HITRIplus
Heavy Ion Therapy Research Integration

Work package 10
Multiple Energy Extraction System

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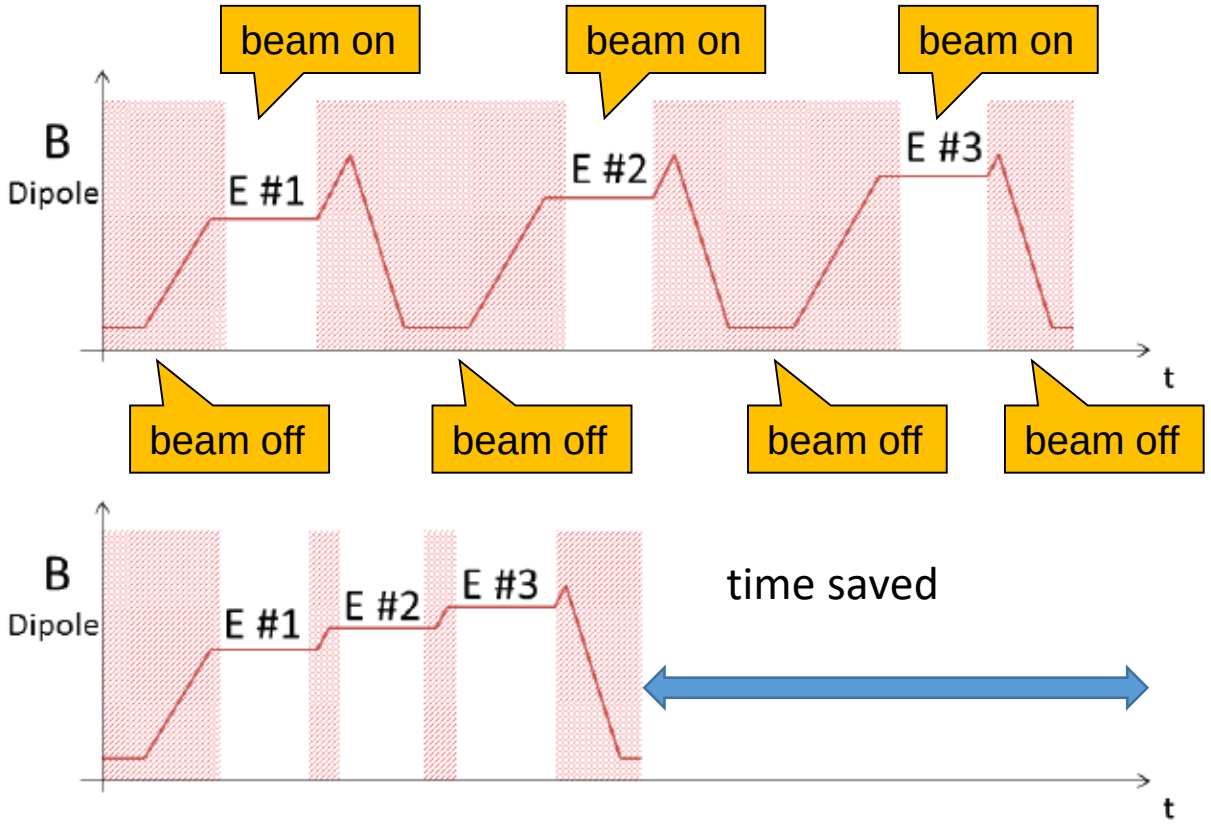
HITRIplus project meeting
Marburg, 23.05.2024

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101008548

WP10
Multiple energy extraction system

- **Motivation**:
  Ion extractions at different energies within one synchrotron cycle
  → shorten treatment times
- **Goal:**
  Development of architectural model for accelerator control system



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Challenges for accelerator control system

- Number and values of beam energy steps not known at the start of the synchrotron cycle → cycle cannot be pre-calculated
- Re-acceleration phase depends on initial and final beam energy
  → Huge number of possible combinations

Solution:

– Calculate control data on the fly!

– Perform calculations on the device controllers to avoid network delays

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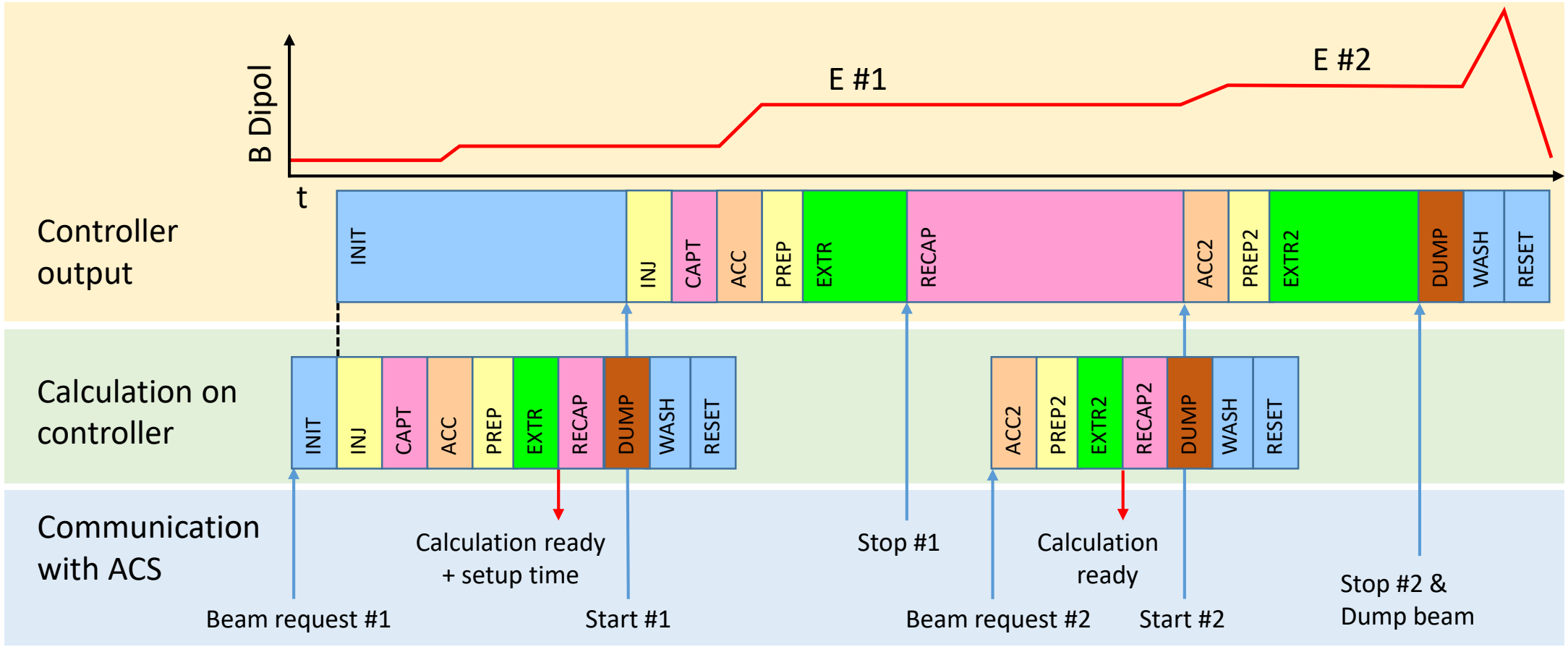
Taks 10.2: Timing requirements



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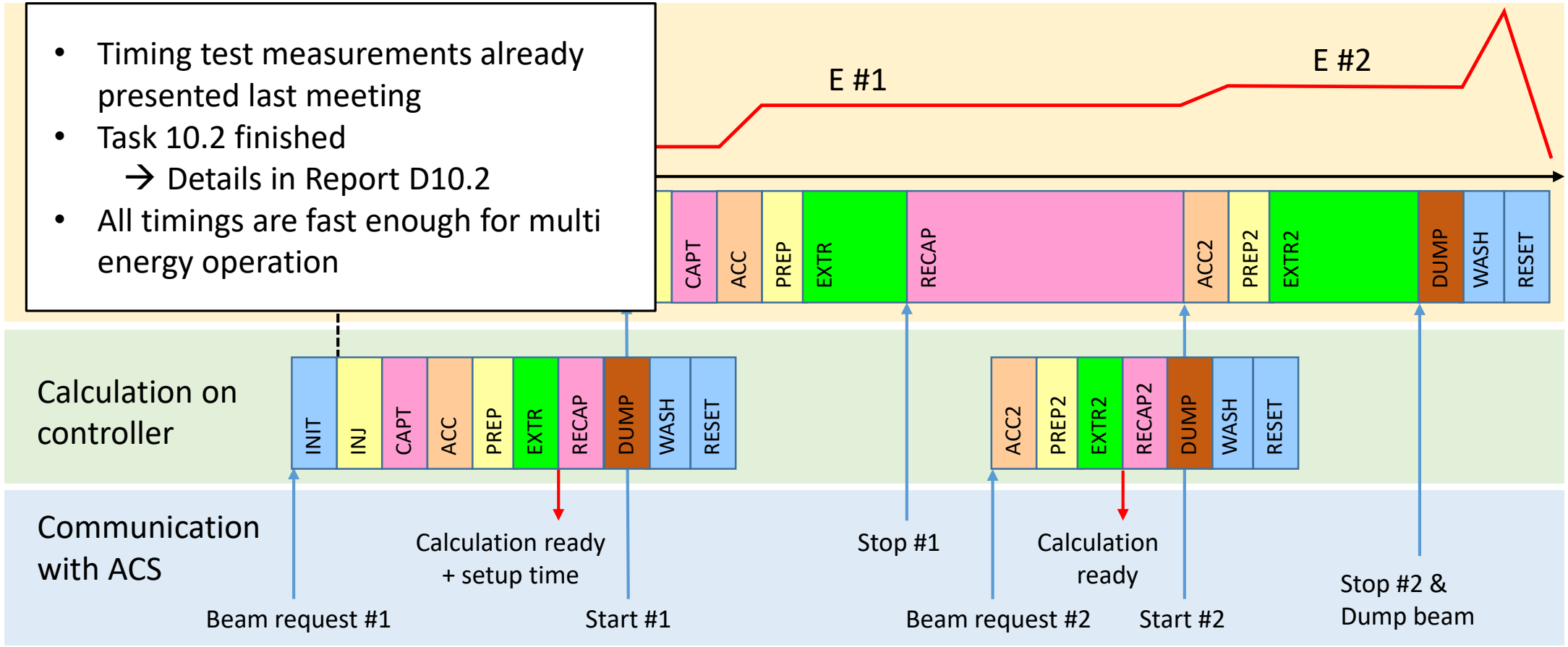
Taks 10.2: Timing requirements

- Timing test measurements already presented last meeting
- Task 10.2 finished
  → Details in Report D10.2
- All timings are fast enough for multi energy operation



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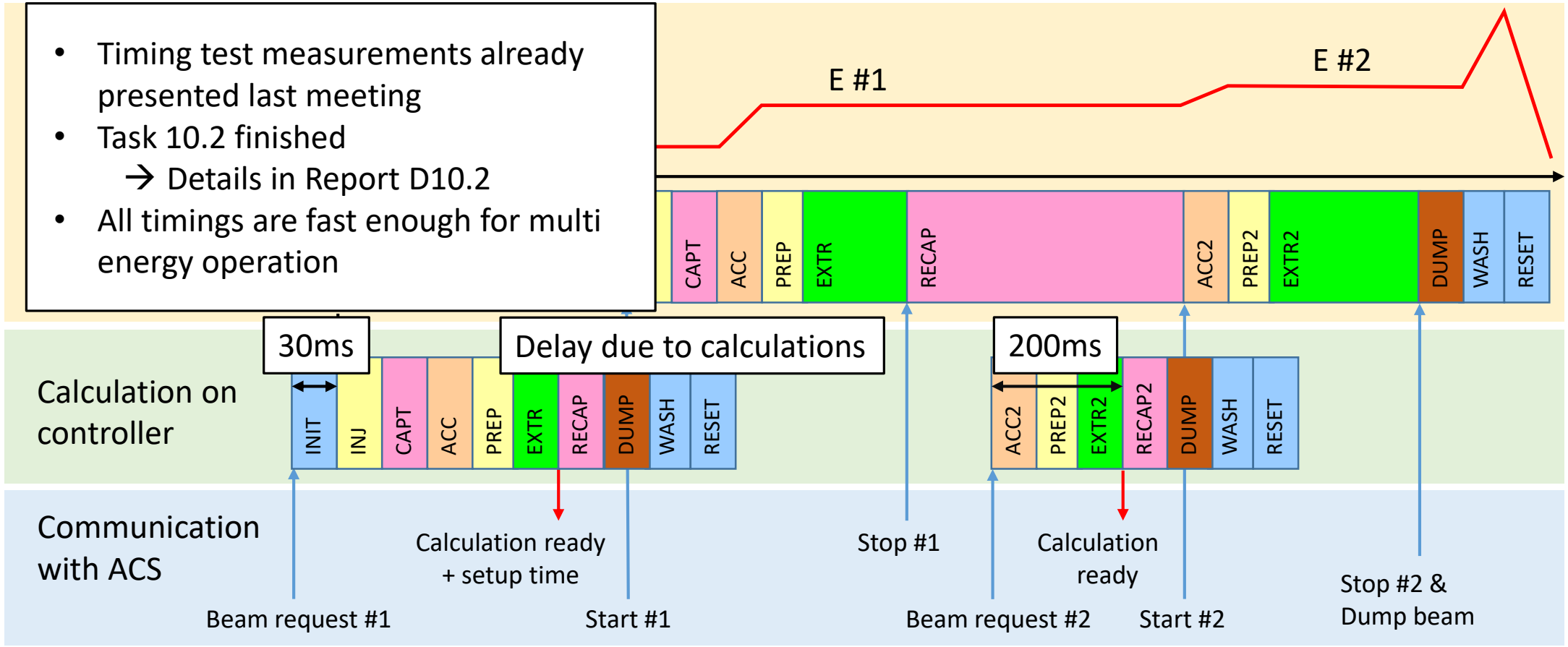

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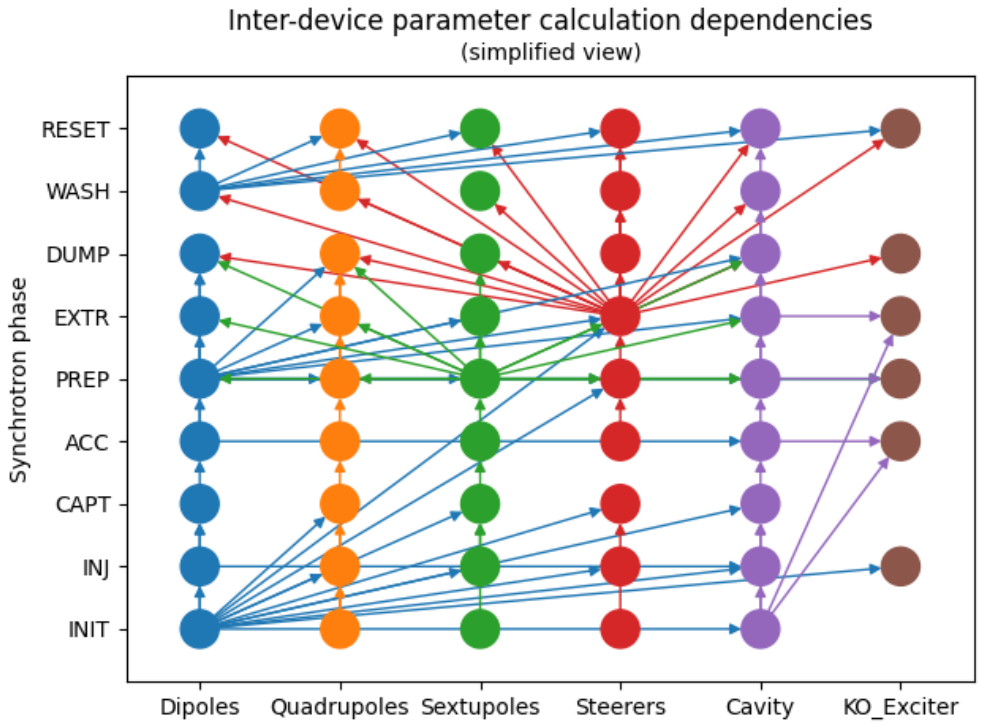
New control data supply module

Last presentation

Calculates data

- For each device
- For each synchrotron phase
- Independent of other devices

→ Dependencies between devices need to be resolved



A → B: Parameters calculated in A needed for B

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Resolve dependencies

Example for quadrupole magnets

Function `Quadrupole_INIT_S0QG1F`:

```
BprimeL_S0QG1F_INJ = KL_S0QG1F_INJ * Brho_INJ;
```

```
I_S0QG1F_INJ = F_I_BprimeL_S0QG1F(abs(BprimeL_S0QG1F_INJ));
```

```
I_S0QG1F_INIT[] =  make_table(
   make_ramp_INIT(I_Park_S0QGxy, I_S0QG1F_INJ),
   Tgrid_INIT, Nphase_INIT );
```

```
dI_S0QG1F_INIT[] = tab_deriv(I_S0QG1F_INIT[]);
{U_S0QG1F_INIT[], DeltaU_S0QG1F_INIT[] } =
   U_of_I_S0QG1F(I_S0QG1F_INIT[], dI_S0QG1F_INIT[]);
```

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Resolve dependencies

Example for quadrupole magnets

calculates

Dependent on

Function Quadrupole_INIT_S0QG1F:

```
BprimeL_S0QG1F_INJ = KL_S0QG1F_INJ * Brho_INJ;

I_S0QG1F_INJ = F_I_BprimeL_S0QG1F(abs(BprimeL_S0QG1F_INJ));

I_S0QG1F_INIT[] =  make_table(
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dI_S0QG1F_INIT[] = tab_deriv(I_S0QG1F_INIT[]);
{U_S0QG1F_INIT[], DeltaU_S0QG1F_INIT[] } =
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```

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Resolve dependencies

Create a table for each function

Function Quadrupole_INIT_S0QG1F	
Calculates	Depends on
BprimeL_S0QG1F_INJ	KL_S0QG1F_INJ
I_S0QG1F_INJ	Brho_INJ
I_S0QG1F_INIT[]	F_I_BprimeL_S0QG1F
dI_S0QG1F_INIT[]	make_ramp_INIT
U_S0QG1F_INIT[]	I_Park_S0QGxy
DeltaU_S0QG1F_INIT[]	Tgrid_INIT
	Nphase_INIT
	U_of_I_S0QG1F

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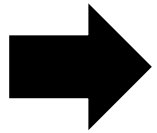
I_S0QG1F_INJ	Brho_INJ
I_S0QG1F_INIT[]	F_I_BprimeL_S0QG1F
dI_S0QG1F_INIT[]	make_ramp_INIT
U_S0QG1F_INIT[]	I_Park_S0QGxy
DeltaU_S0QG1F_INIT[]	Tgrid_INIT
	Nphase_INIT
	U_of_I_S0QG1F



Calculated in function
KL_S0QGxz_INJ
general_calculations
load_parameters
INIT_precalc
load_parameters
calc_Tgrids
INIT_precalc
calc_U_of_I_S0QG1F

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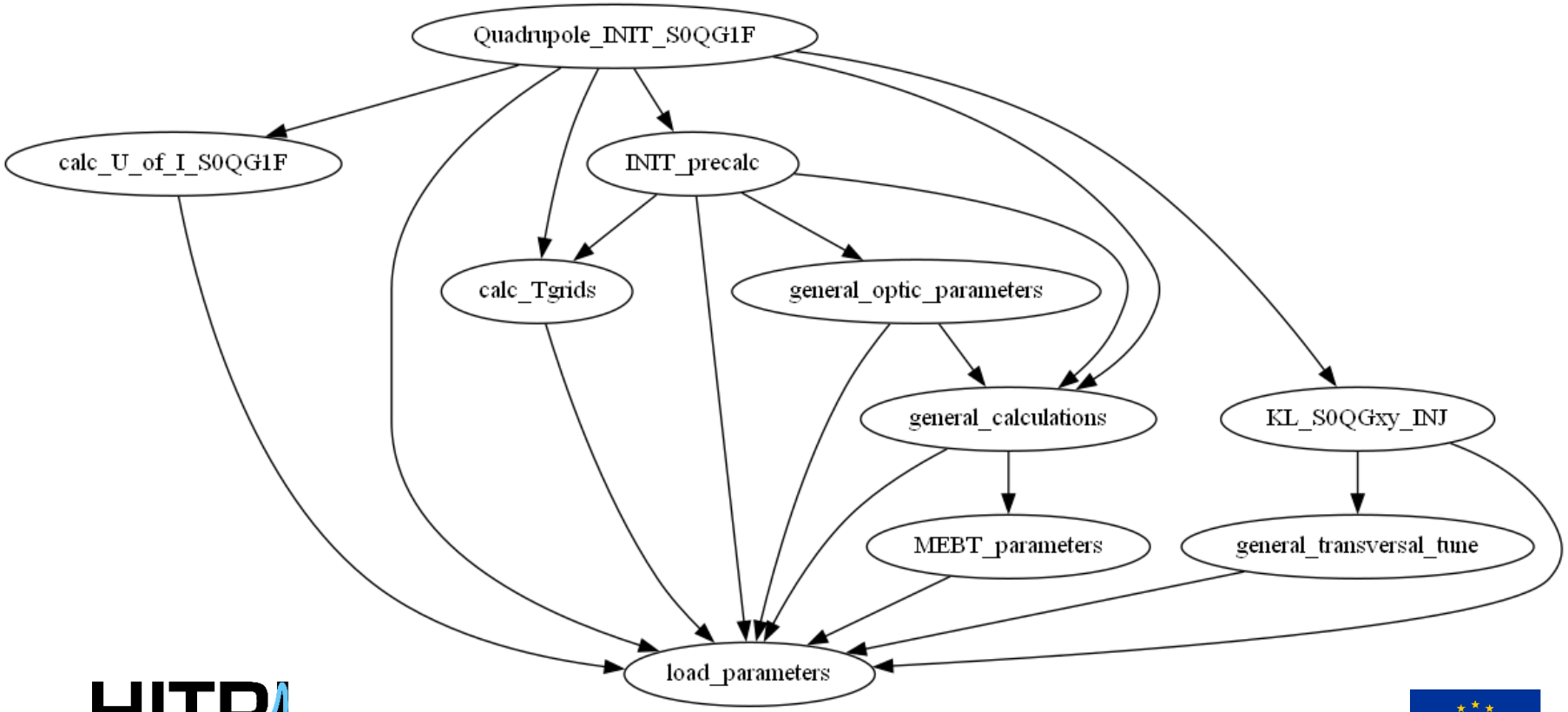
Resolve dependencies

Create dependency graph



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KL_S0QGxz_INJ
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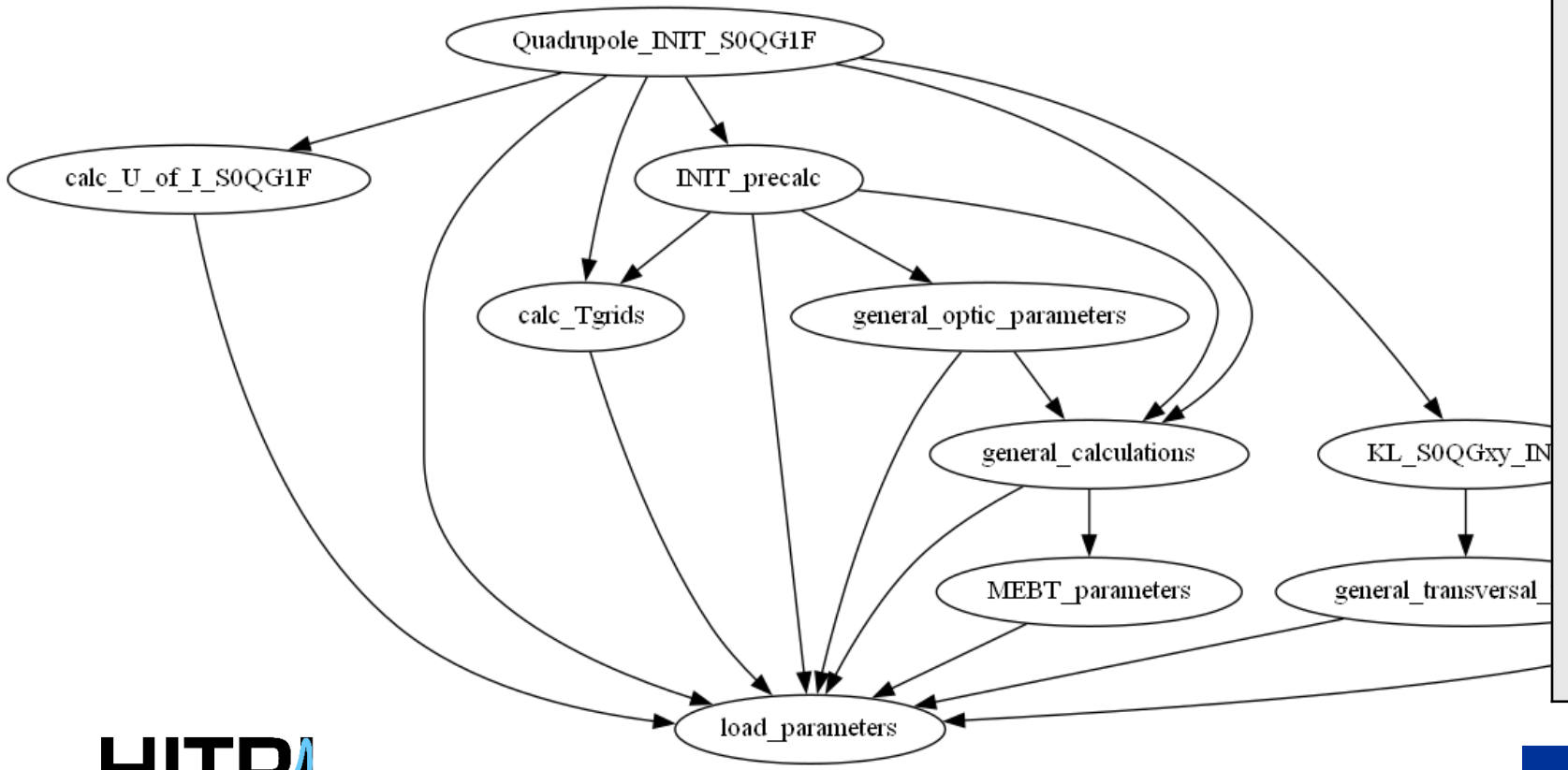
Resolve dependencies

Get calculation order



Order of calculation
1. load_parameters
2. calc_U_of_I_S0QG1F
3. general_transversal_tune
4. KL_S0QGxy_INJ
5. MEBT_parameters
6. general_calculations
7. general_optic_parameters
8. calc_Tgrids
9. INIT_precalc
10. Quadrupole_INIT_S0QG1F

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Automation with Python

Python module written to evaluate dependencies for the whole data supply model

- **Input**: YAML files with function configurations
- Checks if all dependent variables are calculated within the model.
- **Output**: Calculation order

→ Module will be distributed with deliverable 10.3

```yaml
name: Quadrupole_INIT_S0QG1F
dependencies:
  - I_Park_S0QGxy
  - F_I_BprimeL_S0QG1F
  - KL_S0QG1F_INJ
  - Brho_INJ
  - Tgrid_INIT
  - Nphase_INIT
  - U_of_I_S0QG1F
  - FitPrec_nobm_S0QGxy
  - make_ramp_INIT
calculates:
  - I_S0QG1F_INJ
  - SEGPOLY_I_S0QG1F_INIT
  - I_S0QG1F_INIT[]
  - dI_S0QG1F_INIT[]
  - U_S0QG1F_INIT[]
  - DeltaU_S0QG1F_INIT[]
  - SEGPOLY_U_S0QG1F_INIT
  - BprimeL_S0QG1F_INJ
pseudocode: |
  BprimeL_S0QG1F_INJ = KL_S0QG1F_INJ * Brho_INJ;
  I_S0QG1F_INJ = F_I_BprimeL_S0QG1F(abs(BprimeL_S0QG1F_INJ));
  I_S0QG1F_INIT[] =
    make_table(make_ramp_INIT(I_Park_S0QGxy, I_S0QG1F_INJ), Tgrid_INIT, Nphase_INIT);
  dI_S0QG1F_INIT[] = tab_deriv I_S0QG1F_INIT[];
  { U_S0QG1F_INIT[], DeltaU_S0QG1F_INIT[] } =
    U_of_I_S0QG1F(I_S0QG1F_INIT[], dI_S0QG1F_INIT[]);
```

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Conclusion

- Task 10.2 finished
  - Report D10.2 delivered
  - Control data computing speed sufficient for multi-energy operation
- Task 10.3 ongoing:
  - Tool developed to resolve dependencies for single device calculation
  - Applied to HIT data supply module
- Upcoming:
  - Perform calculations on prototype of new HIT device controller
  - Merge all parts into the description of the architectural model
    → Report D10.3

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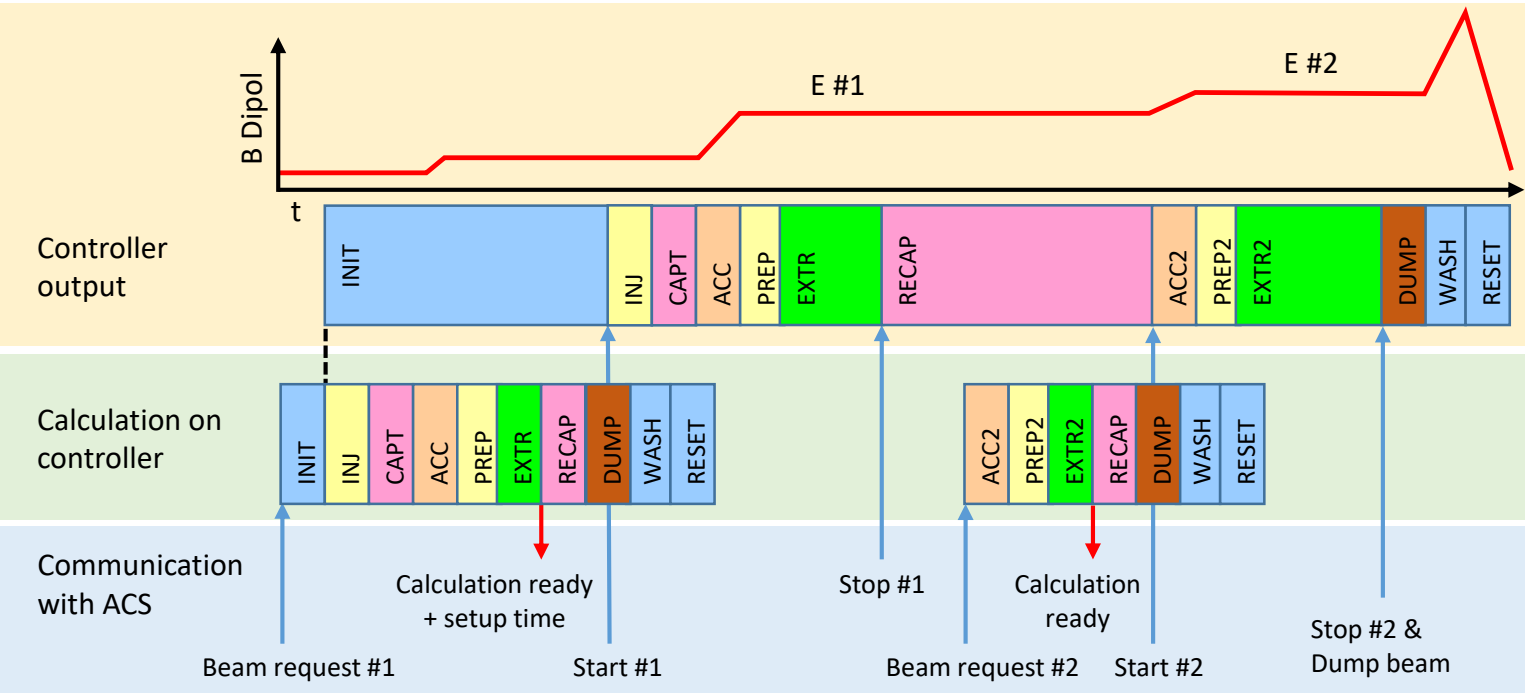
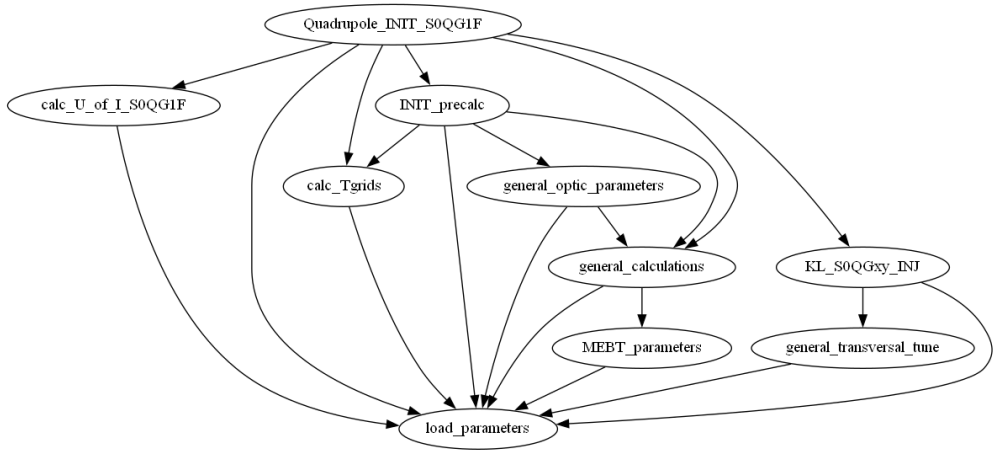
Thank you for your attention!





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