DLHA

Dark matter Les Houches Agreement

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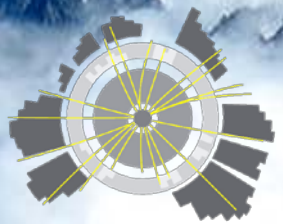

DLHA

Who **Coordinator**: C Balázs **AMIDAS**: C-L Shan **DarkSUSY**: L Bergström, T Bringmann, G Duda, J Edsjö, P Gondolo **DMFIT & DMMW**: S Profumo, T Jeltema **DRAGON**: C Evoli, D Gaggero, D Grasso, L Maccione **FeynRules**: C Duhr, B Fuks **GALPROP**: I Moskalenko, E Orlando, T Porter, A Strong **ISAJET**: H Baer **micrOmegas**: G Bélanger, F Boudjema, A Pukhov **PPPC4DMID**: M Cirelli, M Kadastik, P Panci, M Raidal **SLHA**: S Kreiss, F S Thomas **Semi-analytical prop models**: T Delahaye, F Donato, J Lavalle, D Maurin, P Salati, R Taillet **SuperISO**: A Arbey, F Mahmoudi**;** D G Cerdeno, R Leane, M Kakizaki, S Kraml, C Savage, P Scott, S Sekmen

What Standardized interface for exchanging DM info

Why Enhanced flexibility of DM calculators

How Utilize modularity in DM calculations

Allow user to access I/O for ‘modules’

Let the user ‘go wild’ without hurting anyone

DLHA! Why?

Experiment Dark matter signals

DAMA, CoGeNT, CRESST, CDMS-II, XENON100, PAMELA, Fermi-LAT, AMS, WMAP, PLANCK, DanHooper...

Theory Dark matter models

$$\lim_{t \to 2014}(N) = \infty$$

It's the golden age of opportunity!

Are these signals “real”?

Which model do they come from?

Start calculating signals in many models!

DLHA! Why?

Tools Dark matter calculators

µicrΩmegas, DarkSUSY, SuperIso Relic, ISATools, GalProp, DRAGON, USINE, PPPC4DMID, DMFIT, DMMW, AMIDAS, …

Each has strengts and limitations

Uses use, misuse, abuse = run, tweak, hack

Why use?

Why misuse?

Why abuse?

There's a need for DLHA

Modularity of DM calculations

Lagrangian

Feynman rules

scattering amplitudes

cross sections & decay rates

dark matter abundance

dark matter-nucleon scattering rates

cosmic ray fluxes

neutrino yields

…

Modularity of DM calculations

Idea: allow users to ‘access’ individual modules

Lagrangian

Feynman rules

scattering amplitudes

cross sections & decay rates

dark matter abundance

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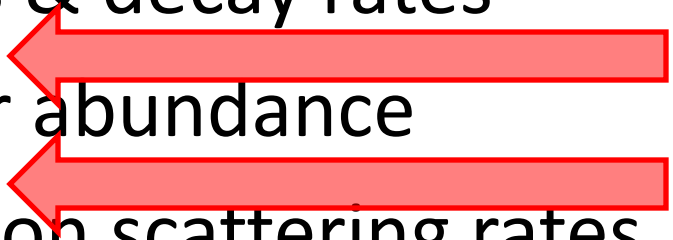
neutrino yields

…



tweak here

Modularity of DM calculations

DLHA: ‘safe’ tweaking, mixing & matching

Lagrangian

Feynman rules

scattering amplitudes

cross sections & decay rates

dark matter abundance

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cosmic ray yields

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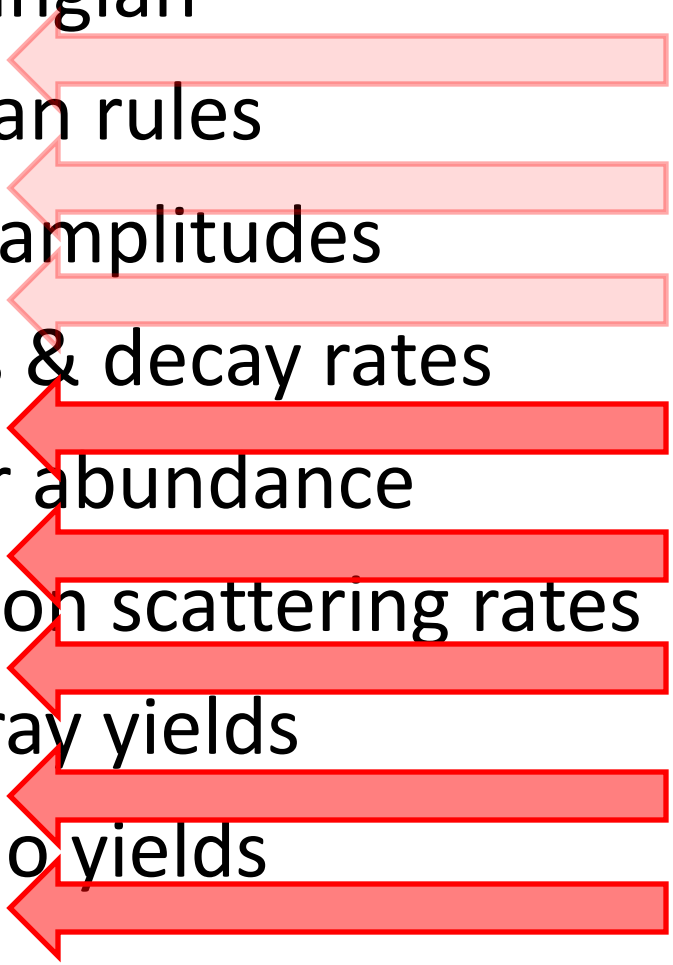
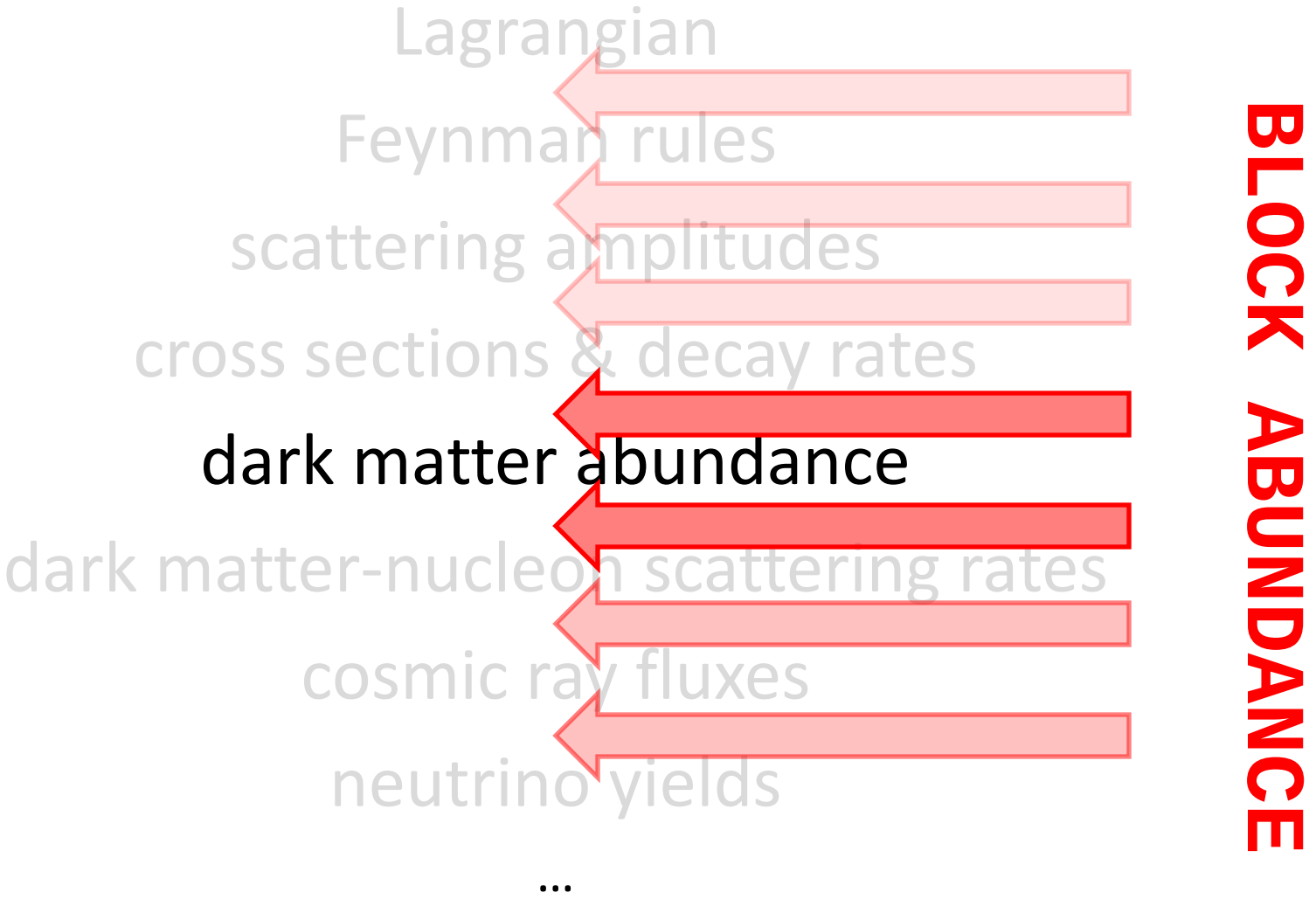


Modularity of DM calculations

Example: intercept I/O for the abundance calculation



Standardized interface

Example: intercept I/O for the abundance calculation

Module I/O: SLHA style BLOCK format

```
BLOCK ABUNDANCE
# identifier(s)  parameter value     comment
  1              5.16392660E+00   #  T_f [GeV/k]
  2              1.50000000E+00   #  alpha
  3              3.18452057E-26   #  <sigma v>(T_f) [cm^3/s]
  4              0.11018437E+00   #  Omega h^2 thermal
# annihilation channel contribution to <sigma v>(T_f) [%]
# identifier(s) PGD code 1  PGD code 2    %
  6               ...           ...          ...
```

DLHA fixes: BLOCK names, structure and content

BLOCK list (A-Z)

BLOCK ABUNDANCE	abundance related info
BLOCK ANNIHILATION	total & partial annihilation cross sections
BLOCK ASTROPROPAG	propagation model info for charged CRs
BLOCK COSMOLOGY	cosmological parameters
BLOCK DETECTOR_NUCLEI	nuclear structure functions
BLOCK DMCLUMPS	DM substructures
BLOCK DMSPADIST	DM density distribution in astro objects
BLOCK DMVELDIST	DM velo. distribution in astro objects
BLOCK DOFREEDOM	relevant degrees of freedom
BLOCK EFFCOUPLING	effective dark matter-nucleon couplings
BLOCK FORMFACTS	nucleon form factors
BLOCK INDIRDETSPECTRUM	annihilation/decay spectra in halo/Sun/etc.
BLOCK MASS	standard SLHA block
BLOCK NDMCROSSSECT	nucleon-DM elastic scattering cross sections
BLOCK QNUMBERS	Les Houches BSM Generator Accord block
BLOCK STRUCTFUN	nuclear structure functions

DLHA vs. SLHA

using & modifying various codes = hacking

DLHA vs. SLHA

using & modifying various codes = hacking

SLHA = hacking^2

DLHA vs. SLHA

using & modifying various codes = hacking

$\text{SLHA} = \text{hacking}^2$

$\text{DLHA} = e^{\text{hacking}}$

DLHA challenges

Challenges

(programming) language independence

platform independence

(physics) model independence

particle physics, astrophysics, cosmology

vectors, arrays, tables, functions, methods

speed, flexibility, ease of use, tranparency

reader/writer

…

FUNCTION

SLHA type BLOCK useful for I/O of single values

To facilitate function I/O, DLHA introduces

```
FUNCTION <name> type=<type> args=<number of arguments>
  ...
END_FUNCTION
```

`type = P` for a predefined function
`type = C` for a C function
`type = F` for a FORTRAN function
`type = T` for a tabular function
`type = L` for a pre-compiled library function

DLHA specifies: function names, arguments, parameters, predefined assignments

FUNCTION list (A-Z)

`FUNCTION EnerLoss`	energy loss coefficient
`FUNCTION F_A`	nuclear structure function
`FUNCTION fv_g`	dark matter velocity distribution
`FUNCTION g_eff`	effective degrees of freedom of thermal bath
`FUNCTION gstar`	effective degrees of freedom of thermal bath
`FUNCTION h_eff`	effective degrees of freedom of thermal bath
`FUNCTION Hubble`	normalized Hubble expansion rate
`FUNCTION rho_D`	‘dark’ energy density - non-standard cosmologies
`FUNCTION rho_g`	shape of the dark matter density distribution
`FUNCTION S_ij`	nuclear structure function
`FUNCTION s_D`	‘dark’ entropy density - non-standard cosmologies
`FUNCTION Sigma_D`	‘dark’ entropy prod. rate - non-st. cosmologies
`FUNCTION SpatDiff`	spatial diffusion coefficient

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FUNCTION examples

DM galactic distributions: ***predefined*** profiles

DLHA rho_g 1: Hernquist-Zhao profile, as given in Eq. (71),
DLHA rho_g 2: NFW density profile, defined by Eq. (71),
DLHA rho_g 3: Kravtsov et al. profile, defined by Eq. (71),
DLHA rho_g 4: Modified isothermal profile, as given in Eq. (72),
DLHA rho_g 5: Einasto profile, as given in Eq. (73),
DLHA rho_g 6: Moore et al. profile, as given in Eq. (74),
DLHA rho_g 7: Burkert profile, as given in Eq. (75).

FUNCTION examples

DM galactic distributions: ***predefined*** profiles

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FUNCTION examples

DM galactic distributions: Einasto profile

$$\rho_g(r) = \rho_0 \exp\left(-\frac{2}{\alpha}\left(\frac{r^\alpha}{r_s^\alpha} - 1\right)\right) \qquad (73)$$

A DLHA file may refer to this as a ***predefined*** object:

```
FUNCTION rho_g type=P args=1
 DLHA rho_g 5
 PARAMETERS
  alpha=1
 END_PARAMETERS
END_FUNCTION
```

FUNCTION examples

DM galactic distributions: Einasto profile

$$\rho_g(r) = \rho_0 \exp\left(-\frac{2}{\alpha}\left(\frac{r^\alpha}{r_s^\alpha} - 1\right)\right) \qquad (73)$$

… or as a ***C language*** object:

```
FUNCTION rho_g type=C args=2
 #include<math.h>
 double Einasto(double r, double alpha)
 { return exp(-2*(pow(r,alpha)-1)/alpha);}
END_FUNCTION
```

FUNCTION examples

DM galactic distributions: Einasto profile

$$\rho_g(r) = \rho_0 \exp\left(-\frac{2}{\alpha}\left(\frac{r^\alpha}{r_s^\alpha} - 1\right)\right) \qquad (73)$$

… or as a ***tabular*** object:

```
FUNCTION rho_g type=T args=2
 r: 2  alpha: 3
#  r              alpha          rho_g
   0.000000E+00   1.000000E+00   2.345678E+00
   1.000000E-05   1.000000E+00   1.234567E+00
   0.000000E-05   2.000000E+00   4.567890E+00
   1.000000E-05   2.000000E+00   3.456789E+00
   0.000000E-05   3.000000E+00   6.789012E+00
   1.000000E-05   3.000000E+00   5.678901E+00
END_FUNCTION
```

FUNCTION examples

DM galactic distributions: Einasto profile

$$\rho_g(r) = \rho_0 \exp\left(-\frac{2}{\alpha}\left(\frac{r^\alpha}{r_s^\alpha} - 1\right)\right) \qquad (73)$$

… or as a ***compiled*** (library) object:

```
FUNCTION rho_g type=L args=2
  libName=libisared.a
  funcName=rhoEinasto
END_FUNCTION
```

DLHA Future

DLHA is an ***agreement*** at the moment

- we should make it a Les Houches Accord
  - that'll require a bit of tuning it up,
  - re-writing it as a journal paper, and
  - implementing it in our codes

DLHA is an accord

- so, your suggestions for improvement come …
  - here, and
  - here, and also
  - here …

DLHA Future

Having FUNCTIONs, do we need BLOCKs?

- blocks contain constant values
- a constant is a function with zero independent variables and a parameter
- any BLOCK can be replaced by one or more FUNCTIONs

FUNCTION consistency and foolprofing

- make arguments explicit
- clarify difference between variable & parameter

Improve consistency & overlap issues

DLHA Future

FUNCTION face-lift

```
FUNCTION name=<name> type=<type> dim=<# of components>
 ARGUMENTS
   <argument name 1>
   <argument name 2>
   <argument name 3>
   ...
 END_ARGUMENTS
 PARAMETERS
   <parameter name 1> = <value 1>
   <parameter name 2> = <value 2>
   <parameter name 3> = <value 3>
   ...
 END_PARAMETERS
 <function body>
END_FUNCTION
```

DLHA Future

Compatibility/compliancy

- DLHA is useless unless it's implemented in dark matter related codes

DLHA Web-page

- keeping track of codes, tools, news, etc.
- twiki style editing???

Standardized I/O?

- standardized reader/writer is desirable

Much more

- see discussions starting after this talk!

DLHA Future

DLHA:
far from perfect
far from finished

Open issues
From DLHA
write-up
arXiv.1203.1488

```
6.000000E-02     2    24   -24  # W- W+
4.000000E-02     2    23   -23  # Z0 Z0
```

4 OPEN ISSUES

A partial list of open issues is addressed in various degrees of detail.

4.1 Cosmology related open issues

- Other generalizations of the standard cosmological equations.
- The standard inflation scenario should be discussed as well.
- Decaying inflaton scenario? Can be presented as an example.

4.2 Astrophysics related related open issues

- The notation in BLOCK DMSPADIST is confusing. ρ_0 is not the density at R_0. The local density could be called $\rho_\odot$ and the Galactocentric distance $R_\odot$. It should be clearly stated that either the density is defined with respect to the change of slope (or the interior mass) and then parameters (1, 2, 3, 4, and 5) are needed, or with respect to the local density, which requires parameters (2, 3, 4, 5, 6, and 7). Giving all the parameters is also possible but one needs to check consistency.
- Ideally, DLHA should be able to accommodate innately anisotropic distributions.
- A capability for non-spherical and/or clumped halo distributions are also desirable.
- Notation: should we relabel ρ_0 to ρ_N (such as ρ normalisation without any more specification as N-body codes use different definitions) and $\rho_\oplus$ to ρ_0 so that $\rho_0 = \rho(r = R_0)$?

4.3 Direct detection related open issues

- For non-self conjugate dark matter particles there is a need to present nuclear cross sections for antiparticles. This is not possible within the present setup.

4.4 Indirect detection related open issues

- Photon energy losses.
- Solar modulation - lack of unified treatment.
- Standardize the quantities that enter the transport equation (for example, the diffusion coefficient, the re-acceleration term and so on), in such a way that free parameters are identified.

4.5 Other open issues

- Kinetic decoupling of DM particles should be discussed. This sets the small-scale cutoff in the spectrum of density perturbations, viz. the mass of smallest dark matter halos, and can have impact on, e.g., the anisotropy spectrum and the 'boost factor' for indirect searches.
- Concerning the calculation of the relic density, the importance of the QCD phase transition should be stressed. This may impact strongly the calculation if the dark matter candidate is light (10 GeV/c^2 or so). The QCD phase transition temperature should be a parameter to put in BLOCK DOFREEDOM.
- BLOCK DMPDGCODE: suggestion for a new block more explicitly identifying the DM candidate(s).

```
1    0  1000022 # neutralino
1    1  1000012 # sneutrino
...
2    0  9999999 # axion
```

- Issue of large tables in large para scans: I/O may take a long time.
- Scenarios/models with Z_3, Z_4 etc., different interactions, processes appear.
- Semi-annihilations?
- Possible conflict between multi-component dark matter and asymmtry/clumping/non-spherical halo.

ACKNOWLEDGEMENTS

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DLHA Future

help shaping DLHA

discuss, discuss, discuss DLHA

let me know what you think

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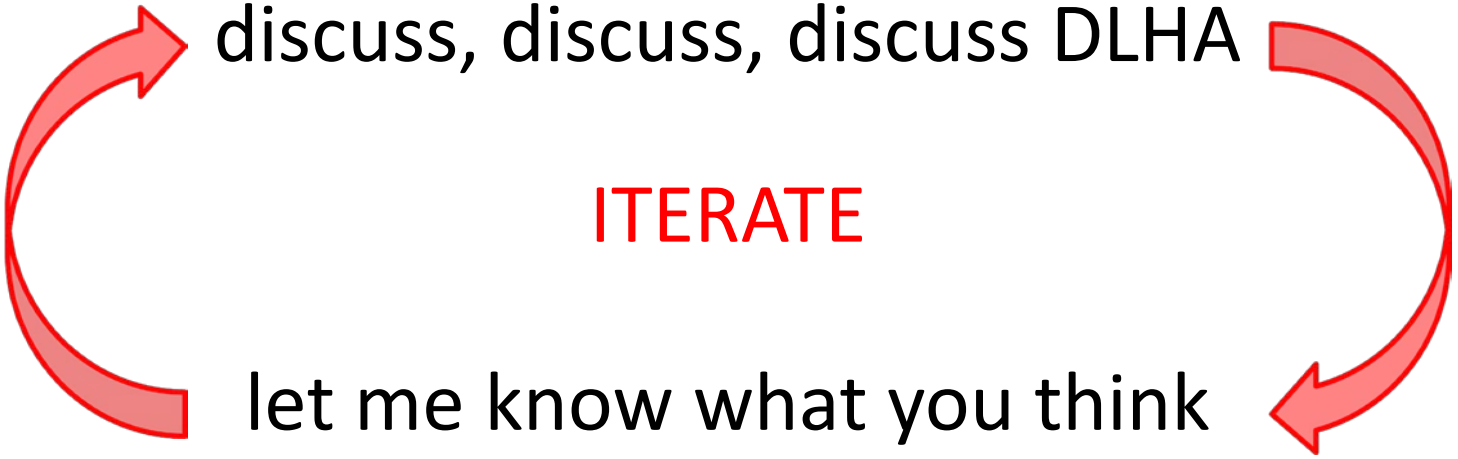
DLHA Future

help to shape DLHA



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What Standardized interface for exchanging DM info

Why Enhanced flexibility of DM calculators

How Utilize modularity in DM calculations

Allow user to access I/O for ‘modules’

Let the user ‘go wild’ without hurting anyone

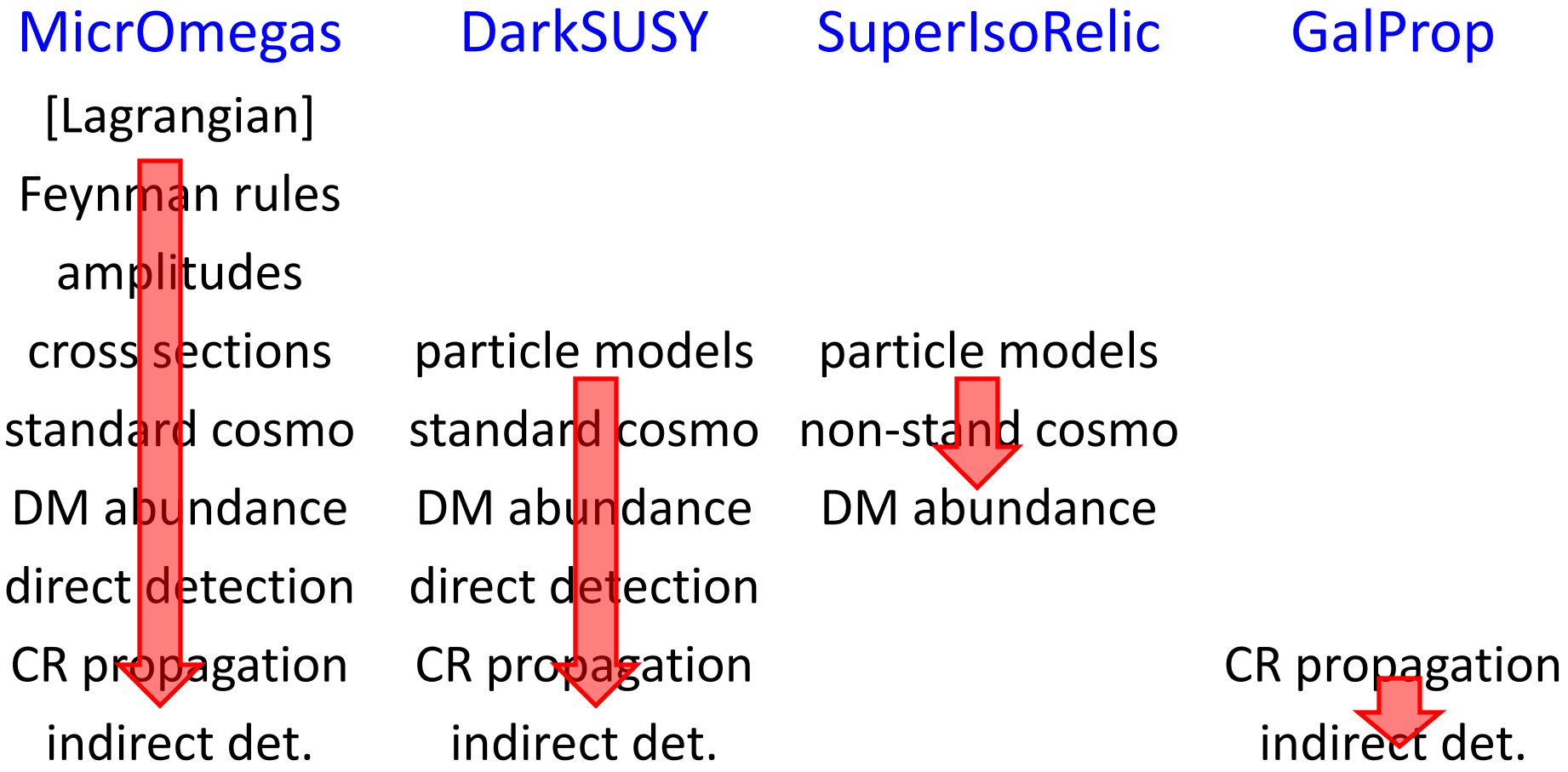
The End

The End
… of this talk but just the beginning of DLHA

Old slides

DLHA Why

Present workflow



DLHA Why

Present workflow

MicrOmegas

[Lagrangian]

Feynman rules

amplitudes

cross sections

standard cosmo

DM abundance

direct detection

CR propagation

indirect det.

DarkSUSY

particle model

standard cosmo

DM abundance

direct detection

CR propagation

indirect det.

SuperIsoRelic

particle models

non-standard cosmo

DM abundance

GalProp

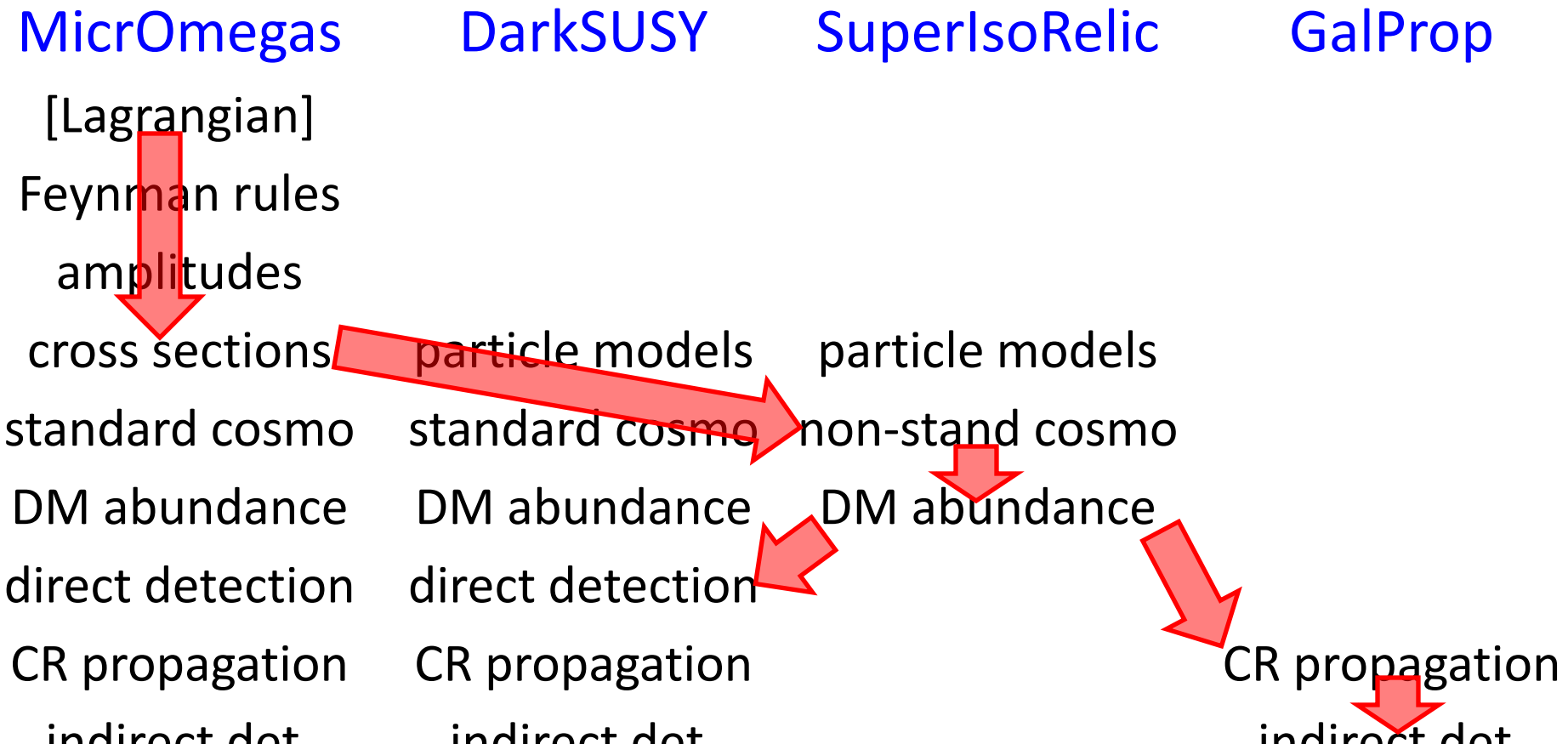
CR propagation

indirect det.

Rigid

DLHA Why

DLHA workflow



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