Breakout rooms

- Now go to one of the following breakout rooms

  You can swap later. Material from all rooms (1-5) will be provided later.

  1. Relic density (standard)
  2. Relic density (dark sector, coupled Boltzmann eqs.)
  3. Gamma-ray (and other CR) spectra
  4. J-factors
  5. Neutrino signals
  6. General technical support [installation/coding/shell usage/…]

- You can start right away with problem I and II above…

  See also the link to the tutorial from the ISAPP homepage

Actively help each other while Joakim and me go around !

Scalar Singlet model, continued

- Now let's have a look at one of the example programs

Problem III:

Copy examples/aux/ScalarSinglet_RD.f **to your private directory and**

1. **make sure that you can compile and run this main program**
2. **Try to understand what the program does, and how**
   [you can ignore/comment out the parts about kinetic decoupling; we don't need them here]
3. **Produce a plot that shows $\lambda(m_\chi)$ resulting in the correct relic density, as well as the change (in percent) when instead using the 'correction' of the annihilation rate from problem II**

Hint :

- **The default setting is a rather dense tabulation. To save time, in particular when testing, you thus want to first increase the parameter settings for** logdeltam **and** logdeltamres

Thermal averages

- Understanding a relic density plot like from the previous example typically boils down to understanding the behaviour of the thermally averaged annihilation cross section $\langle \sigma v \rangle$

Problem IV:

Choose one (or two) parameter combinations of $\lambda(m_\chi)$ where you expect differences in the relic density calculation for the two 'models' from the previous problem. Plot $\langle \sigma v \rangle (T)$ for these cases, and convince yourself that this explains the differences you found in problem III.

Hint :

- **The thermal average is computed by the function** src/rd/dsrdthav.f

Variations of the 'Steigman plot'

- Now let's have a look at variations of the same theme, for a slightly more complex example program

Problem V:

Copy $\mathrm{examples/aux/oh2\_generic\_wimp.f}$ **to your private directory and**

1. **make sure that you can compile and run it**
   [Note the effect of the two makefile targets for this program! Cf. also Fig. 3 in the DarkSUSY article
2. **Produce the 'Steigman plot' for '*p*-wave annihilation', i.e. assume** $\sigma v \propto v^2$
   [Cf. Fig. 4 in https://arxiv.org/pdf/2007.03696]
3. **Add a generic Sommerfeld enhancement** $S(v)$ **of the *s*-wave cross section, assuming a mediator mass of 1 GeV.**
4. **Explore the effect of adding a sharp Breit-Wigner resonance, by using** $\sigma v \propto 1/[(s-m_R^2)^+ m_R^2\Gamma_R^2]$**, with *m*$_R$=200 GeV and *Γ/m*=0.001.**

Hints :

- **@3 Particle physics-dependent, but 'generic' auxiliary functions like Sommerfeld enhancement factors are found in** $\mathrm{src\_models/common/aux/}$
- **@4 Does your code capture the resonance correctly? Remember (from the general intro) that the RD routines build on *two* interface functions…**