CERN

Reorganization of (HL-)LHC mask

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Based on the work of:

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Outline

- **Introduction**
  - Online resources
- **How to setup a simulation**
  - The structure of the main configuration file
- **Organization of the code**
  - Overview of the modules
- **Documentation of external interfaces**
- **How to contribute to the mask**
- **Repository for the beam-beam macros**

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Introduction

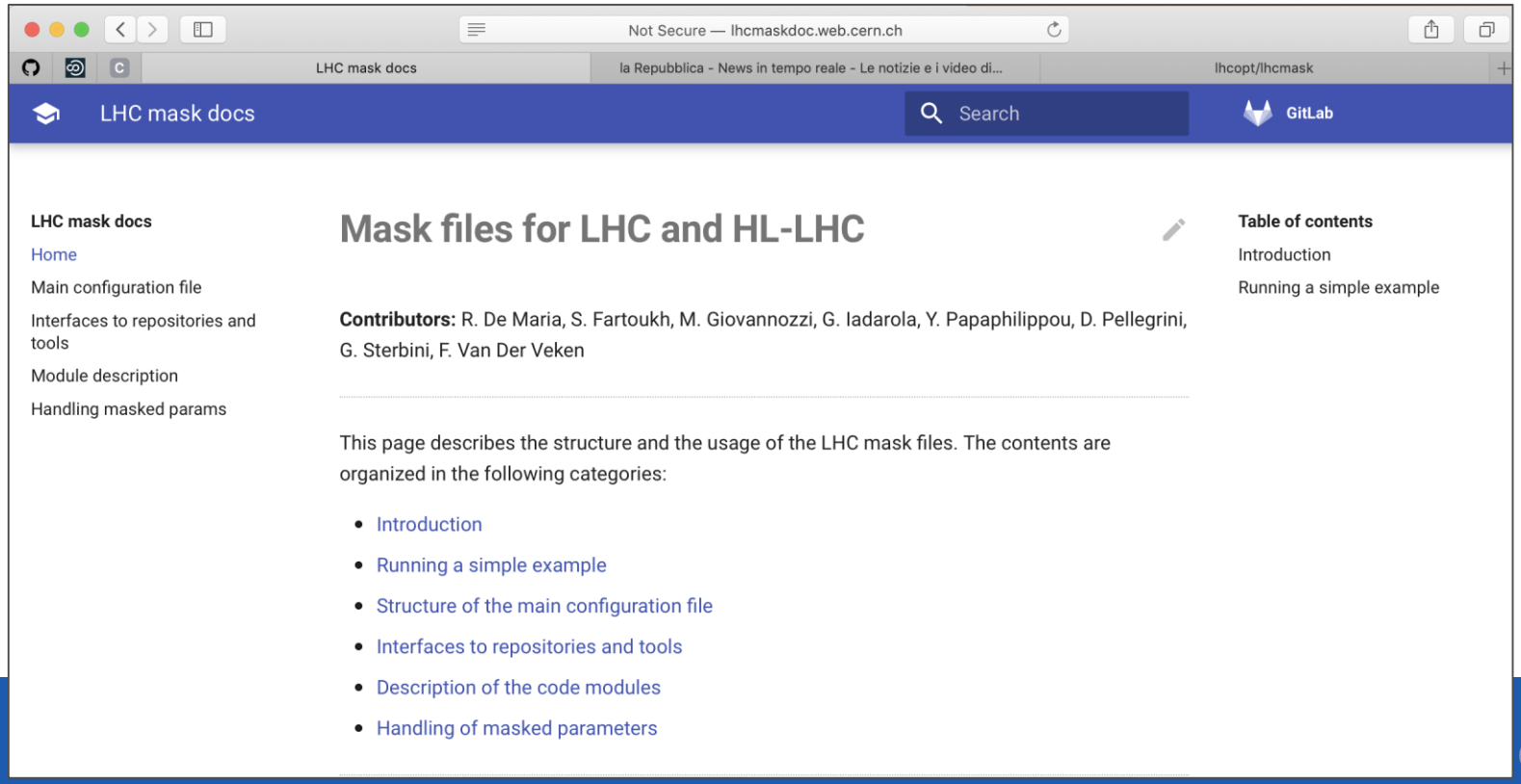
We tried to address a series of shortcomings of the present mask:

- **No central repository**, proliferation of “quasi-copies”
  - Difficult to propagate fixes of known bugs
- **Lack of documentation**
- **Monolithic structure**
  - Different **functionalities are entangled** (difficult to identify a maintainter)
  - **Interleaved settings and code**
  - **Difficult to separate general functionalities from optics-dependent** or configuration-dependent parts (LHC vs HL-LHC, injection/collision)
- **Not well-defined interface with optics** (which knobs are used).
  - Nested dependencies through macros (in madx everything is global)
- Several absolute links to different **AFS locations**

→ **Error-prone and difficult to use, develop and maintain**

Reorganized (HL-)LHC mask file

- We prepared a **reorganized version** of the LHC mask file
  - No change in the physics behavior w.r.t. a legacy reference mask (HL1.4)
  - It is **hosted** and **tracked** on **github** at: https://github.com/lhcopt/lhcmask/
  - It is **available on AFS** at: /afs/cern.ch/eng/lhc/optics/simulation_tools/modules
- **Documentation** is available at: https://cern.ch/lhcmask



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How to setup a simulation

The user edits and runs a **main configuration script** (main.mask) which contains only:

- **Parameters** settings
- **Links** to folders or files (optics, errors, mask, modules)
- **Calls** to madx input files, mostly from centralized repositories

main.mask - machine and beam parameters

All in one place:

```
par_mylhcbeam = 1;

! Beam parameters
par_beam_norm_emit = 2.5E-6; ! [m]
par_beam_sigt = 0.075;       ! [m]
par_beam_sige = 1.1e-4;      ! [-]
par_beam_npart = 1.2E11;     ! [-]
par_beam_energy_tot = 7000;  ! [GeV]

! Settings
par_oct_current = 300;       ! [A]
par_chromaticity = 15;       ! [-] This is the Q'
par_vrf_total = 16.;         ! [MV]

! Integer tunes and tune split
par_qx00 = 62.0;
par_qy00 = 60.0;
par_tsplit = 2.0;

! Tunes with fractional part
par_qx0 = 62.31;
par_qy0 = 60.32;
```

```
!IP specific orbit settings
par_xing_ang_ip15 = 245;         ! [urad]
par_on_x1 = par_xing_ang_ip15;   ! [urad]
par_on_sep1 = -0.75;             ! [mm]
par_on_x5 = par_xing_ang_ip15;   ! [urad]
par_on_sep5 = 0.75;              ! [mm]
par_on_x2 = 170;                 ! [urad]
par_on_sep2 = 1;                 ! [mm]
par_on_x8 = -200;                ! [urad]
par_on_sep8 = -1;                ! [mm]
par_on_a1 = 0;                   ! [urad]
par_on_o1 = 0;                   ! [mm]
par_on_a5 = 0;                   ! [urad]
par_on_o5 = 0;                   ! [mm]
par_on_a2 = 0;                   ! [urad]
par_on_o2 = 0;                   ! [mm]
par_on_a8 = 0;                   ! [urad]
par_on_o8 = 0;                   ! [mm]
par_on_crab1 = -190;             ! [urad]
par_on_crab5 = -190;             ! [urad]
```

```
! Dispersion correction knob
par_on_disp = 1;

! Second order chromaticity
! Correction of residual Q'' by MO's
par_on_qpp =0;
```

```
! Magnets of the experiments
par_on_alice = 7000/par_beam_energy_tot;
par_on_lhcb = 7000/par_beam_energy_tot;

par_on_sol_atlas = 0;
par_on_sol_cms = 0;
par_on_sol_alice = 0;
```

main.mask – beam-beam

```
!*************************!
! Beam-beam configuration !
!*************************!

! If 1 lumi leveling in IP8 is applied
! and q/q' match is done with bb off
par_on_collision = 1;
par_on_bb_switch = 1;

par_b_t_dist = 25.; ! bunch separation [ns]

par_n_inside_D1 = 5;! default # of BBLR in D1

par_nho_IR1 = 11;   ! # of slices for HO in IR1
par_nho_IR2 = 11;   ! # of slices for HO in IR2
par_nho_IR5 = 11;   ! # of slices for HO in IR5
par_nho_IR8 = 11;   ! # of slices for HO in IR8

par_install_crabcavities=1;
```

main.mask - leveling in ip8

```
!*************************!
!     Leveling in IP8     !
!*************************!

! This variables set the leveled luminosity
!in IP8 (considered if par_on_collision=1)
par_lumi_ip8 = 2e33;   ![Hz/cm2]

! These variables define the number of HO
! collisions in the 4 IPs
par_nco_IP1 = 2592;
par_nco_IP5 = par_nco_IP1;
par_nco_IP2 = 2288;
par_nco_IP8 = 2396;
```

main.mask - errors and corrections

```
!*************************!
!  Errors and corrections !
!*************************!

! Select seed for errors
par_myseed = %SEEDRAN;

! Set this flag to correct the errors of D2
! in the NLC
par_correct_for_D2 = 0;

! Set this flag to correct the errors of MCBXF
! in the NLC
par_correct_for_MCBX = 0;

par_on_errors_LHC = 1;
par_on_errors_MBH = 1;
par_on_errors_Q5 = 1;
par_on_errors_Q4 = 1;
par_on_errors_D2 = 1;
par_on_errors_D1 = 1;
par_on_errors_IT = 1;
par_on_errors_MCBRD = 1;
par_on_errors_MCBXF = 1;
```

main.mask - select sources

```
!*************************!
!   Prepare environment   !
!*************************!

system, "ln -fns /afs/cern.ch/eng/lhc/optics/simulation_tools simulation_tools";

! Mask code folder
system, "ln -fns simulation_tools/modules modules";

! Machine folder
system, "ln -fns simulation_tools/machines machines";

! Toolkit folder
system, "ln -fns simulation_tools/tools tools";

! Beam-beam macros folder
system, "ln -fns simulation_tools/beambeam_macros beambeam_macros";

! Errors folder
system, "ln -fns simulation_tools/errors errors";
```

main.mask – select sequence and optics

```
! Choose build-sequence script
system, "ln -fns machines/sequences/hl14_thin.madx   make_sequence.madx";

! Choose optics (magnet strengths)
system, "ln -fns /afs/cern.ch/eng/lhc/optics/HLLHCV1.4/round/\
                                        opt_round_150_1500_thin.madx optics.madx";
```

The **make_sequence script** (optionally user-defined):

- Should **define the sequences** complete of all their elements (including place-holders for the sequence)
- Can perform a **slicing** (makethin) and installation of additional elements (e.g. wire)
- Should **cycle the machine** to start from IP3
- Defines **links to the optics repository toolkit** and calls the corresponding macro.madx file

Predefined machine **scripts for common simulation scenarios** are available:

- In AFS at /afs/cern.ch/eng/lhc/optics/simulation_tools/machines
- On githib at https://github.com/lhcopt/lhcmachines

main.mask - run!

The actual **execution** consist in just a set of calls:

```
! Build machine and optics
call, file="make_sequence.madx";
call, file="optics.madx";

! Call mask modules
call, file="modules/module_01_set_orbit.madx";
call, file="modules/module_02_lumilevel.madx";
call, file="modules/module_03_beambeam.madx";
call, file="modules/module_04_install_and_correct_errors.madx";
call, file="modules/module_05_machine_tuning.madx";
call, file="modules/module_06_make_sixtrack_input.madx";
call, file="modules/module_07_last_twiss.madx";

stop;
```

The modules part consists of general functionalities, which **aim at being independent from optics and machine configuration**

→ in most cases they **can be used directly from the repository** without modifications

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What are the modules doing?

The **modules are documented** at **http://lhcmaskdoc.web.cern.ch/modules/**

module_01_set_orbit.madx (main expertise: HSS)

- Defines the madx beams
- Performs a twiss for the sequences as loaded by the make_sequence script
- Applies the user-defined orbit knobs (crossing, separations, experimental magnets) and twiss again
- Save the orbit knobs
- Performs a twiss with flat orbit
- Performs a twiss with the user-defined orbit

What are the modules doing?

The **modules are documented** at **http://lhcmaskdoc.web.cern.ch/modules/**

module_02_lumilevel.madx (main expertise: HSI)

- Separates IP8 (in the horizontal plane) to achieve the target luminosity.
- Run the final crossing_save (overwrites save state of IP knobs)

module_03_beambeam.madx (main expertise: HSI)

- Forces on_disp=0
- Configures and installs the beam-beam lenses
- Generates bb_lenses.dat (to be replaced in the sixtrack input)
- Installs the the crab cavities (if enabled)
- NB: the beam-beam kicks are kept disabled (can be enabled by setting on_bb_charge = 1)

What are the modules doing?

The **modules are documented** at **http://lhcmaskdoc.web.cern.ch/modules/**

module_04_install_and_correct_errors.madx (main expertise: HSS)

- Loads the error tables and applies field-imperfections
- Introduces misalignments
- Applies corrections

module_05_machine_tuning.madx (main expertise: HSS)

- Restores the crossing knobs as saved by module_01_set_orbit or module_02_lumilevel (using crossing_save)
- Power the octupoles as defined by the user
- Matches orbit, tunes and chromaticity
- Corrects the linear coupling
- Clips corrector strengths to maximum allowed
- Switches on the beam-beam lenses (on_bb_charge = 1)
- Introduces RF voltage and lags.

What are the modules doing?

The **modules are documented** at **http://lhcmaskdoc.web.cern.ch/modules/**

module_06_make_sixtrack_input.madx (main expertise: HSS-HSI)

- Produces sixtrack input (call sixtrack command of madx)
- If beam-beam is enabled, inserts data or beam-beam lenses from bb_lenses.dat into fc.3

module_07_last_twiss.madx (main expertise: HSS-HSI)

- Performs a twiss on the last machine configuration.

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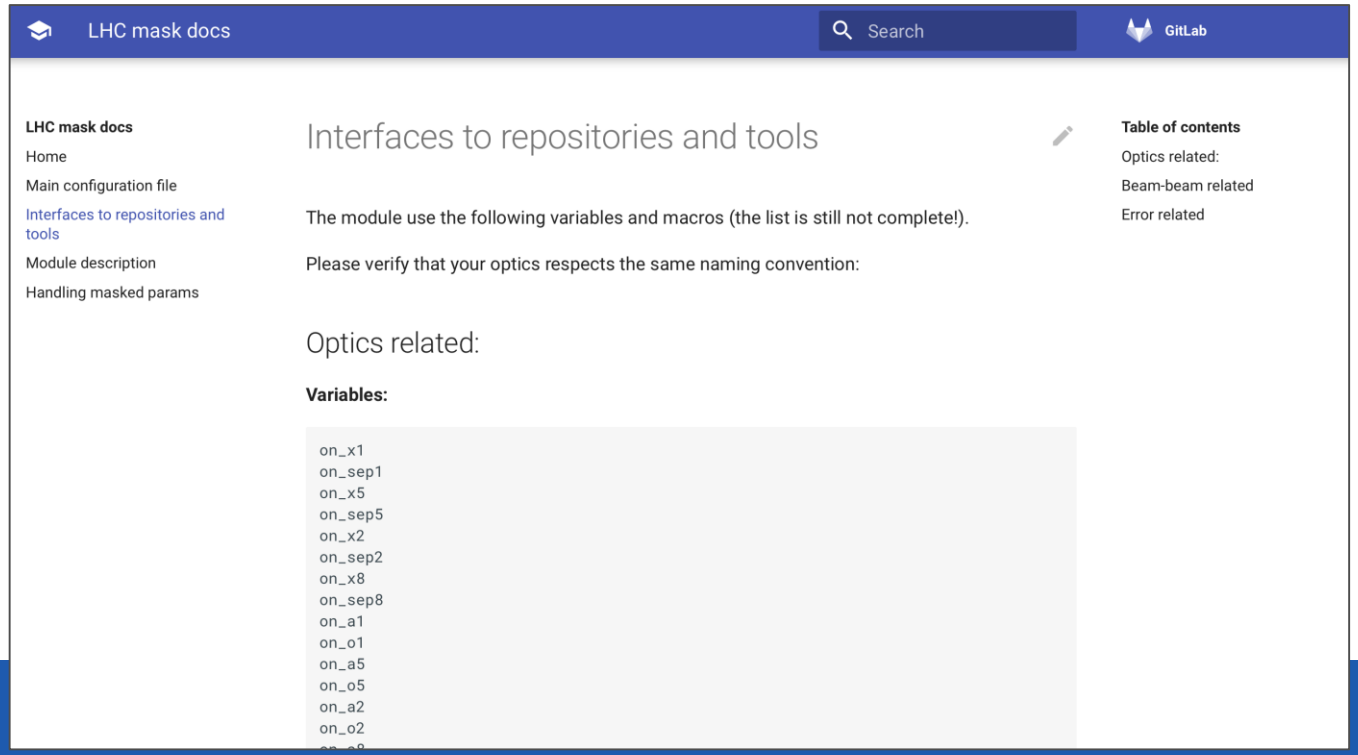
Documentation of external interfaces

- The mask relies on **naming** (and **unit**) **conventions** to interact with the optics and toolkits.
- We started identifying the **status of the present interface** by populating a webpage: http://lhcmaskdoc.web.cern.ch/interfaces/
- In the future we should aim at **standardizing this nomenclature** as much as possible



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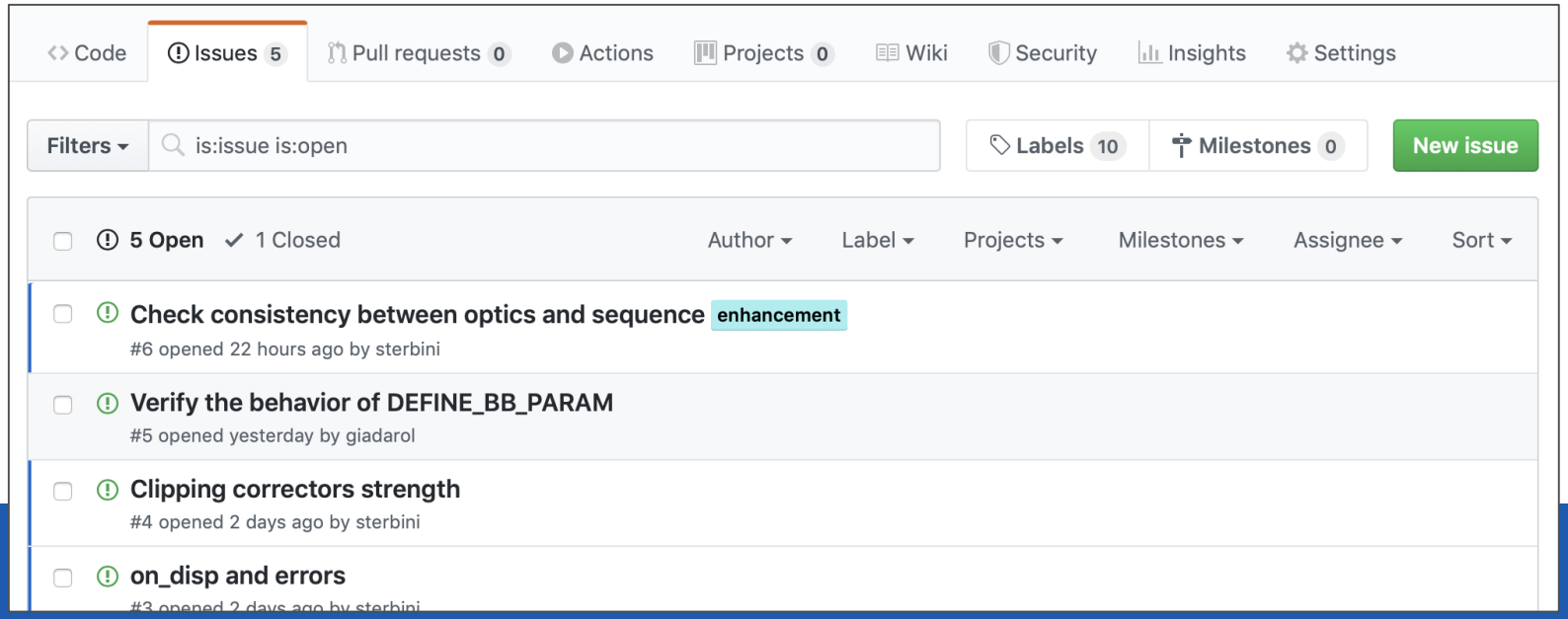
Contributing to the mask

- We will keep an **updated version** of the masks in **AFS** and on **github**
  - We are using github to track issues (bugs, proposals, questions)
- You are very **welcome to contribute** with fixes, improvements, new features, documentation, examples.
  - It's **very important to merge into the main version** new features that are of general interest to avoid proliferation of branches:
    - The preferred way is to use github (fork/pull-request)
    - If you don't use github, just ask one of the maintainers for the merge



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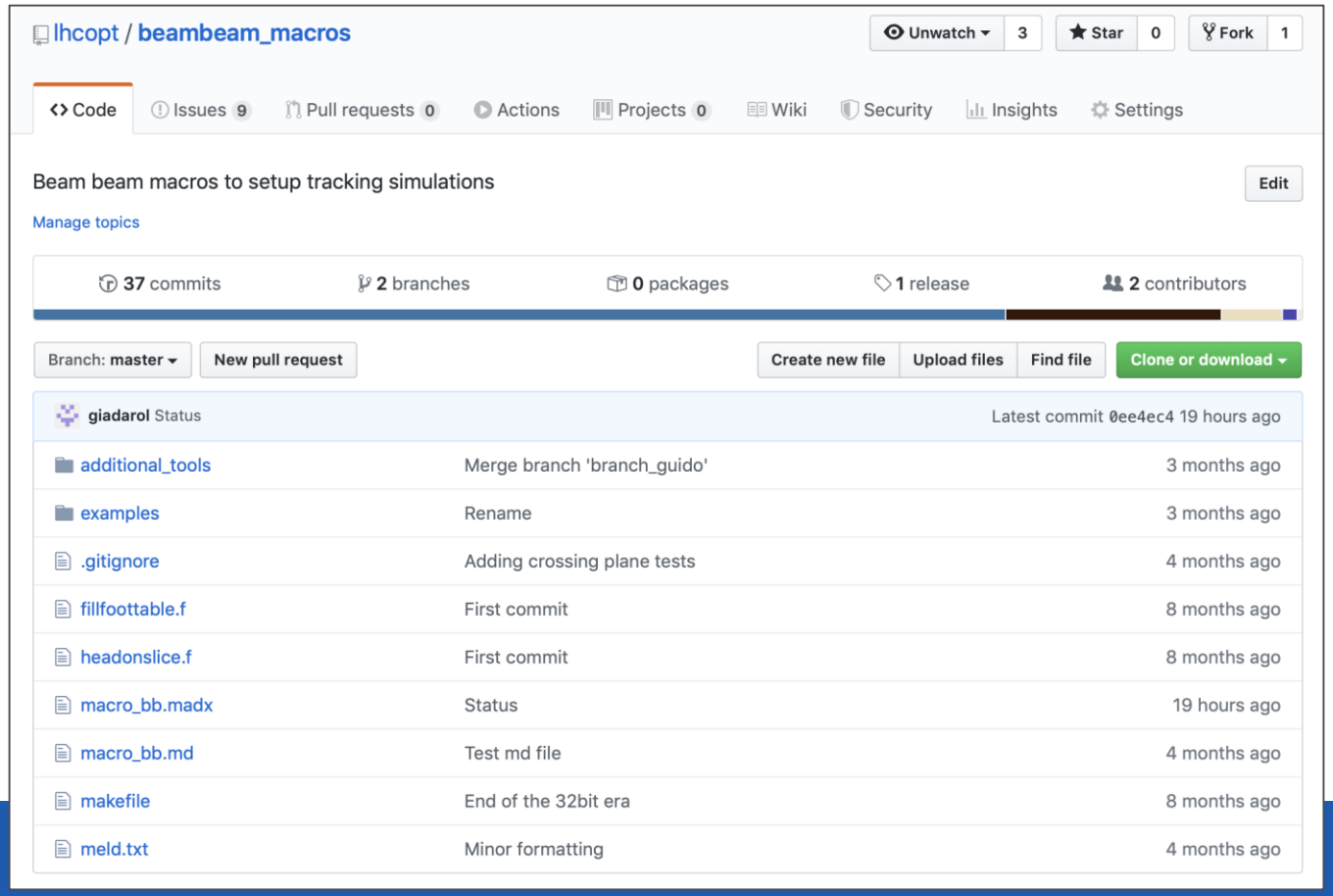
Beam beam macros

- The **beam-beam macros** are hosted and tracked on a dedicated **github** repository: https://github.com/lhcopt/beambeam_macros
- Same development approach → contributions are welcome!



Summary

- We reorganized the (HL-)LHC mask file
- Main features:
  - Separated input from code
  - Code divided in functional modules
  - Isolate as much as possible general code from optics-dependent parts
- The modules are hosted online and on AFS
  - Examples are provided
- A documentation website has been built (please contribute to enrich it!)
- Please try it out
  - Caveat: never use it as a black box, sanity checks are important!
- Please contribute with feedback and improvements (that you might already have)!

Thanks for you attention!

Spare: handling masked parameters

For large scans some of the parameters in the main.mask ion script can be replaced by symbols that will be set by sixdesk

```
! Beam parameters
par_beam_norm_emit = %EMIT_BEAM;      ! [m]
par_beam_sigt = 0.075;                ! [m]
par_beam_sige = 1.1e-4;               ! [-]
par_beam_npart = %NPART;              ! [-]
par_beam_energy_tot = 7000;           ! [GeV]

! Settings
par_oct_current = %OCT%;              ! [A]
par_chromaticity = %CHROM%;           ! [-] This is the Q'
par_vrf_total = 16.;                  ! [MV]
```

An input containing masked parameters cannot be executed directly with madx

We made a little tool to quickly unmask (and optionally run your script)

```
python unmask.py main.mask parameters_for_unmask.txt
madx main.mask.unmasked
```

Spare: an example of build-sequence

```
! Specify machine version (used by errors)
ver_lhc_run = 0; ver_hllhc_optics = 1.4;

! Get the toolkit
call, file="/afs/cern.ch/eng/lhc/optics/HLLHCV1.4/toolkit/macro.madx";

! Build sequence
if (mylhcbeam==4){
  call,file="/afs/cern.ch/eng/lhc/optics/runIII/lhcb4.seq";
} else {
  call,file="/afs/cern.ch/eng/lhc/optics/runIII/lhc.seq";};

!Install HL-LHC
call, file="/afs/cern.ch/eng/lhc/optics/HLLHCV1.4/hllhc_sequence.madx";

! Slice nominal sequence
exec, myslice;

! Install placeholder elements for errors (set to zero)
call, file="errors/HL-LHC/install_MQXF_fringenl.madx";
call, file="errors/HL-LHC/install_MCBXFAB_errors.madx";
call, file="errors/HL-LHC/install_MCBRD_errors.madx";

!Cycling w.r.t. to IP3
if (mylhcbeam<3){
seqedit, sequence=lhcb1; flatten; cycle, start=IP3; flatten; endedit;}
seqedit, sequence=lhcb2; flatten; cycle, start=IP3; flatten; endedit;
```