Joint ICTP-IAEA Workshop on Monte Carlo Radiation Transport and Associated Data Needs for Medical Applications
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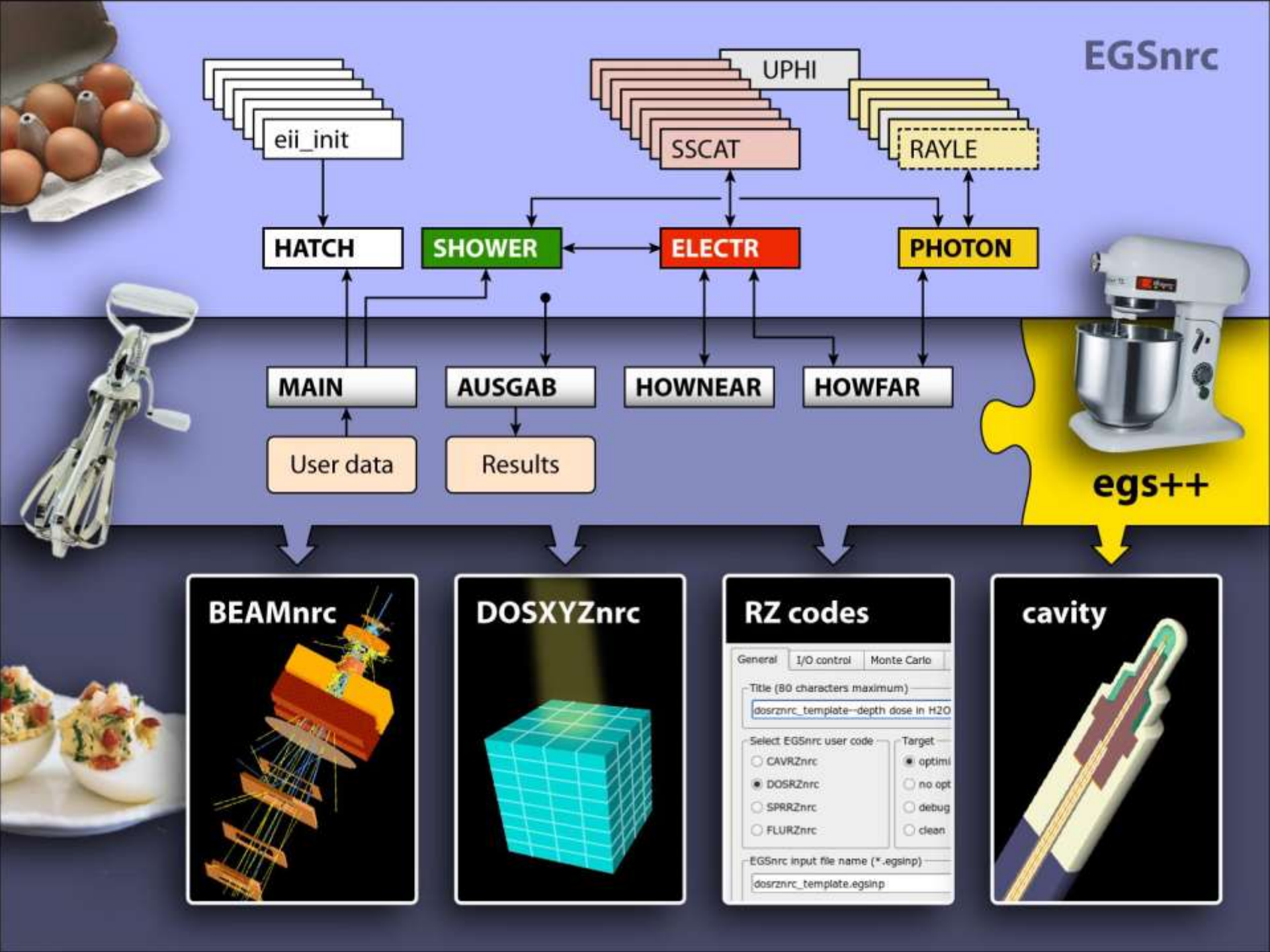
Lecture 4

Looking inside EGSnrc

Reid Townson

Metrology Research Centre
National Research Council Canada

Government of Canada | Gouvernement du Canada
Carleton University
Université de Montréal
nova scotia health


EGSnrc
eii_init
UPHI
SSCAT
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HATCH
SHOWER
ELECTR
PHOTON
MAIN
AUSGAB
HOWNEAR
HOWFAR
User data
Results
egs++
BEAMnrc
DOSXYZnrc
RZ codes
General
I/O control
Monte Carlo
Title (80 characters maximum)
dosrznrc_template--depth dose in H2O
Select EGSnrc user code
CAVRZnrc
DOSRZnrc
SPRRZnrc
FLURZnrc
Target
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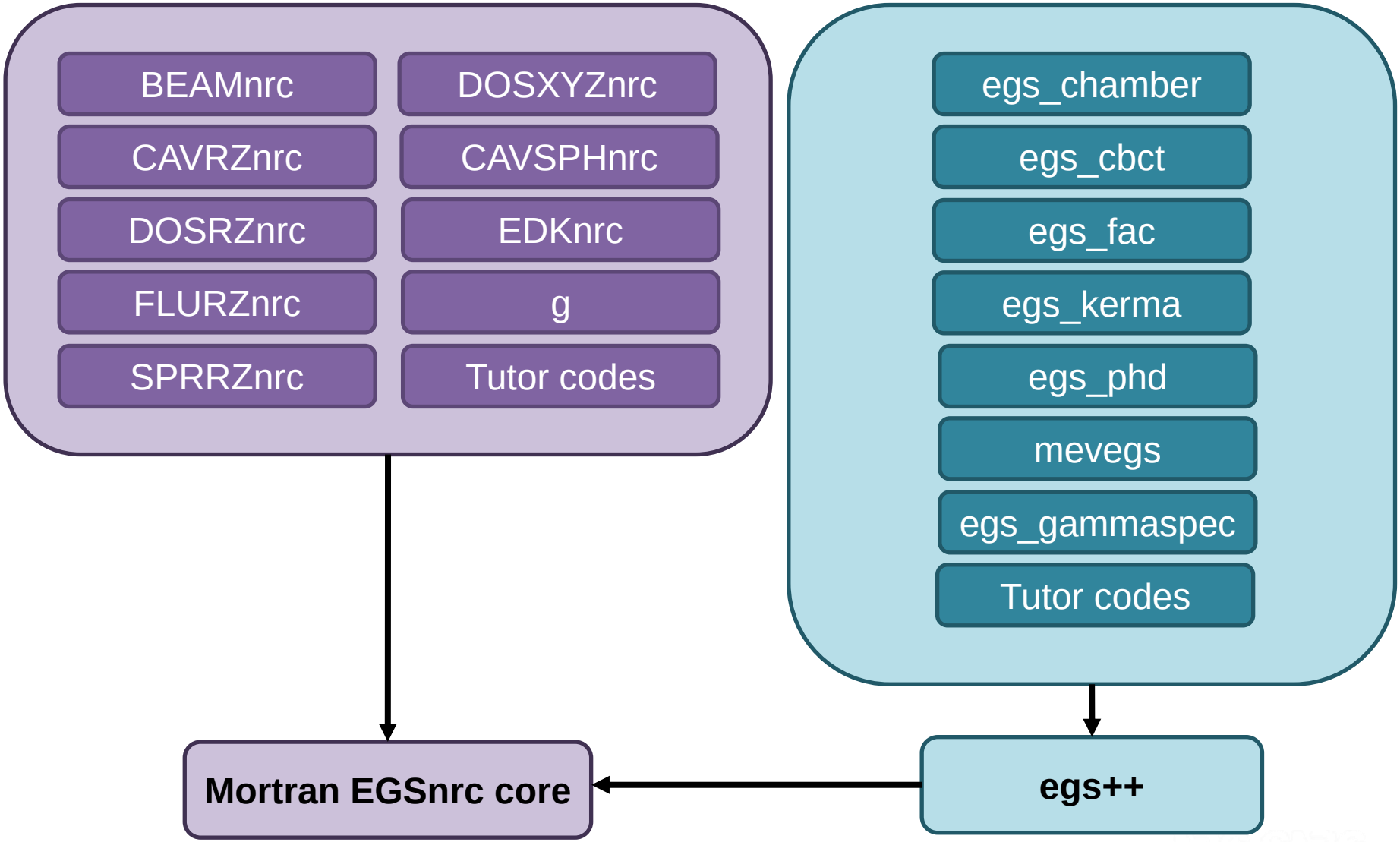
no opt
debug
clean
EGSnrc input file name (*.egsinp)
dosrznrc_template.egsinp
cavity


BEAMnrc
DOSXYZnrc
CAVRZnrc
CAVSPHnrc
DOSRZnrc
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FLURZnrc
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SPRRZnrc
Tutor codes
egs_chamber
egs_cbct
egs_fac
egs_kerma
egs_phd
mevegs
egs_gammaspec
Tutor codes
Mortran EGSnrc core
egs++

MORTRAN

Looking inside MORTRAN applications

- MORTRAN is simply a **string processor** that produces Fortran77 code
- Primarily this is for code re-use via **macros**

- Application code gets packaged with the EGSnrc core:
  - **egsnrc.macros + yourApp.mortran + egsnrc.mortran**

- The package is processed by **mortran3.f**, converting to a final Fortran file **yourApp.f**

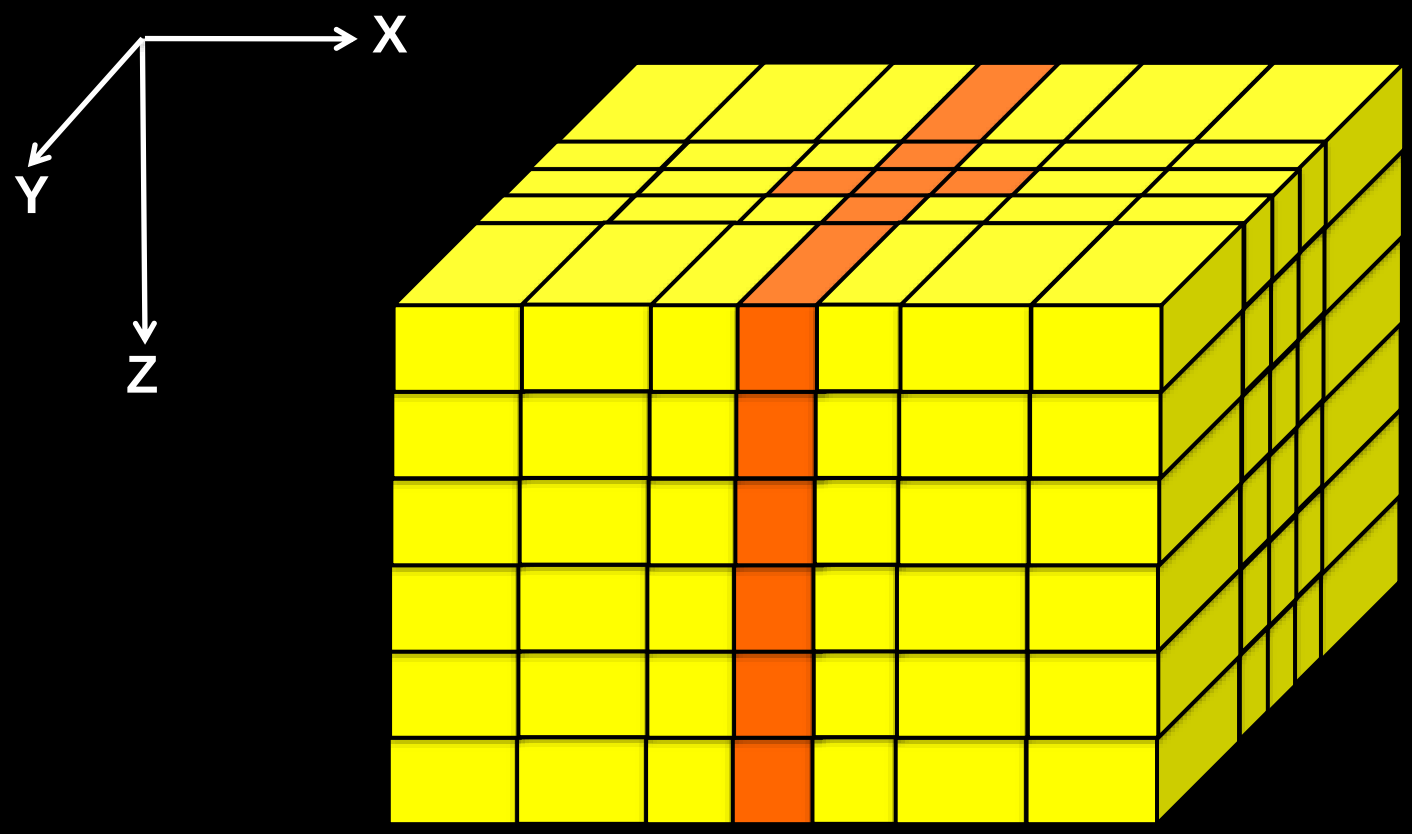
EGSnrc MORTRAN applications don't share*

- Each application must define its own:
  - **Particle sources**
  - **Geometries**
  - **Input/output**
  - **Interaction with EGSnrc core**
    - **initialization, shower() calls, etc.**

*except when they do

DOSXYZnrc: dose in voxels

- 22 sources
- 1 geometry type
- Unique input/output



DOSXYZnrc gets packaged

```
SOURCES = $(EGS_SOURCEDIR)egsnrc.macros \
          $(EGS_UTILS)timing.macros \
          $(MACHINE_MACROS) $(RANDOM).macros \
          dosxyznrc_user_macros.mortran srcxyznrc.macros \
          $(EGS_SOURCEDIR)transportp.macros \
          $(EGS_SOURCEDIR)pegs4_macros.mortran \
          $(EGS_UTILS)phsp_macros.mortran $(IAEA_PHSP_MACROS)\
          $(USER_CODE).mortran \
          $(EGS_SOURCEDIR)get_inputs.mortran \
          $(EGS_SOURCEDIR)get_media_inputs.mortran $(MACHINE_MORTRAN) \
          srcxyznrc.mortran $(RANDOM).mortran \
          $(EGS_UTILS)nrcaux.mortran \
          $(EGS_SOURCEDIR)egs_utilities.mortran \
          $(EGS_SOURCEDIR)egs_parallel.mortran \
          $(EGS_SOURCEDIR)pegs4_routines.mortran \
          $(EGS_SOURCEDIR)egsnrc.mortran
```

From **$EGS_HOME/dosxyznrc/Makefile**

- MORTRAN creates **dosxyznrc_yourMachine.F**
- Fortran compiles the binary **dosxyznrc**

MORTRAN

egs++

Looking inside egs++ applications

- egs++ is a C++ class library
- Applications inherit the class **EGS_AdvancedApplication**

- Shared classes:
  - **particles sources**
  - **geometries**
  - **input/output** functionality

- Inherit application class, scoring routines, I/O functions, etc.

```
#include "egs_advanced_application.h"
#include "egs_scoring.h"
#include "egs_interface2.h"
#include "egs_functions.h"
#include "egs_input.h"
#include "egs_base_source.h"
#include "egs_rndm.h"

class APP_EXPORT Tutor7_Application : public EGS_AdvancedApplication {
     ...
```

SOURCE

class **EGS_BaseSource**
Base source class. All particle sources must be de

class **EGS_BaseSpectrum**
Base class for energy spectra. All energy spectra i

class **EGS_BaseSimpleSource**
Base class for 'simple' particle sources. **More...**

class **EGS_AngularSpreadSource**
A source that adds additional Gaussian angular sp

class **EGS_BeamSource**
A BEAM simulation source. **More...**

class **EGS_CollimatedSource**
A collimated particle source. **More...**

class **EGS_FanoSource**
A Fano source. **More...**

class **EGS_IsotropicSource**
An isotropic source. **More...**

class **EGS_ParallelBeam**
A parallel beam. **More...**

class **EGS_PhspSource**
A phase-space file source. **More...**

class **EGS_PointSource**
A point source. **More...**

class **EGS_RadionuclideSource**
A radionuclide source. **More...**

class **EGS_SourceCollection**
A source collection. **More...**

class **EGS_TransformedSource**
A transformed source. **More...**

class **IAEA_PhspSource**
An IAEA phase-space file source. **More...**

GEOMETRY

class **EGS_Box**
A box geometry. **More...**

class **EGS_SimpleCone**
A single cone that may be open (i.e. extends to infinity

class **EGS_ParallelCones**
A set of "parallel cones" (*i.e.* cones with the same axis

class **EGS_ConeSet**
A set of cones with different opening angles but the sa

class **EGS_ConeStack**
A cone stack. **More...**

class **EGS_CylindersT< T >**
A set of concentric cylinders. **More...**

class **EGS_IPlanes**
A set of planes intersecting in the same axis. **More...**

class **EGS_PlanesT< T >**
A set of parallel planes. **More...**

class **EGS_PlaneCollection**
A collection of non-parallel planes. **More...**

class **EGS_PrismT< T >**
A class for modeling prisms. **More...**

class **EGS_PyramidT< T >**
A template class for modeling pyramids. **More...**

class **EGS_RoundRectCylindersT< Tx, Ty >**
A set of concentric rounded rectangles. **More...**

class **EGS_Space**
The entire space as a geometry object. **More...**

class **EGS_cSpheres**
A set of concentric spheres. **More...**

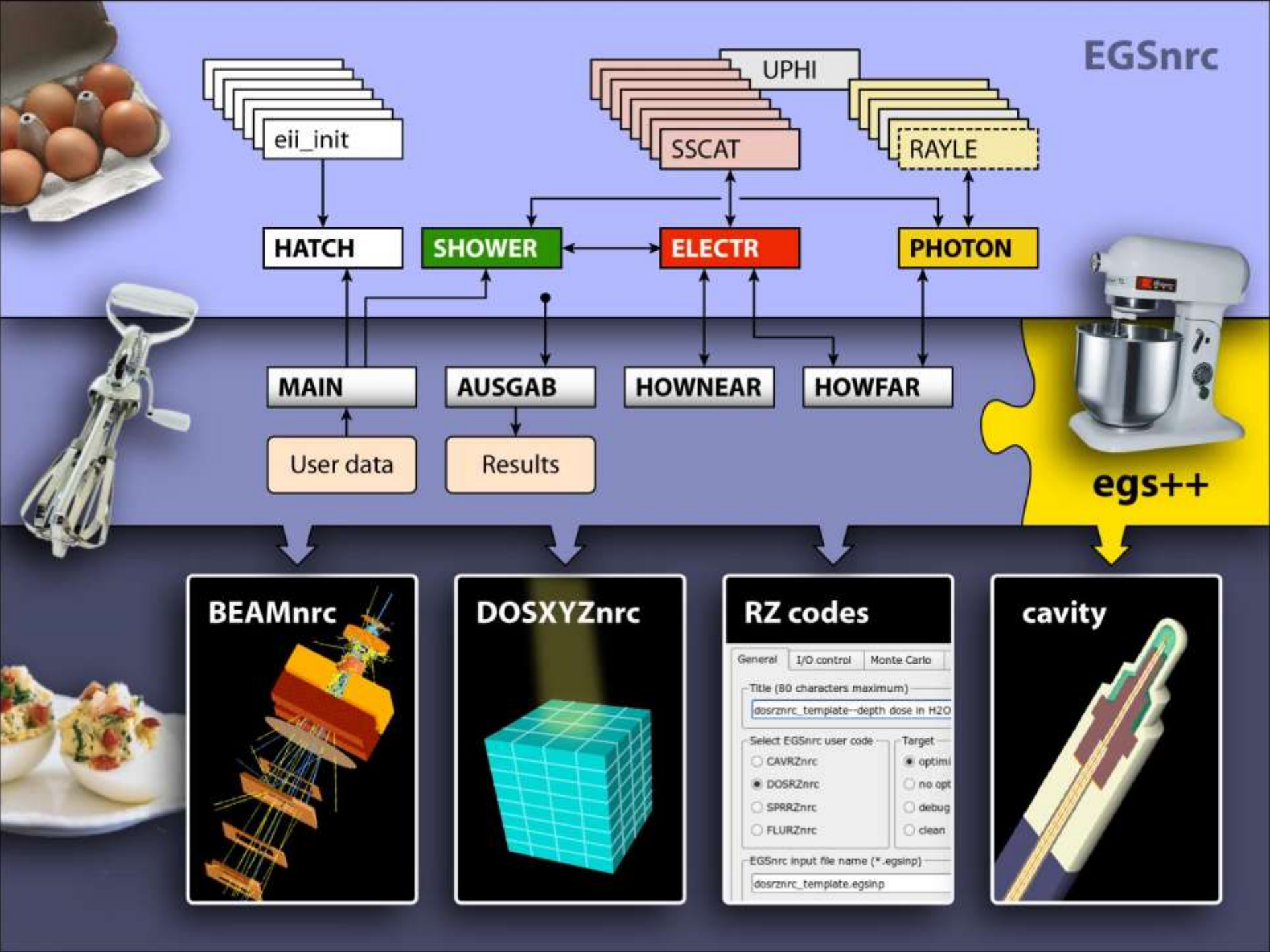
egs++ interfaces with EGSnrc core

- Most physics still occurs in EGSnrc core
- Functions are mapped between C++/MORTRAN

```
#define egsHatch F77_OBJ_(egs_hatch,EGS_HATCH)
extern __extc__ void egsHatch(void);
```

egs++

Application functions


EGSnrc
eii_init
UPHI
SSCAT
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HATCH
SHOWER
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MAIN
AUSGAB
HOWNEAR
HOWFAR
User data
Results
egs++
BEAMnrc
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General
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Title (80 characters maximum)
dosrznrc_template--depth dose in H2O
Select EGSnrc user code
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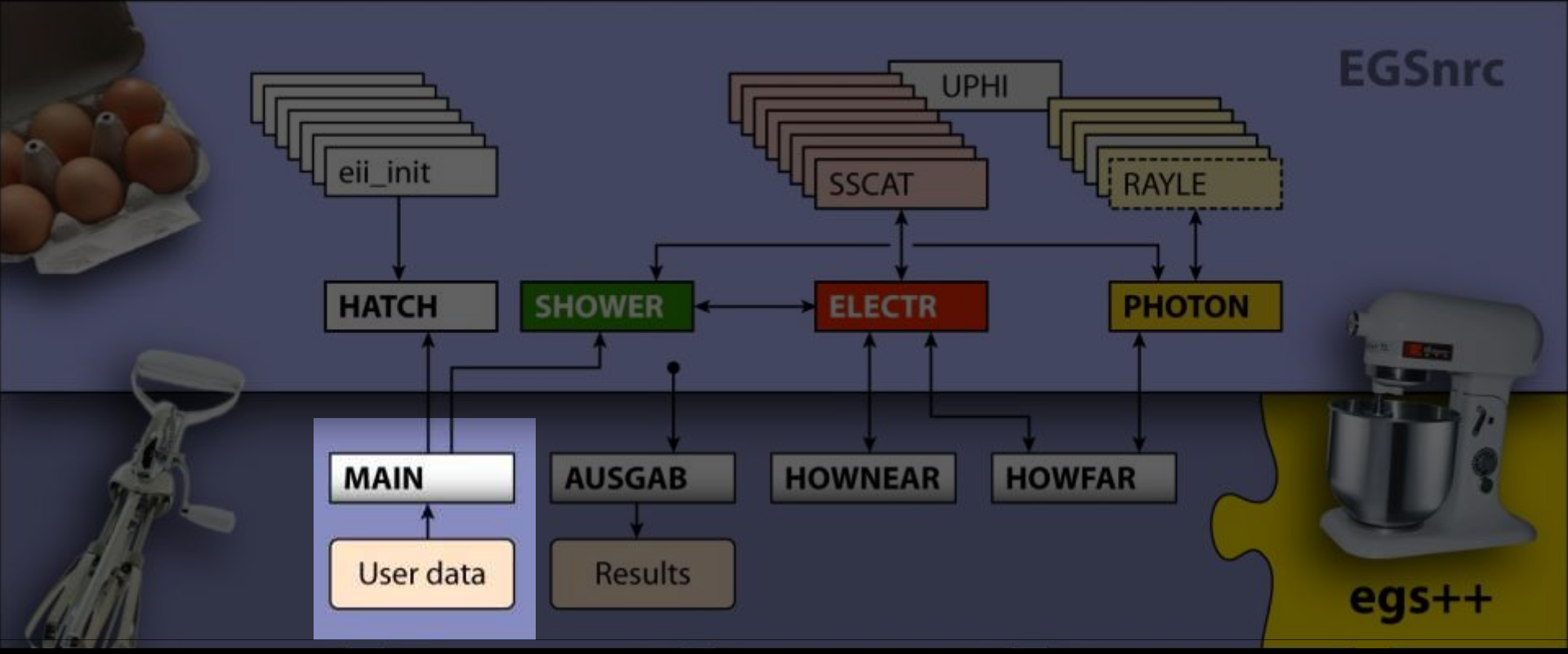
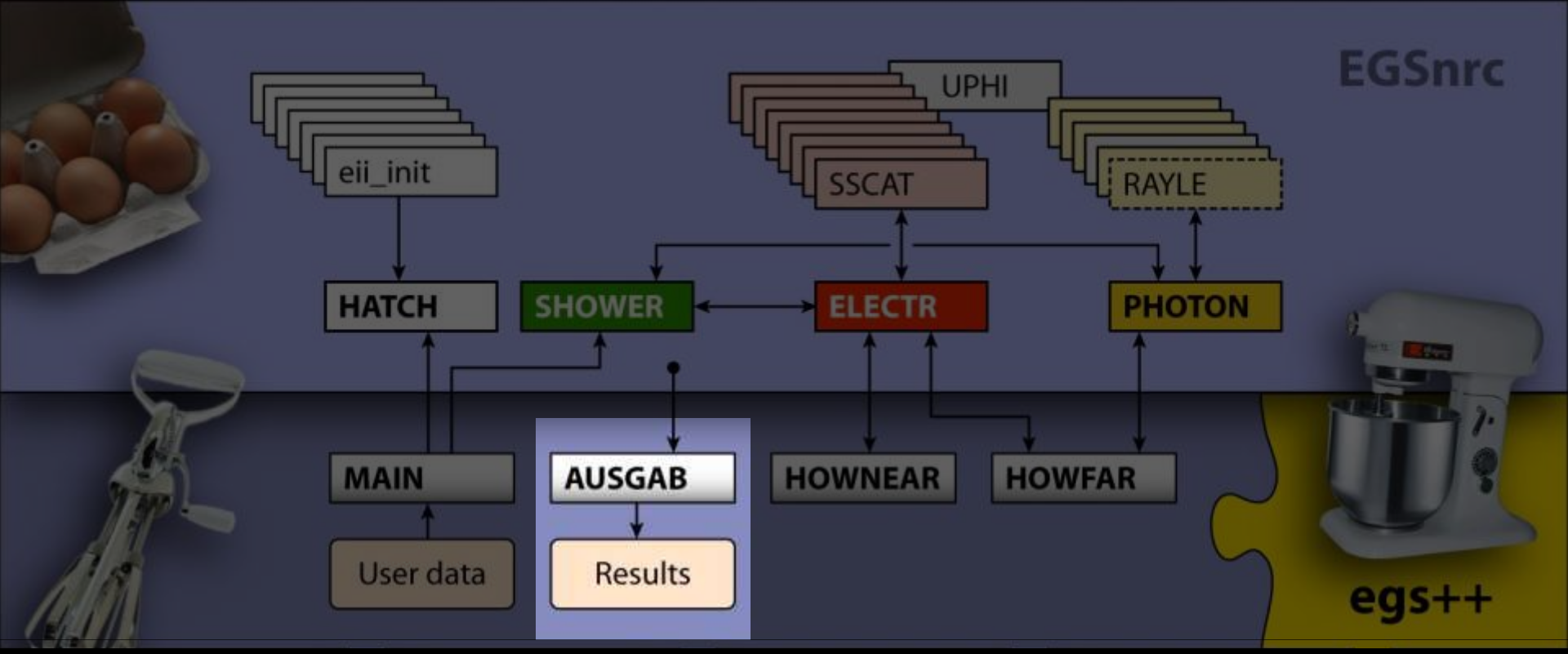
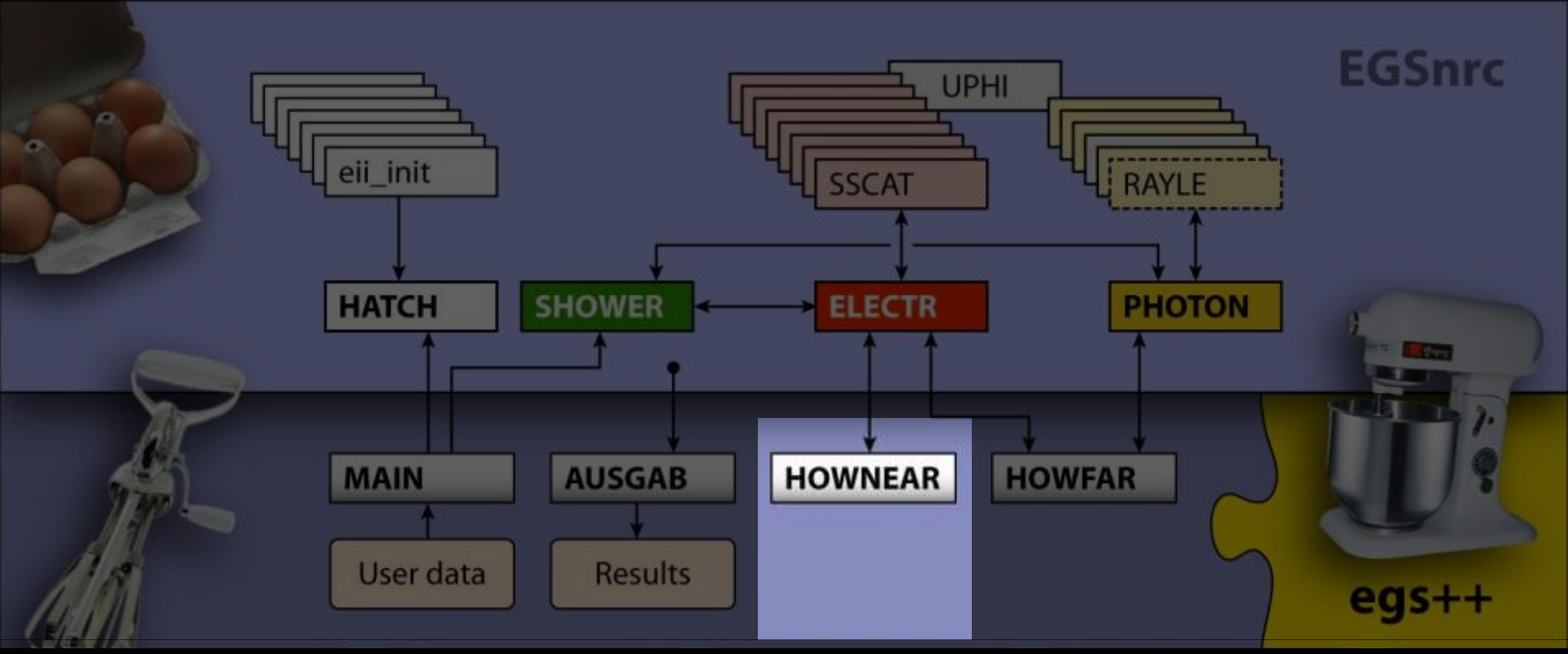
DOSRZnrc
SPRRZnrc
FLURZnrc
Target
optimi
no opt
debug
clean
EGSnrc input file name (*.egsinp)
dosrznrc_template.egsinp
cavity



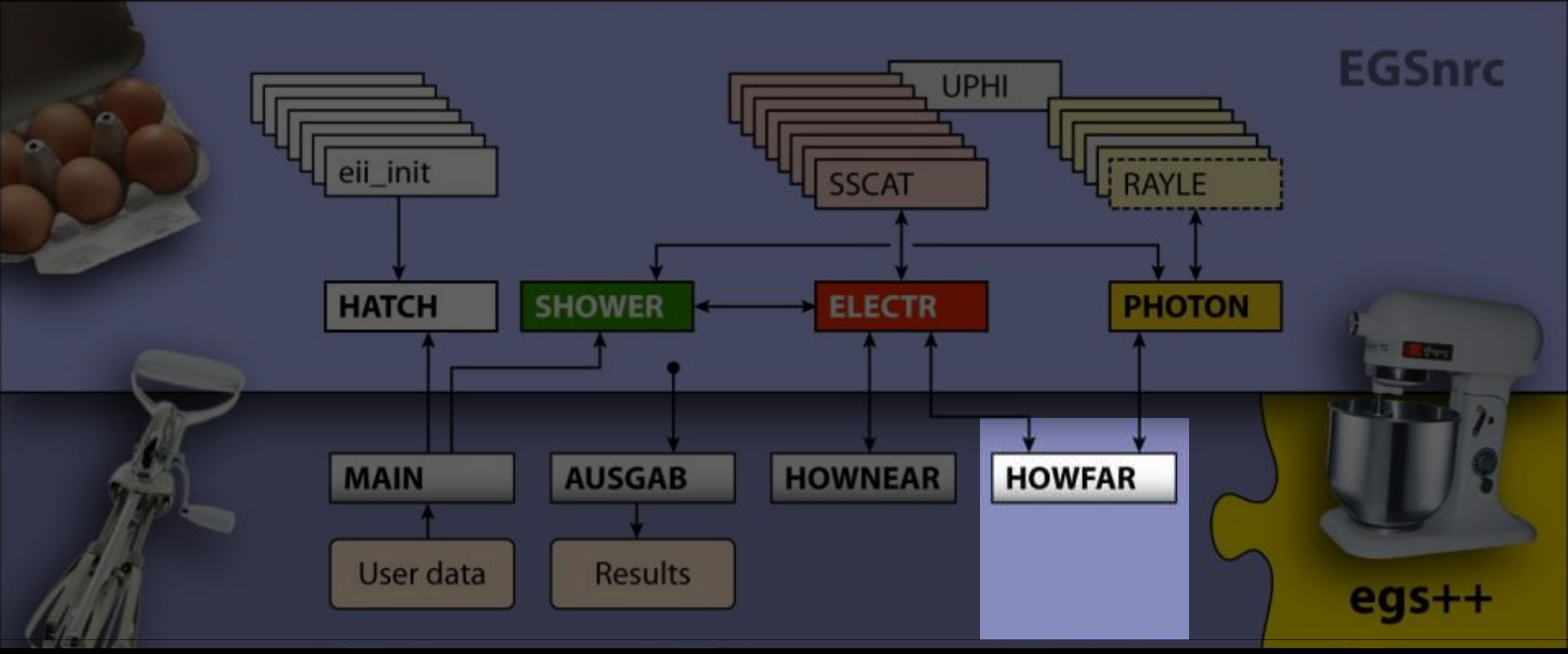
- Read input files
- Initialize/finalize
- Get source particles
- Ask for transport



- Output control
- Receives “call-backs” during transport
  - E.g. after every Compton event
  - Scores results



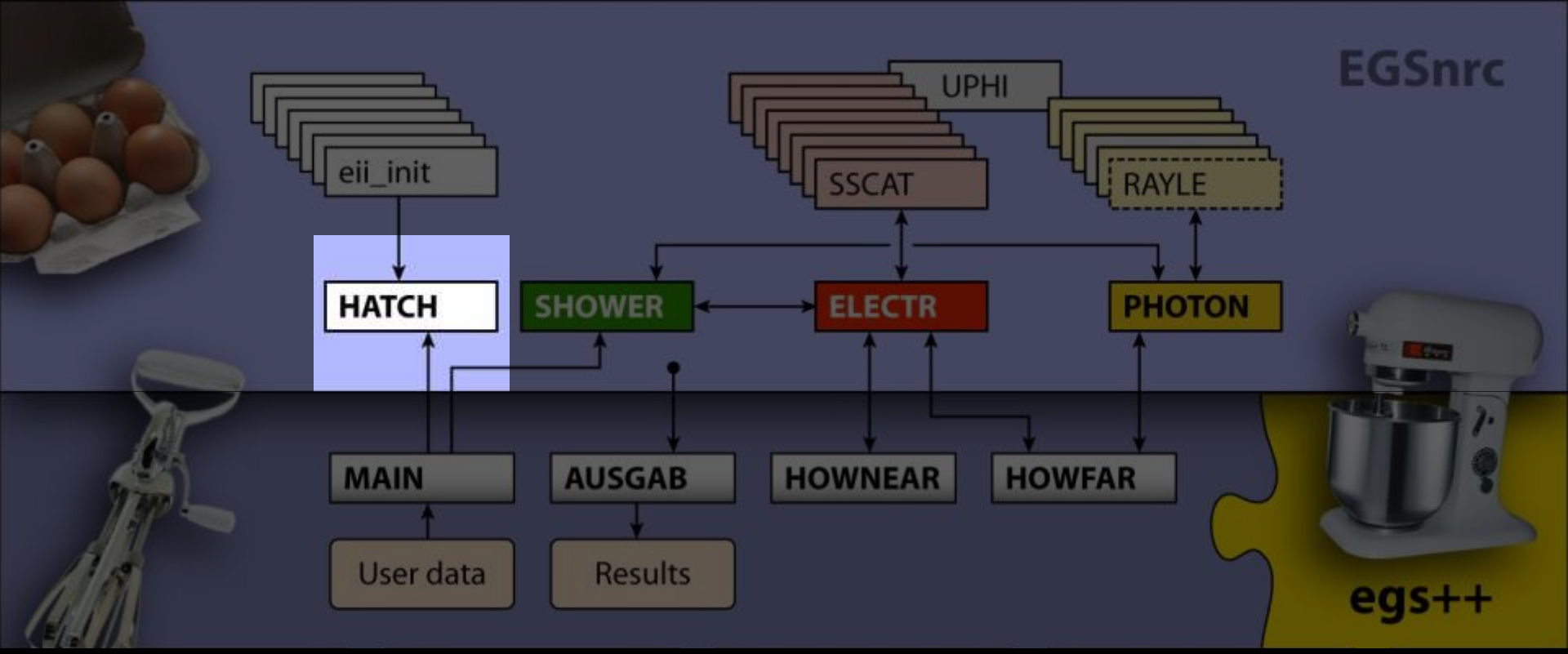
- Defined by geometry
- Calculates perpendicular distance to nearest region boundary
  - Essential for charged particle transport



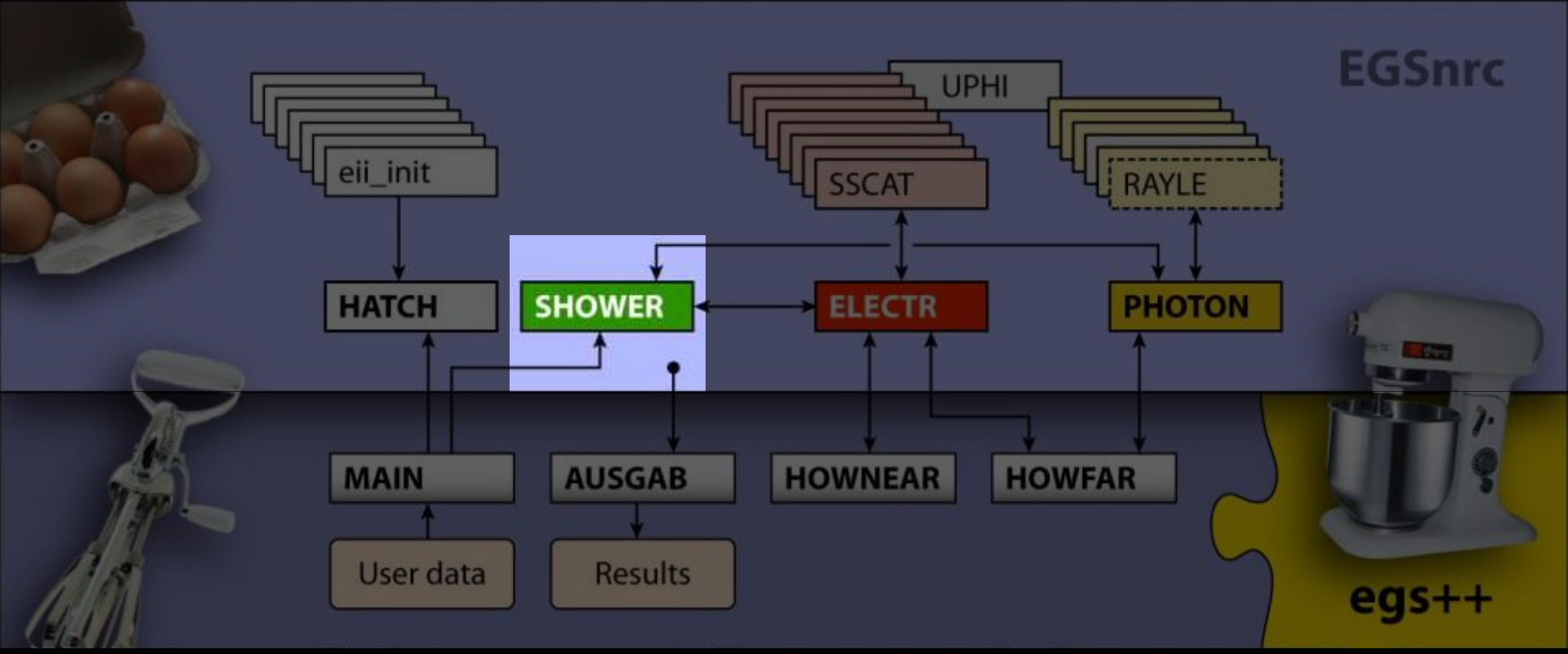
- Defined by geometry
- Calculates distance to the next boundary in the particle's direction
  - If intended particle step USTEP is larger than this distance, resets USTEP to the distance to the boundary
  - If particles reaches a boundary, resets the current region index to the new region

Application functions

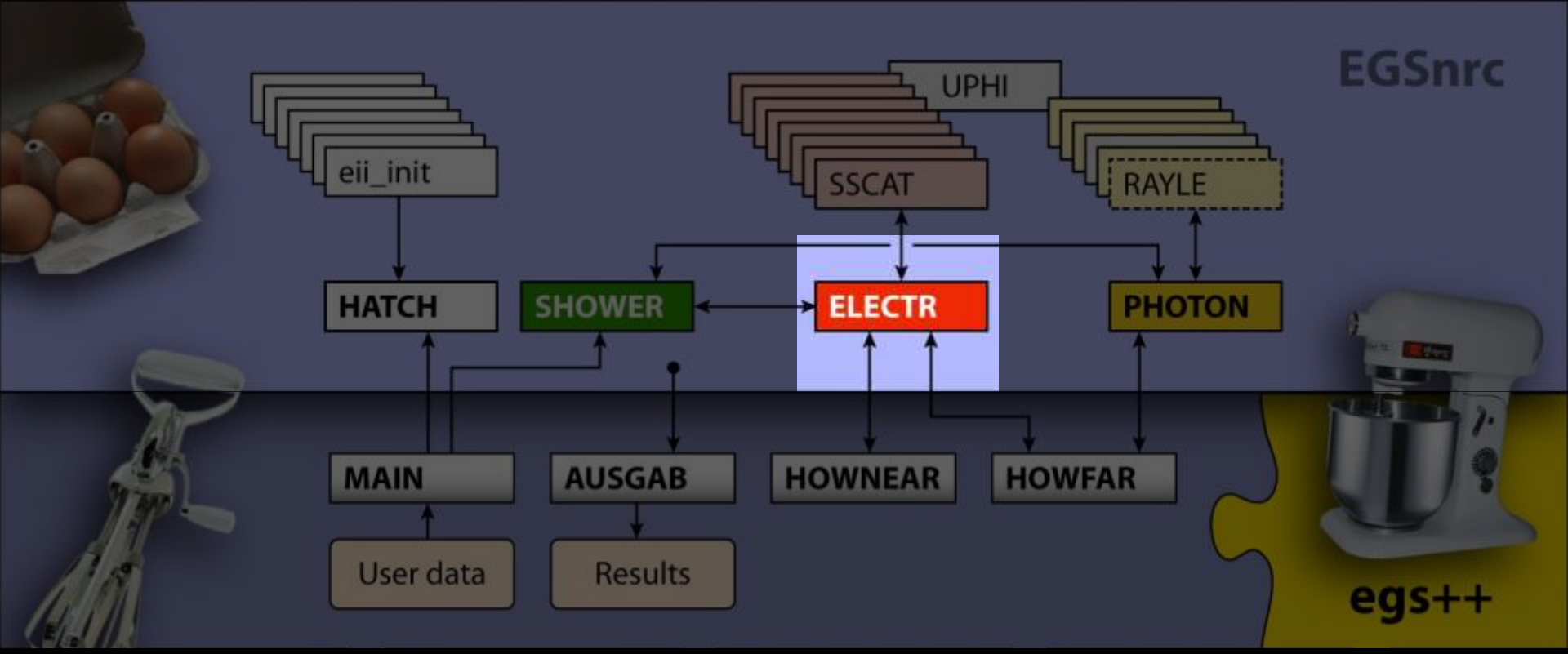
EGSnrc core



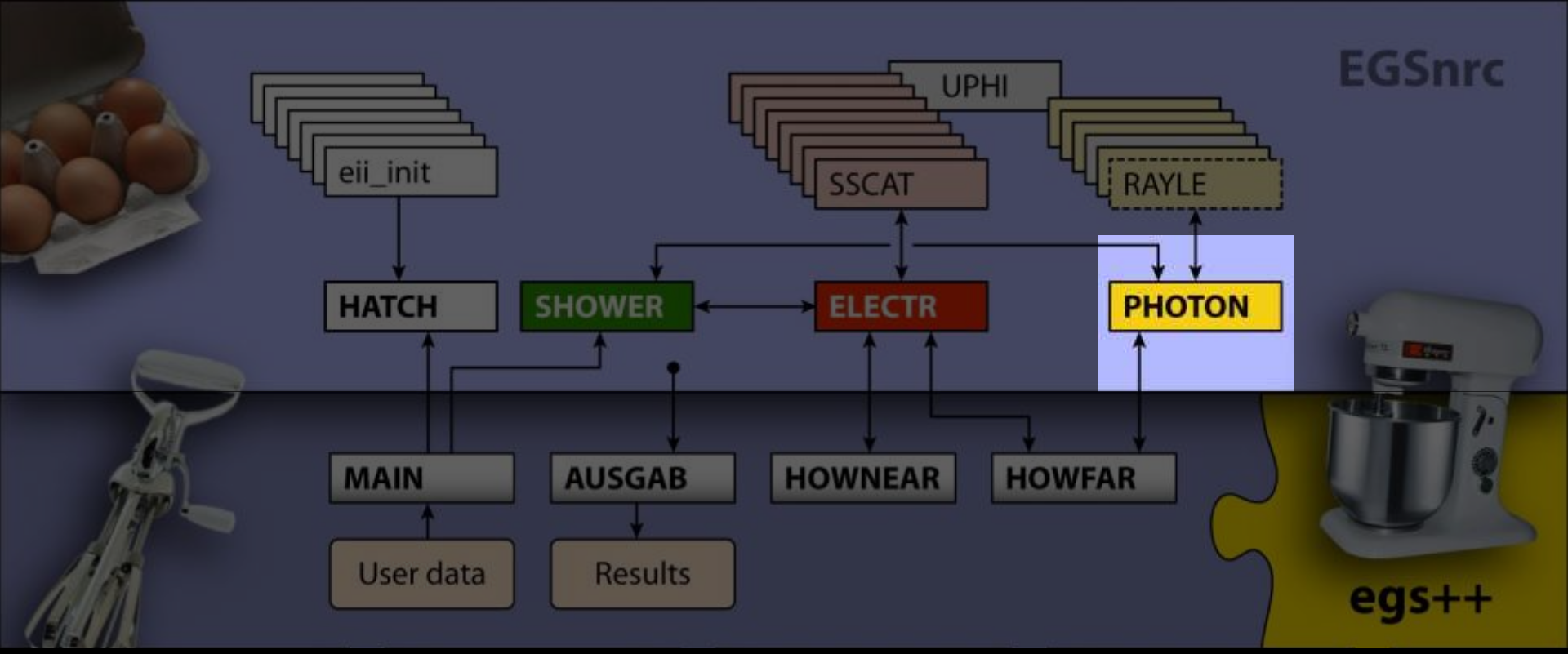
- Initialization
  - Cross section data
  - Atomic relaxation data
  - Material data (PEGS4, density corrections)



- Starts transport from a source particle
- Also starts transport of any secondaries
- Essentially just calls **ELECTR()** or **PHOTON()** in a loop



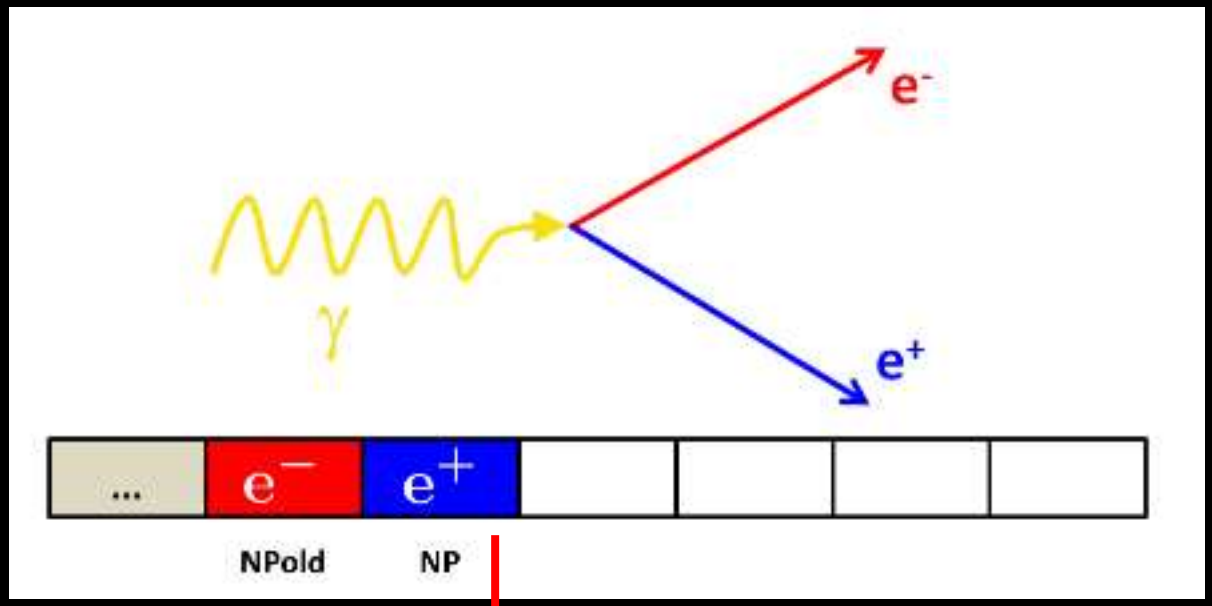
- Transports an electron until it is absorbed or escapes
- Adds secondary particles to the **stack**



- Transports a photon until it is absorbed or escapes
- Adds secondary particles to the **stack**

The stack is an array of particles

- Secondary particles get placed on the stack *for later*
- Ausgab/scoring routines often analyze the stack



particle stack

NPold	NP	IR(NP)	$\vec{X}$(3,NP)	$\vec{\Omega}$(3,NP)	E(NP)	IQ(NP)	WT(NP)	DNEAR(NP)	LATCH(NP)

EGSnrc core

File structure

Your input files go in $EGS_HOME

- You set* the $EGS_HOME environment variable, e.g.

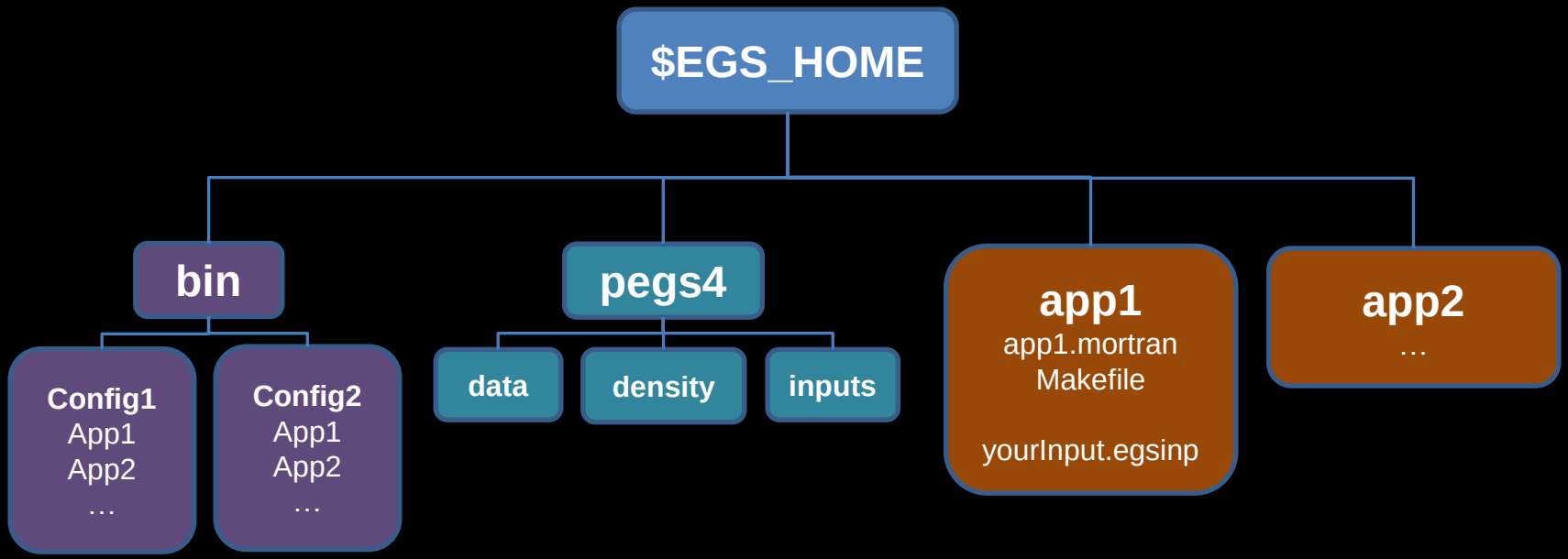
  EGS_HOME = /home/you/EGSnrc/egs_home

- Each application has a folder in $EGS_HOME, e.g.

  $EGS_HOME/dosxyznrc

- Also contains:
  - input files
  - custom data (PEGS4)
  - compiled application binaries

***No spaces or special characters in file paths!**
Keep paths *short


$EGS_HOME
bin
Config1
App1
App2
…
Config2
App1
App2
…
pegs4
data
density
inputs
app1
app1.mortran
Makefile
yourInput.egsinp
app2
…

The EGS are in the $HEN_HOUSE

- You set the $HEN_HOUSE environment variable, e.g.

  HEN_HOUSE = /home/you/EGSnrc/HEN_HOUSE

- Contains code & data
  - EGSnrc core
  - egs++ core
  - Data files
  - Installation & other tools

$HEN_HOUSE

Category	Folder	Description
EGSnrc core	omega	- BEAMnrc source code - addphsp, beamdp, ctcreate, dosxyz_show, readphsp, and statdose - tcl GUIs for beamdp, BEAMnrc and DOSXYZnrc
	previewRZ	- tcl GUI for viewing geometries from DOSRZnrc, CAVRZnrc, FLURZnrc and SPRRZnrc
	src	- EGSnrc core MORTRAN source code
	user_codes	- Application source code (C++ and MORTRAN)
	utils	- Various MORTRAN tools
egs++ and Qt	cutils	- C tools for parallel jobs and BEAMnrc sources
	egs++	- C++ class library - ausgab objects, geometries and sources
	gui	- Qt GUIs: egs_configure, egs_gui and egs_inprz
	iaea_phsp	- C++ tools for IAEA phase-spaces
	interface	- The code that connects C++ and MORTRAN
data	data	- photon cross section data - bremsstrahlung cross section corrections - eii cross sections - molecular form factors
	pegs4	- PEGS4 mortran code - PEGS4 data files - density correction files
	spectra	- various energy spectrum data - radionuclide decay data
configuration	makefiles	- template application makefiles
	mortran3	- the MORTRAN core code
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File structure

Simulations

Compile on the command line

- Compile applications using ‘make’
- On linux:

```
cd $EGS_HOME/dosxyznrc
make clean; make
```

- On Windows (with mingw compilers):

```
mingw32-make clean
mingw32-make
```

- Input files must be in the **application folder** in $EGS_HOME

Execute on the command line

- To run a simulation on a single core (e.g. egs_app):

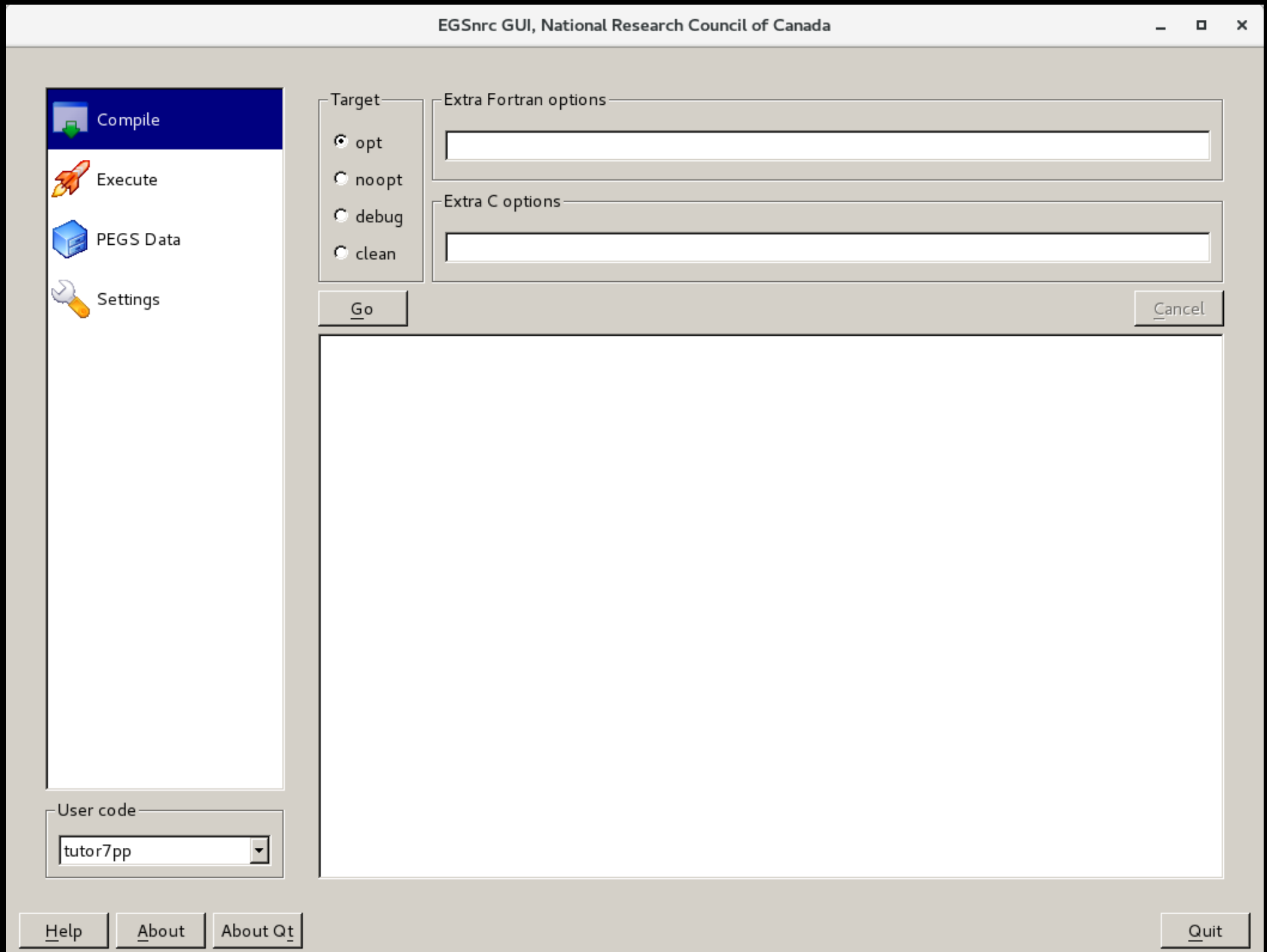
```
egs_app -i myInput [-p myPegs] [other_args]
```

- To run in parallel on local cores (no queueing system):

```
egs-parallel -c 'egs_app -i myInput' --batch cpu -n4 -v
```

- For pbs queueing system:

```
egs-parallel -c 'egs_app -i myInput' -q user1 --batch
pbsdsh -n50 -v
```


EGSnrc GUI, National Research Council of Canada
Compile
Execute
PEGS Data
Settings
User code
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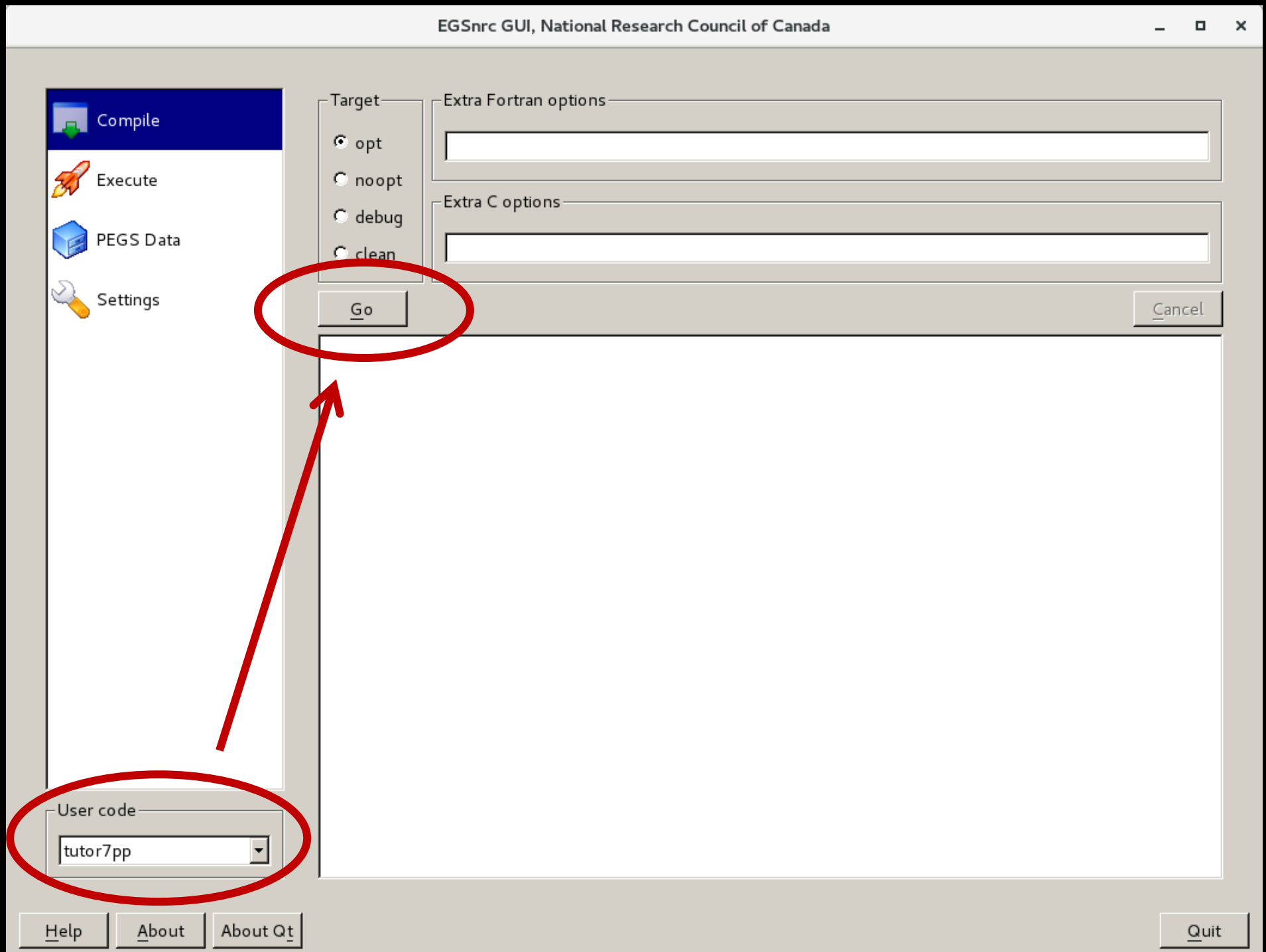
opt
noopt
debug
clean
Extra Fortran options
Extra C options
Go
Cancel
Help
About
About Qt
Quit


EGSnrc GUI, National Research Council of Canada
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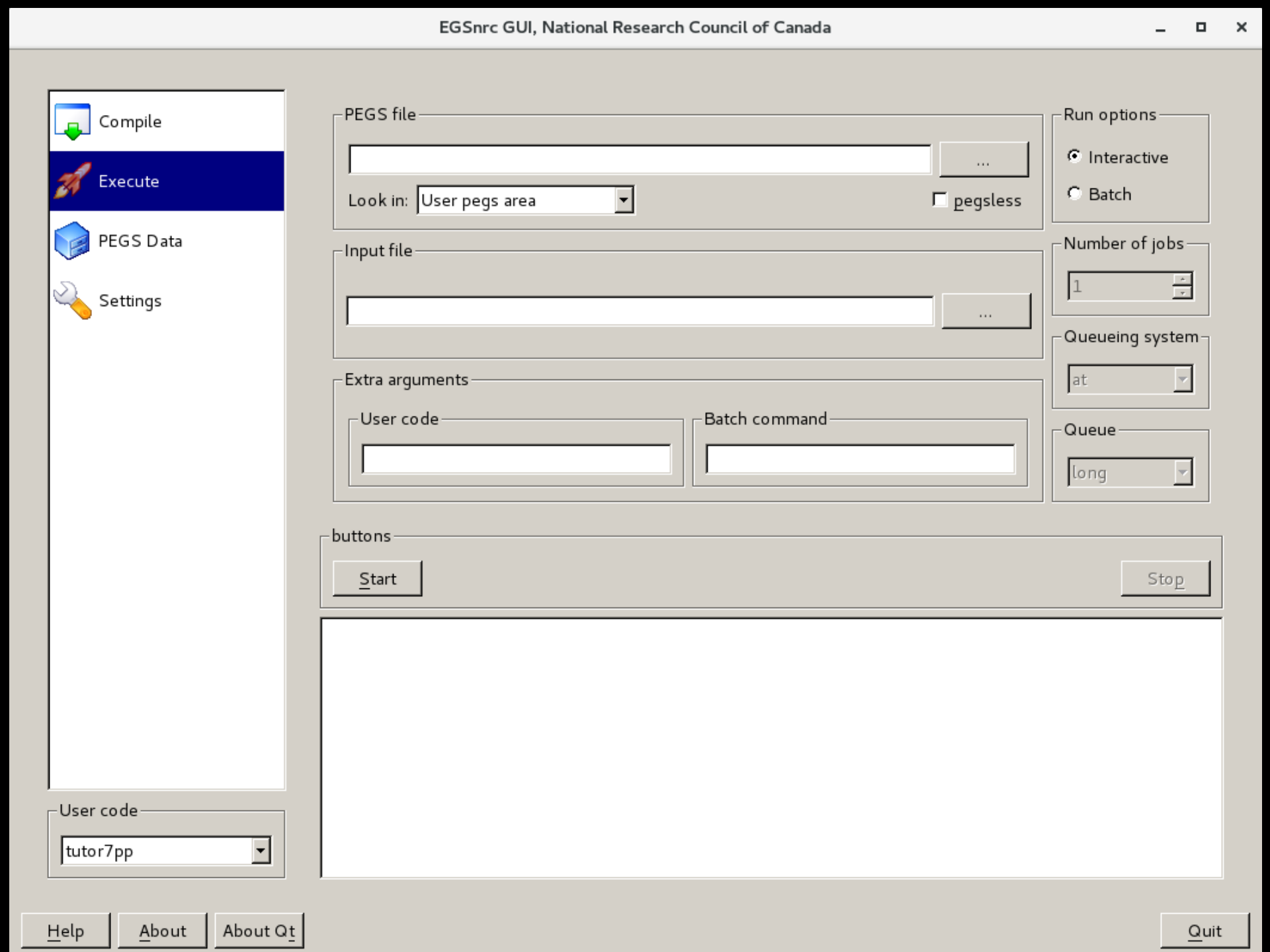
EGSnrc GUI, National Research Council of Canada
Compile
Execute
PEGS Data
Settings
User code
tutor7pp
PEGS file
...
Look in:
User pegs area
pegsless
Input file
...
Extra arguments
User code
Batch command
Run options
Interactive
Batch
Number of jobs
1
Queueing system
at
Queue
long
buttons
Start
Stop
Help
About
About Qt
Quit