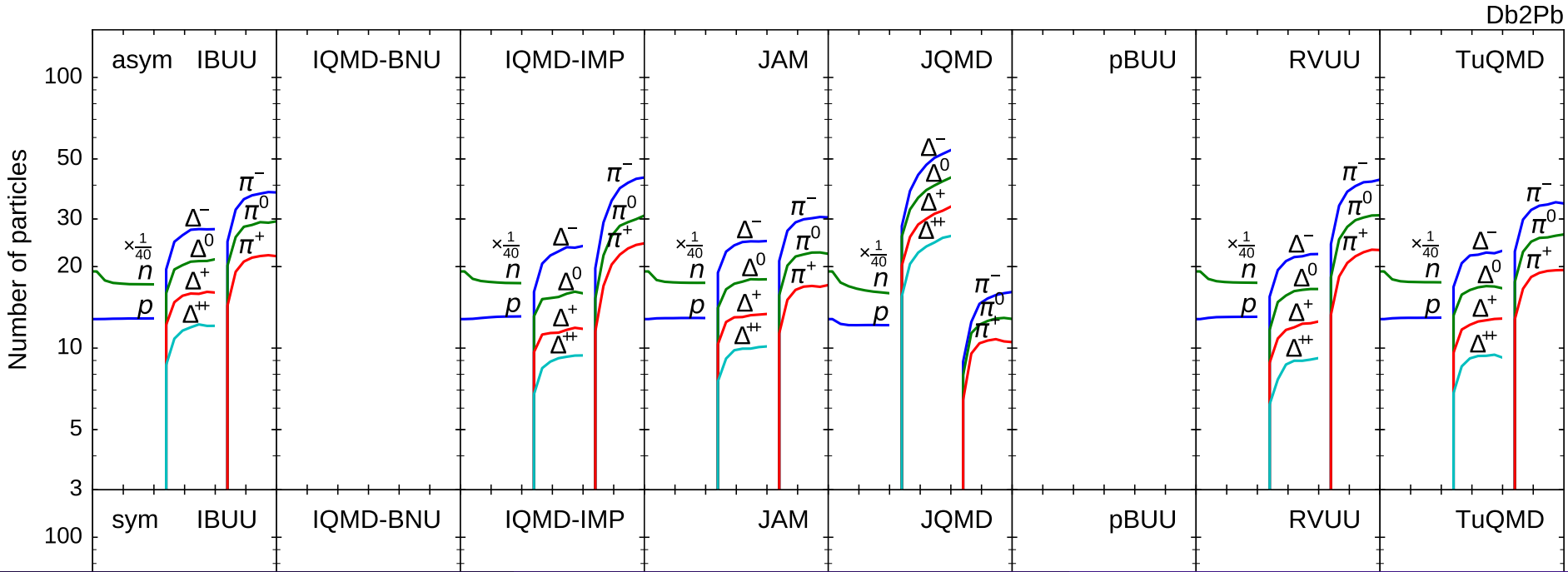
Db2Pb (with pions): Reaction rates for $N\Delta \to NN$



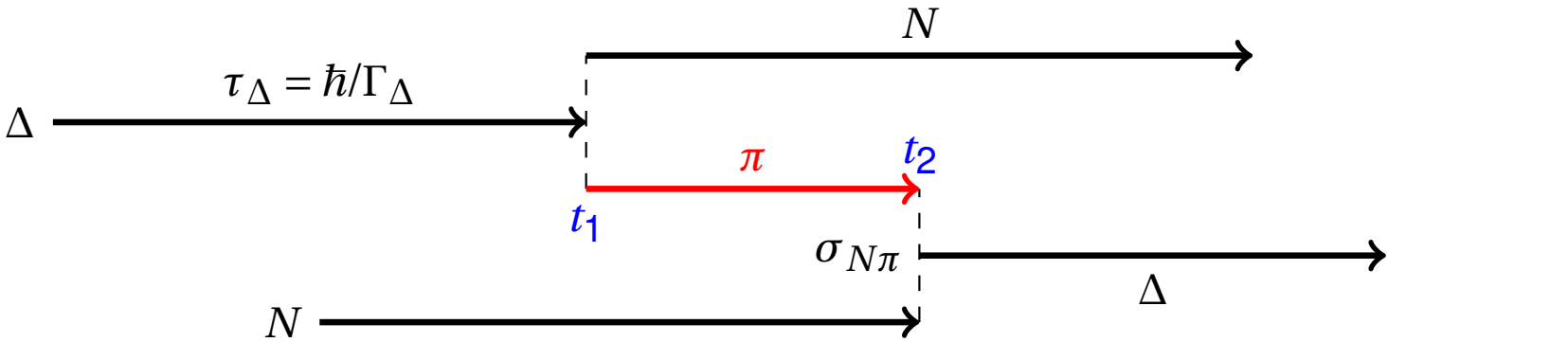
Numbers of Δ and π in Db2Pb

Observations for the numbers of Δ and π

- In JQMD, $\Delta \gg \pi$
- In IBUU, RVUU and TuQMD, $\Delta < \pi$
- JAM is located between them.



Time step problem



JAM

$\tau_\Delta = \hbar/\Gamma_\Delta = 1.72$ fm/c, $\sigma_{N\pi\to\Delta} \lesssim 200$ mb, $\Delta t = 0.5$ or 1.0 fm/c

Questions to code participants

- When a pion is produced, can it interact with other particles in the same time step? How is it done?
- When a Δ is produced, can it decay in the same time step? How is it done?
- Do the results change when a smaller Δt is chosen?

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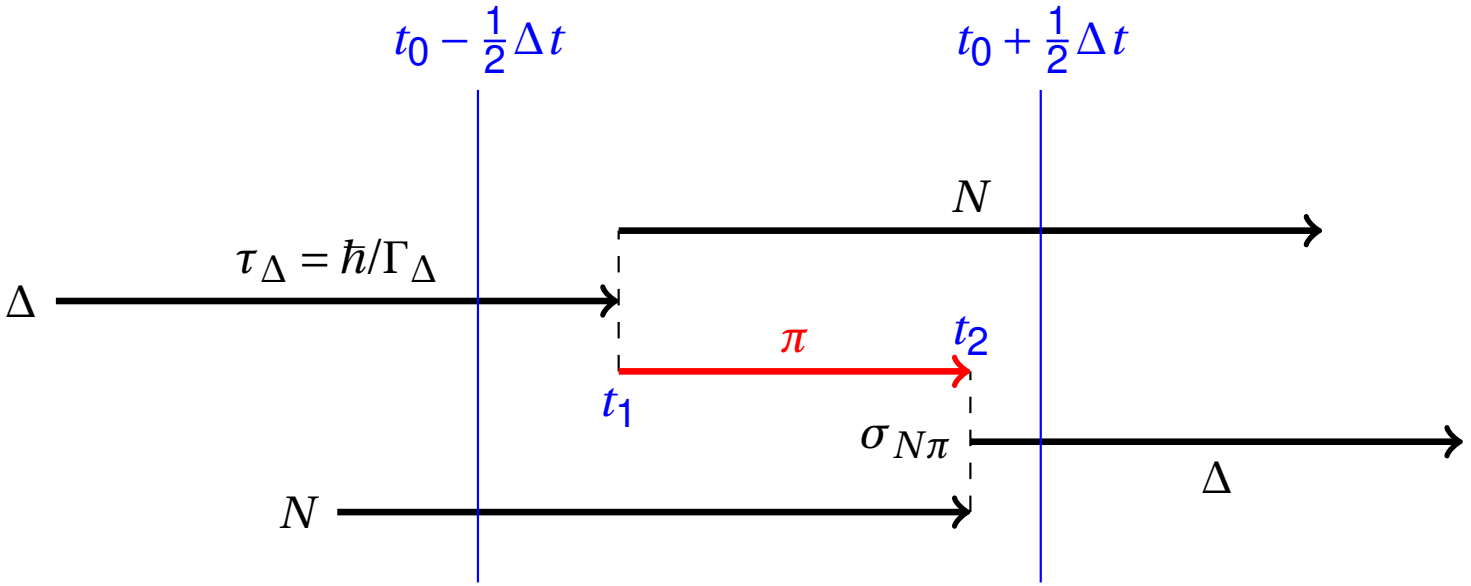

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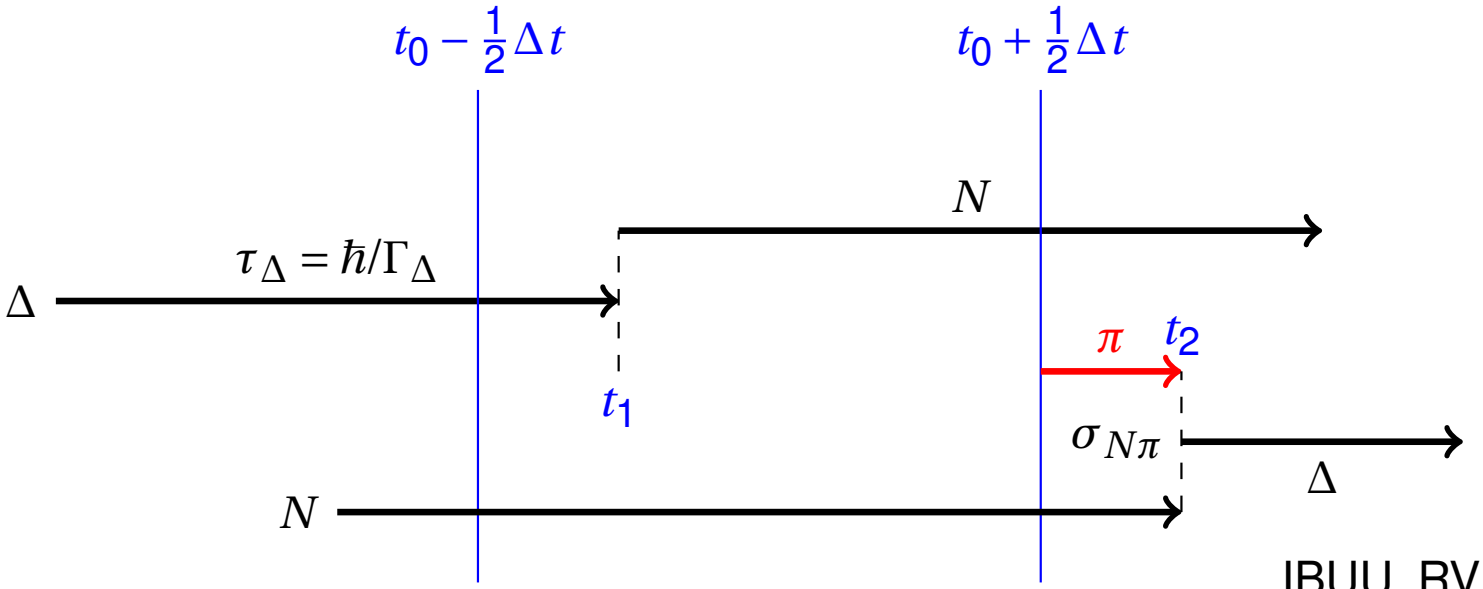

IBUU, RVUU, TuQMD (more π)

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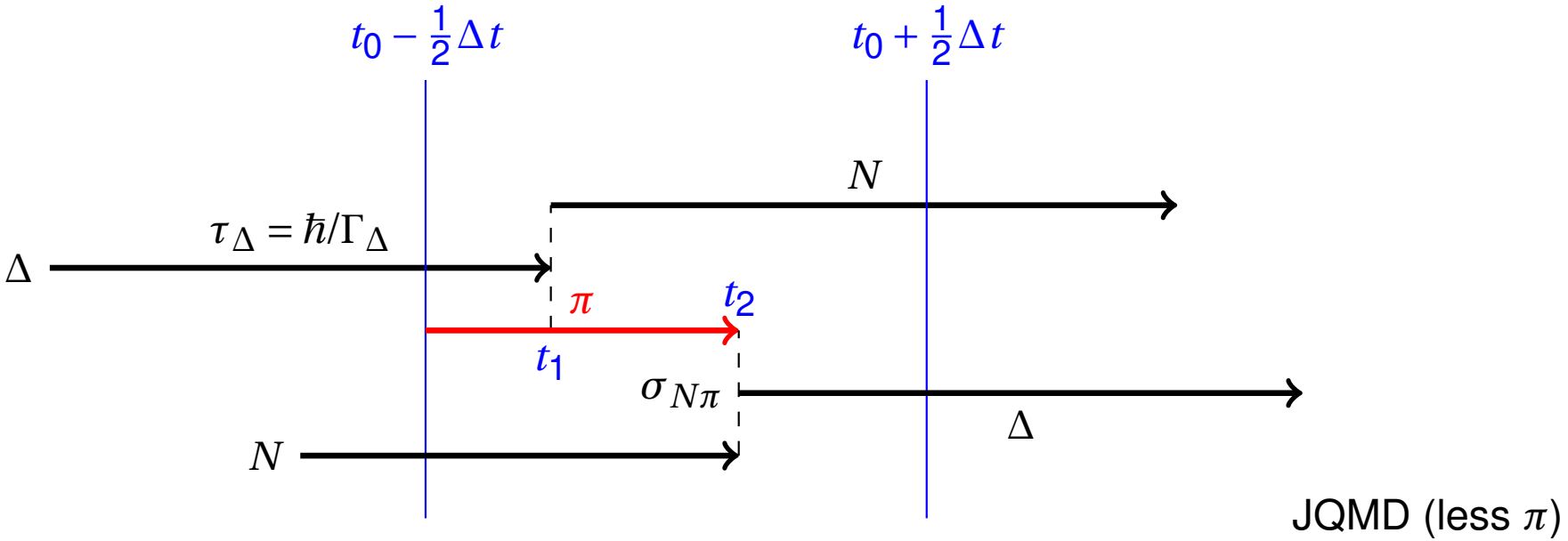

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Summary

- Box Homework 3 results are still coming up. The results shown here are just a snapshot of this morning.
- Trivial mistakes will be fixed as soon as possible.
- The deviations in Dc1P0 and Dc2P0 must be understood.
- Problems appear when pions are turned on (Pb and Pa).
  - Probably related to large $\sigma_{N\pi\to\Delta}$.
  - Probably depends on which are done earlier in a time step, collisions or decays.
- Code participants should describe how the code is doing.
- Check Δt dependence?
- Pb and Pd options are very severe tests of codes.

Code improvements through Box Homework 3

Several types of problems

- Mistakes introduced when the code is changed for the homework.

  $\Rightarrow$ OK... We should be more careful next time.
- Inaccuracy of the original code (for heavy-ion collisions)

  $\Rightarrow$ Most codes have been (are going to be) improved.

  $\Rightarrow$ The predictions by these codes are more reliable in their future works.

  I hope the homework participants will explain in their Wednesday/Thursday talks if the code comparison was useful to improve the codes.