CheckMATE

Current Status

(Re)interpreting the results of new physics searches at the LHC
CERN
15/05/2018

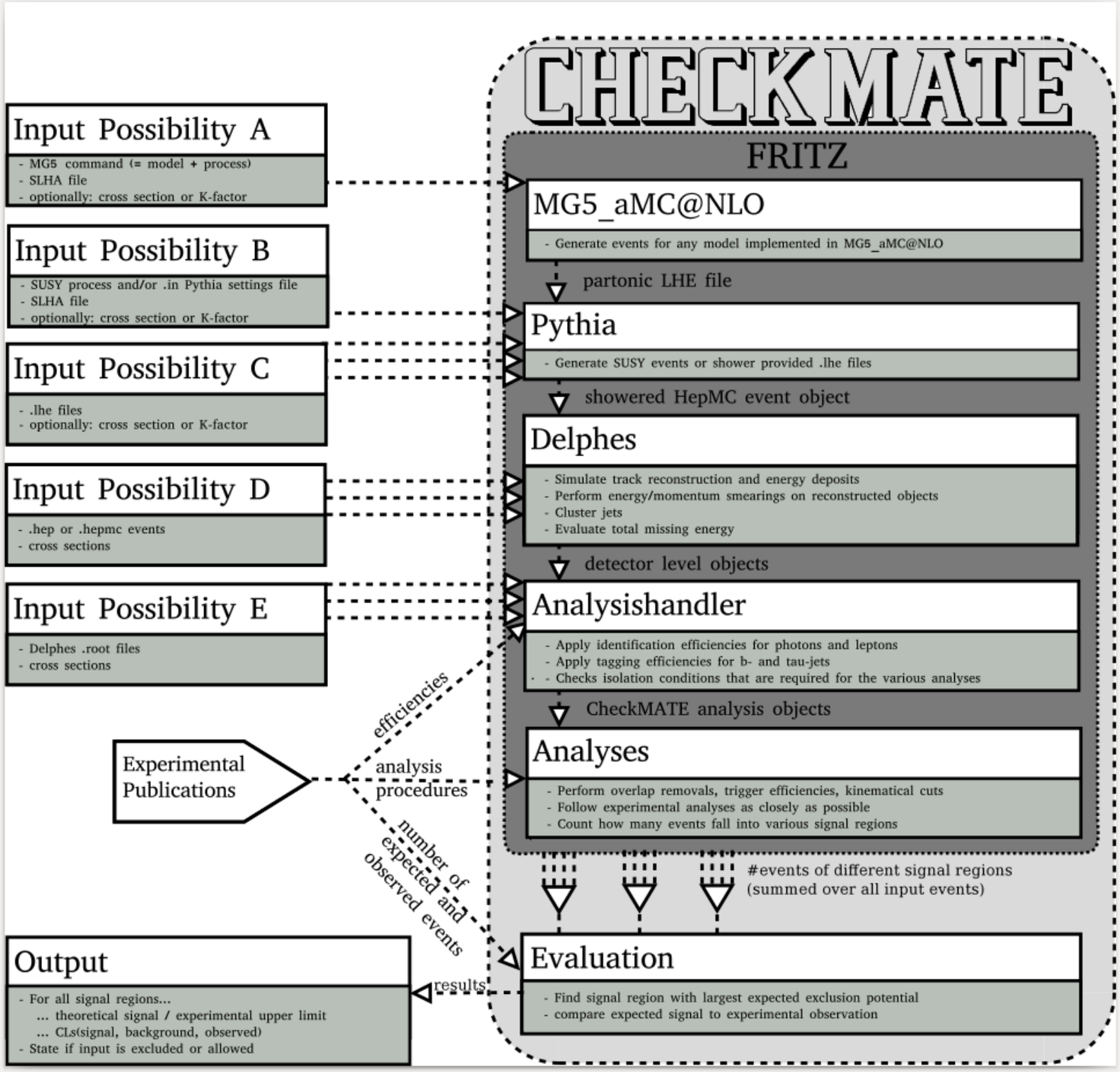
Jong Soo Kim

University of the Witwatersrand, South Africa

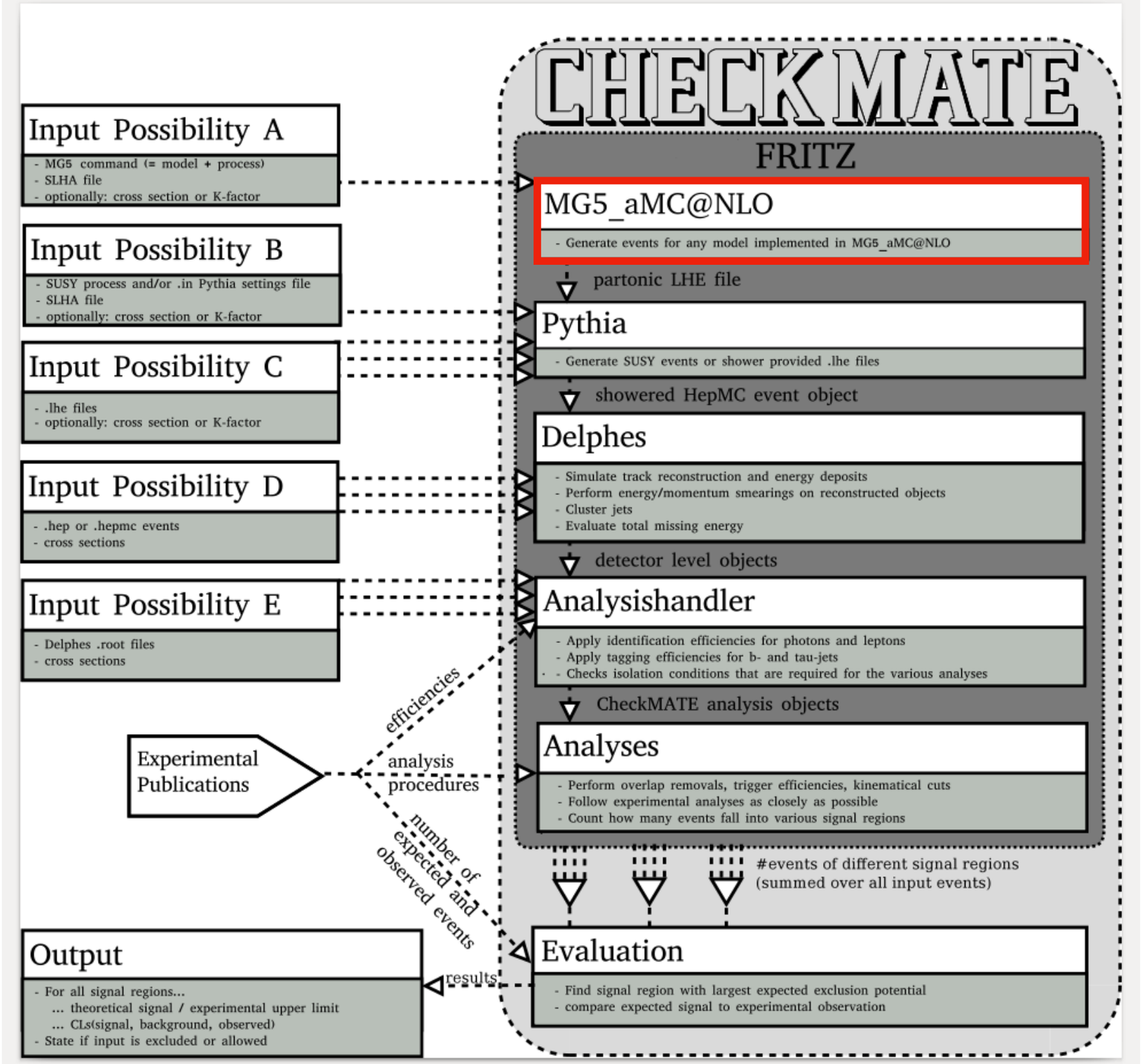
CM Collaboration

- Daniel Dercks (Hamburg University)
- Nishita Desai (University of Montpellier)
- Florian Domingo (IFT-CSIC, Madrid)
- Lukas Heinrich (New York University)
- Sung Hak Lim (KEK)
- Krzysztof Rolbiecki (University of Warsaw)
- Roberto Ruiz de Austri (IFIC, Valencia)
- Liangliang Shang (Henan Normal University, Xinxiang)
- Torsten Weber (RWTH Aachen)
- Yuanfang Yue (Henan Normal University, Xinxiang)

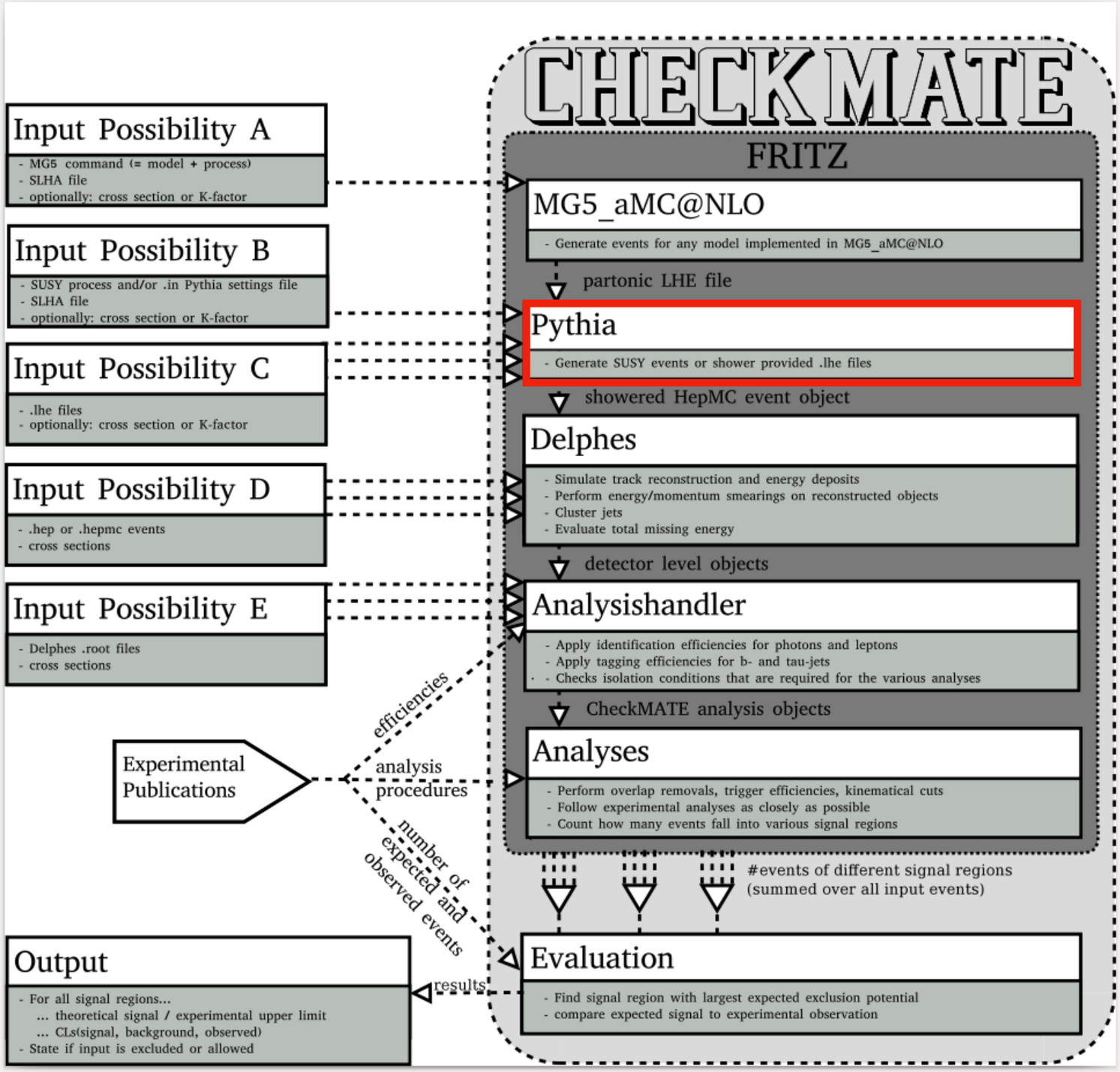
CM Structure



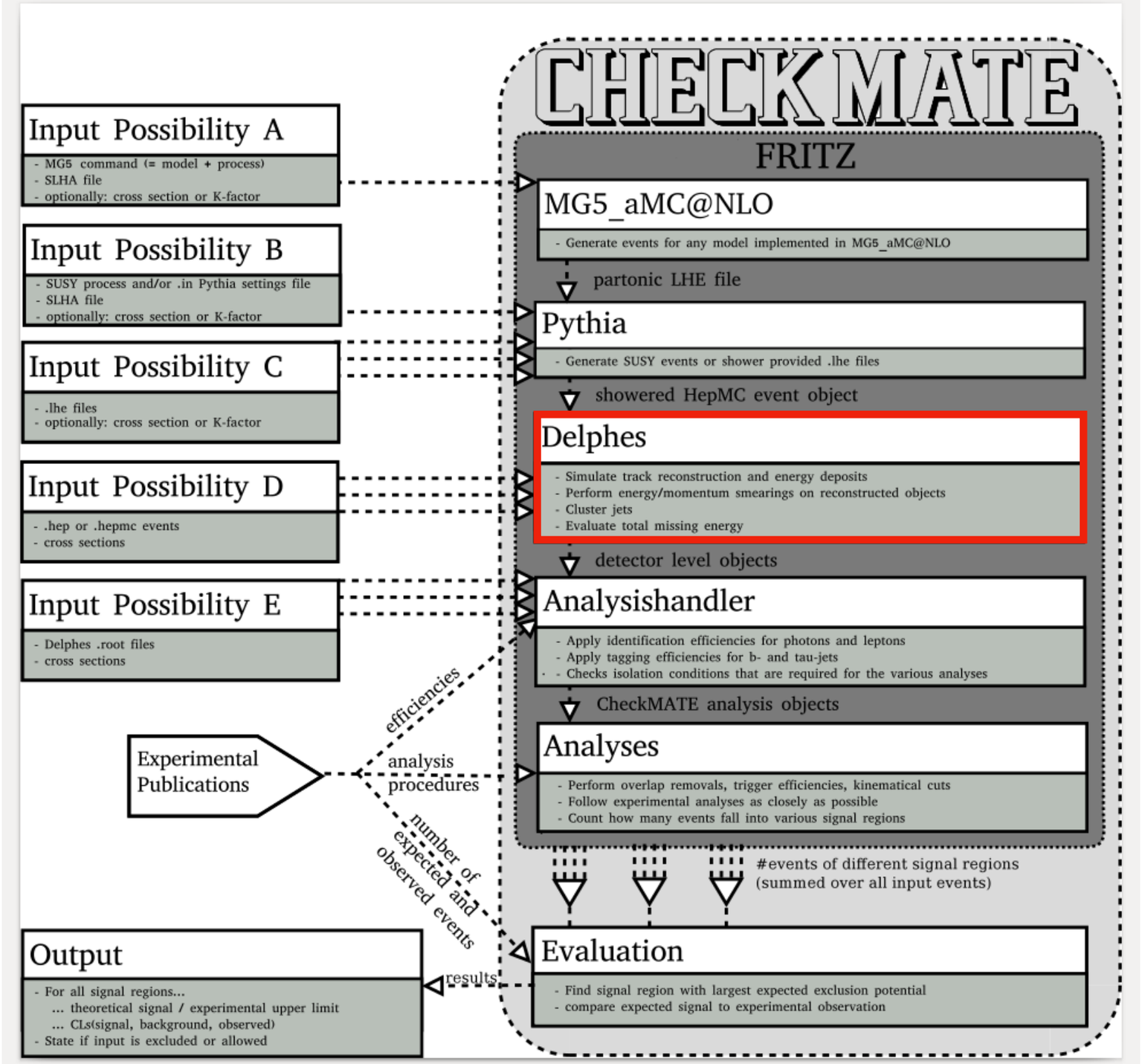
CM Structure



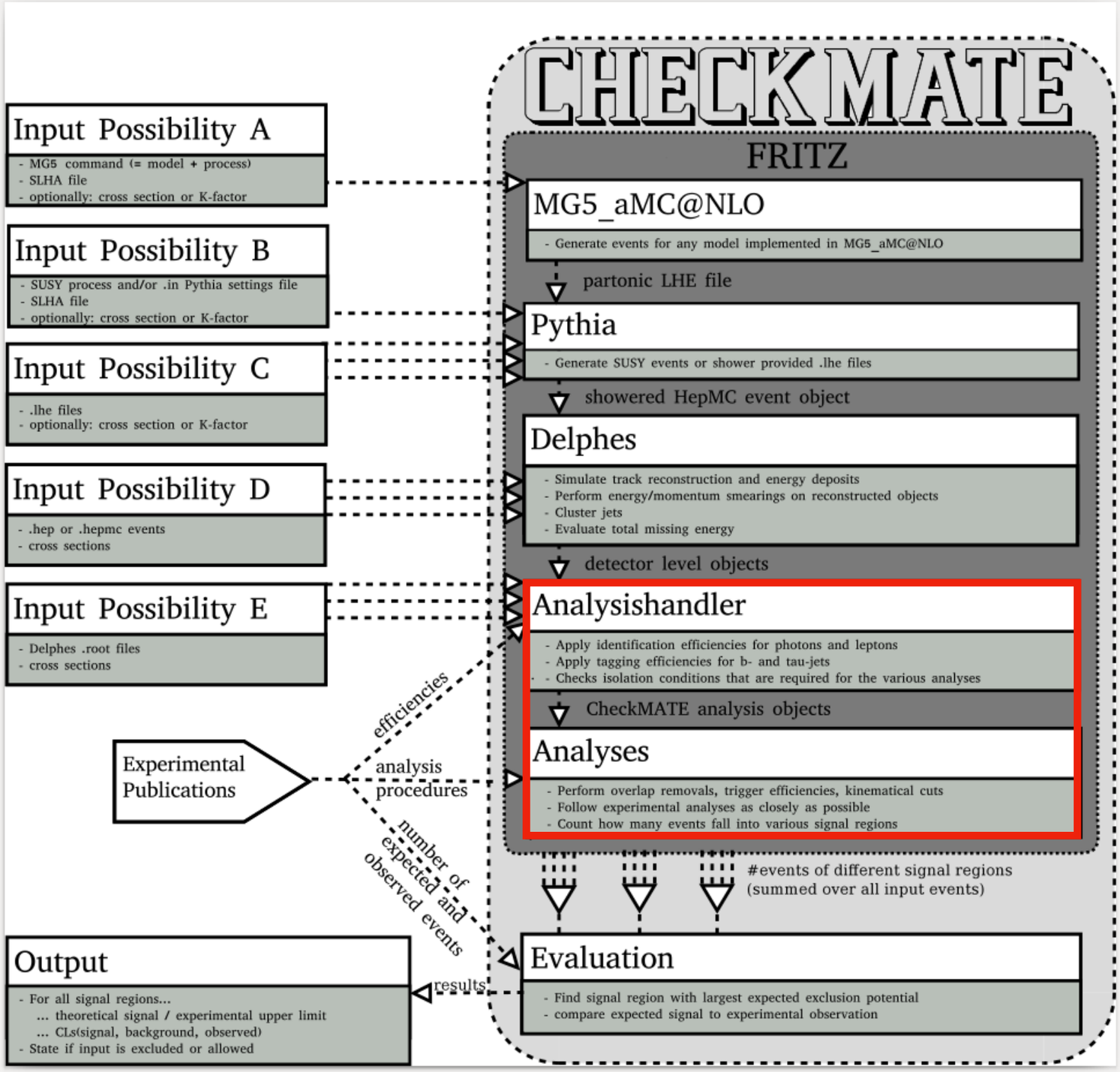
CM Structure



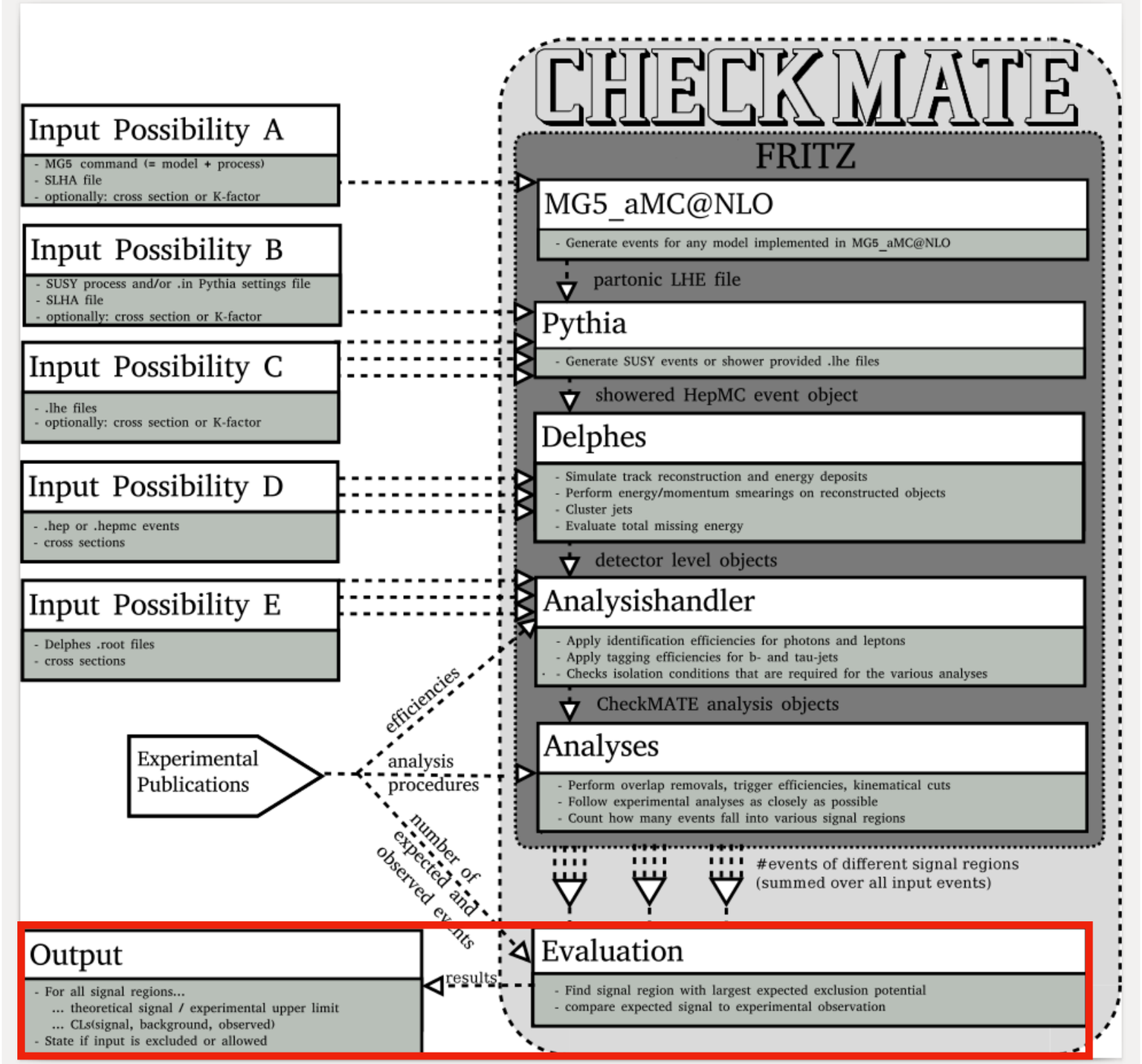
CM Structure



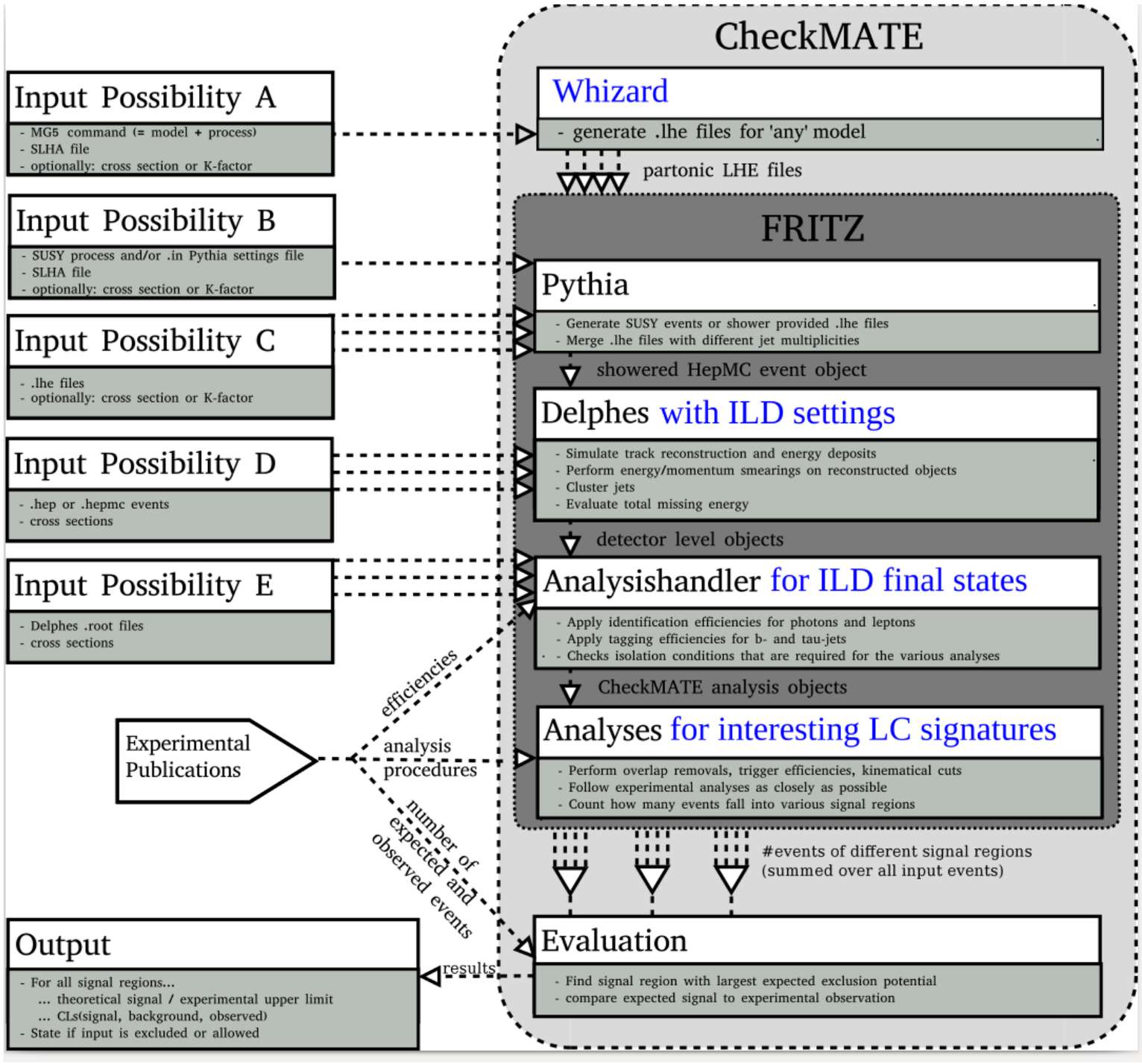
CM Structure



CM Structure



LC module in CM



```
[Parameters]
Name: VectorDM
Analyses: ILD
Collider: ILC
Sqrts:          500 GeV
Luminosity:     500 fb-1 | 200 fb-1 | 200 fb-1 | 50 fb-1 | 50 fb-1
Polarisation:   0:0      | 0.8:-0.3 | -0.8:0.3 | 0.8:0.3 | -0.8:-0.3
InvisiblePIDs: 9000006, -9000006
SLHAFile: [...]/spectrum.slha

[DM]
WhizardSinFile: [...]/whizard.sin
MaxEvents: 10000
```

FIG. 6. Example input file for the **CheckMATE** runs used for this study.

```
model = EffDMVector_UFO (ufo ("[...]/whizard-2.6.0/build/models"))
mVmed = 1900.0
mChi = 200.0
process chichigamma_noisr = "e-", "e+" => "Chi", "Chi~", "a"
compile
cuts = any Pt >= 1.5 GeV [a] and any abs (cos(Theta)) <= 0.998 [a]
[...]
```

FIG. 7. **Whizard .sin** file used for the $e^+e^- \to \bar{c}hi\chi\gamma$ Monte Carlo event generation in **CheckMATE**, see Fig. 6.

13 TeV analyses

#Name	NSR	Description	Lumi
atlas_1604_01306	1	photon + MET search at 13 TeV	3.2
atlas_1605_09318	8	>= 3 b-jets + 0-1 lepton + Etmiss	3.3
atlas_1609_01599	9	ttV cross section measurement at 13 TeV	3.2
atlas_conf_2015_082	1	leptonic Z + jets + Etmiss	3.2
atlas_conf_2016_013	10	4 top quark (1 lepton + jets, vector like quark search)	3.2
atlas_1606_09150	1	diphotons and met	3.2
atlas_conf_2016_050	5	1-lepton + jets + etmiss (stop)	13.3
atlas_conf_2016_054	10	1-lepton + jets + etmiss (squarks and gluino)	14.8
atlas_conf_2016_076	6	2 leptons + jets + etmiss	13.3
atlas_conf_2016_096	8	2-3 leptons + etmiss (electroweakino)	13.3
atlas_conf_2016_066	2	search for photons, jets and met	13.3
atlas_conf_2017_022	24	squarks and gluinos, 0 lepton, 2-6 jets	36.1
atlas_conf_2017_019	6	search for stops with Higgs or Z	36.1
atlas_conf_2017_060	20	monojet search	36.1
atlas_conf_2017_039	37	ATLAS, 2-3 leptons + etmiss, 13 TeV, 37 invfb	36.1
atlas_conf_2017_040	2	Etmiss + Z, 13 TeV	36.1
atlas_1704_03848	5	monophoton dark matter search	36.1
atlas_1710_11412	1	Search for dark matter produced in association with b or top quarks	36.1
atlas_1712_08119	39	electroweakinos search with soft leptons	36.1
atlas_1712_02332	24	squarks and gluinos, 0 lepton, 2-6 jets	36.1
atlas_1709_04183	14	stop pair production, 0 leptons	36.1
atlas_1802_03158	7	search for GMSB with photons	36.1
atlas_1708_07875	2	electroweakino search with taus and MET	36.1
atlas_1706_03731	19	same-sign or 3 leptons RPC and RPV SUSY	36.1
atlas_1804_03602	6	search for supersymmetry in events with four or more leptons	36.1

13 TeV analyses

- we have a small selection of implemented CMS 13 TeV analyses

#Name	NSR	Description	Lumi
cms_sus_15_011	47	CMS, 13 TeV, 2 leptons + jets + MET	2.2
cms_sus_16_046	4	one photon and missing transverse momentum	35.9
cms_sus_16_039	158	electrowekinos in multilepton final state	35.9
cms_sus_16_025	14	electroweakino and stop compressed spectra	12.9

- for the first time, we have started to consider a search based on jet substructure techniques and a LLP search

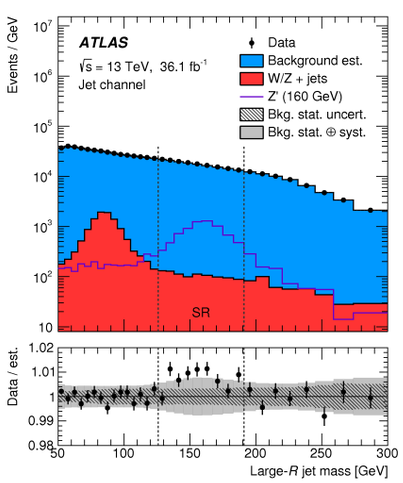
#Name	NSR	Description	Lumi
atlas_1801_08769		Search for light resonances decaying to boosted quark pairs and produced in association with a photon or a jet	36.1
atlas_1712_02118	2	Search for long-lived charginos based on a disappearing-track signature	36.1

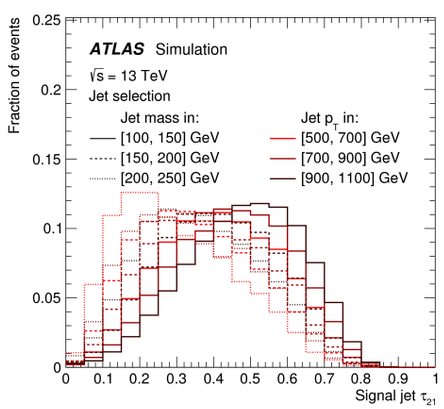
jet substructure analysis

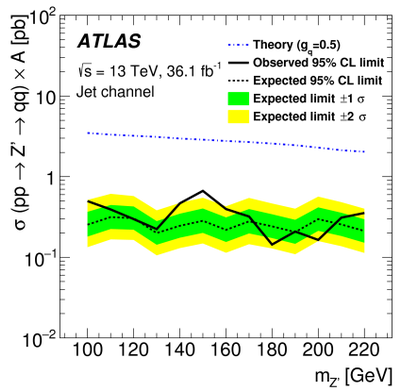
- 1801.08769 targets low mass resonances in association with ISR jet or photon

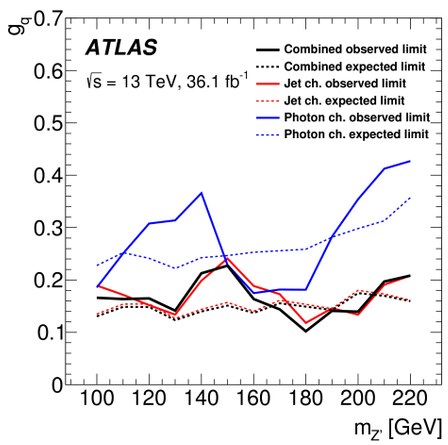
- it requires implementation of large R=1 jet as well as a narrow R=0.4 jet (new CM feature)

- to reduce effects of pile-up and soft radiation, the large-R jets are trimmed









- one of the commonly used jet substructure variable is τ21 = ratio of N-subjettiness τ2 and τ1

- τ21 is a useful discriminant for differentiating between a two-particle jet of a boosted resonance and a single-particle jet

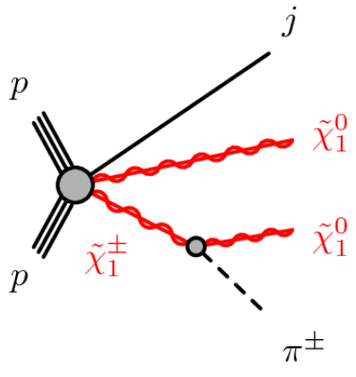
- implementation is straightforward

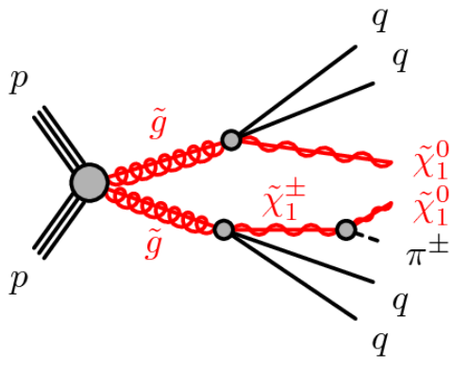
- missing informations in order to implement a subjet variable was very quickly provided by ATLAS

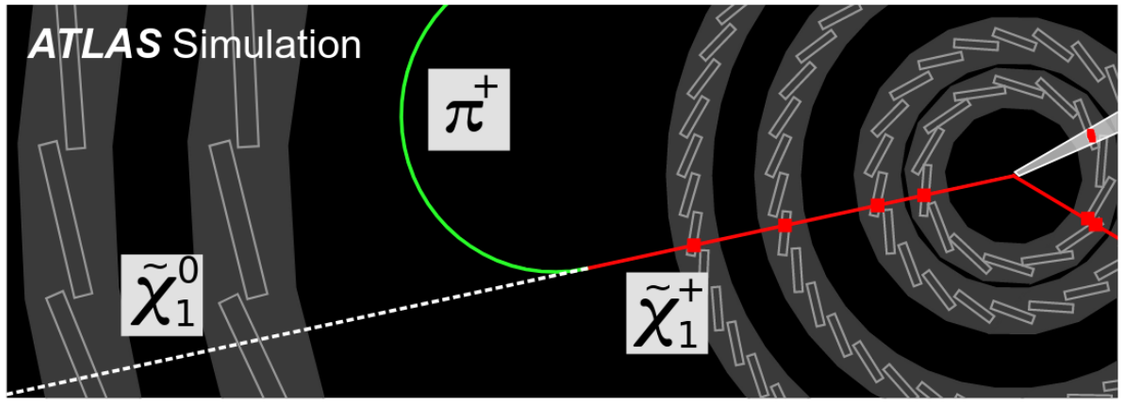
LLP search implementation

- 1712.0211 searches for long-lived charginos based on a disappearing-track

- electroweak and strong production of winos decaying into almost mass degenerate neutralino LSP and soft pions (AMSB)

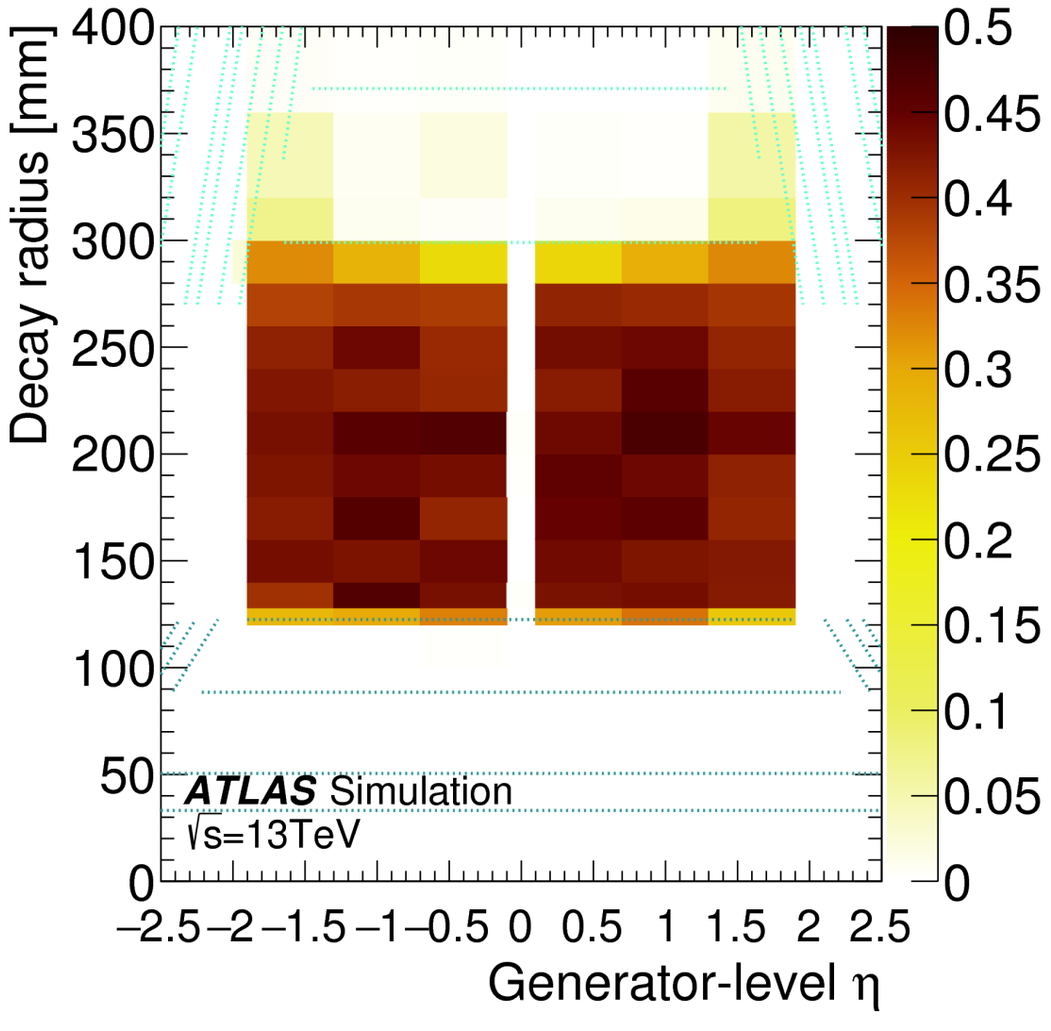






- ATLAS provides on its webpage comprehensive material which allows for a quick and easy implementation

- CM implementation is based on truth level efficiency maps of the long lived chargino (more tomorrow)

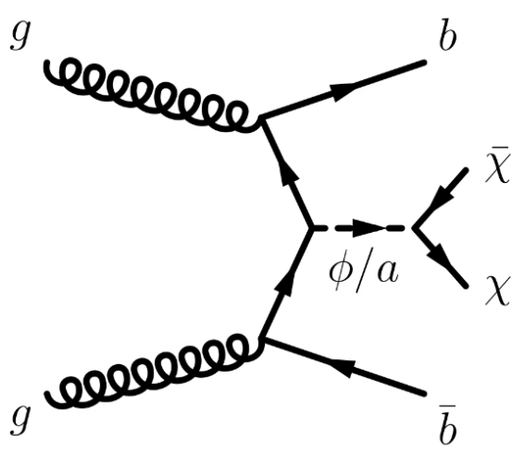


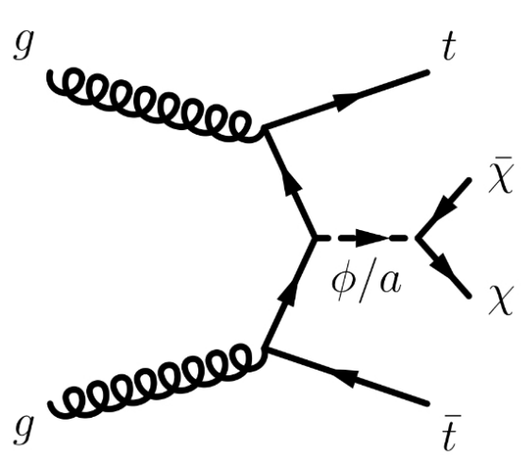
Future Analysis Implementations

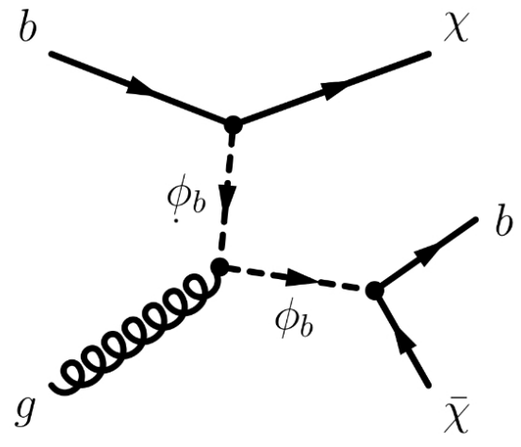
- we want to implement the stop 1 lepton search
- so far, we have mostly implemented SUSY searches
- we plan to implement VLQ searches
- we will assist in implementing LQ searches
- we have started to implement simplified DM searches
- the informations provided by the experimentalists have greatly simplified recasting (talks from Iacopo and Wolfgang)

Search for dark matter produced in association with bottom or top quarks

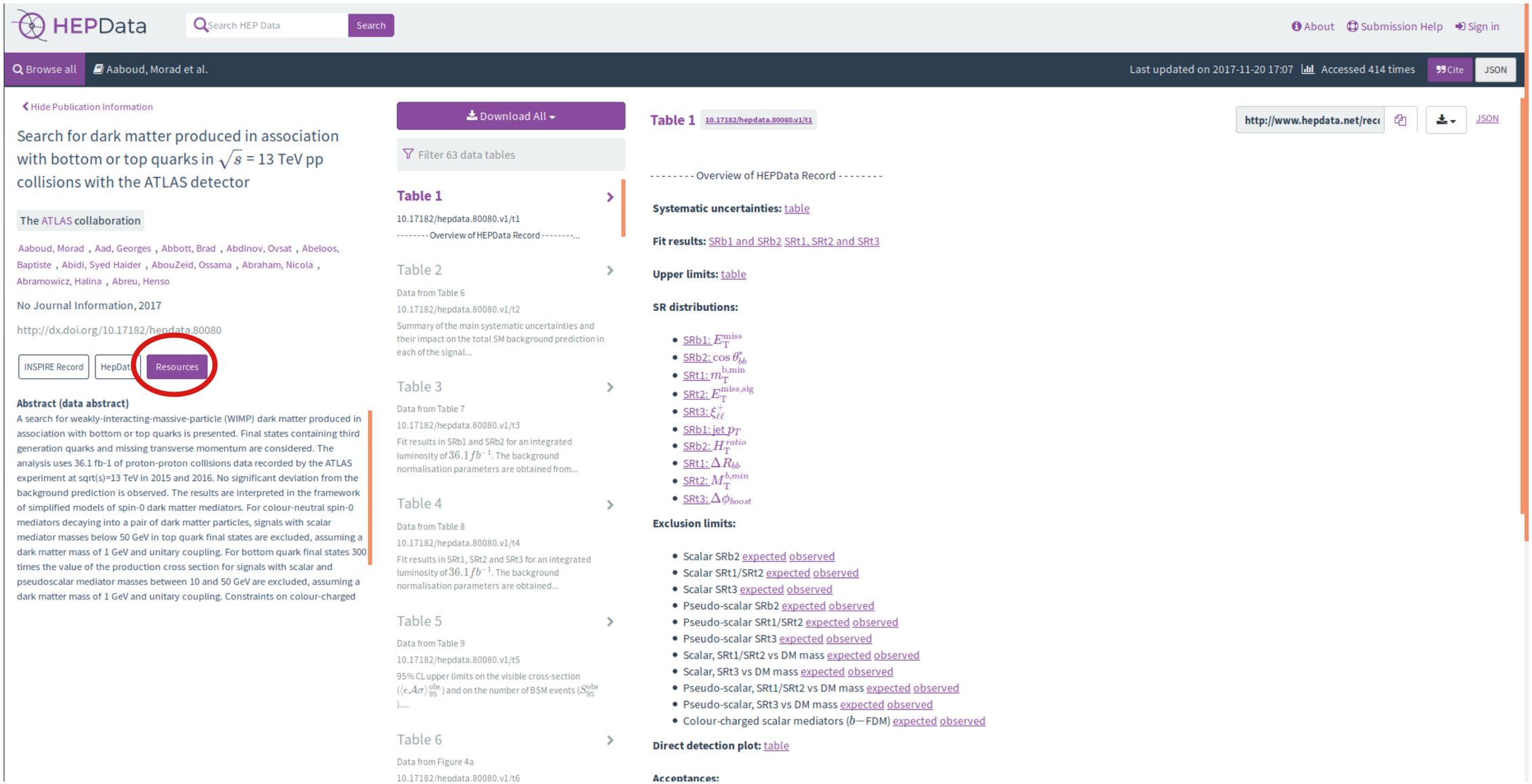
- 1710.11412 focuses on simplified dark matter model with spin 0 mediator
- two signal regions target final states with DM and bottom quarks and three signal regions are optimized for final states with top quarks





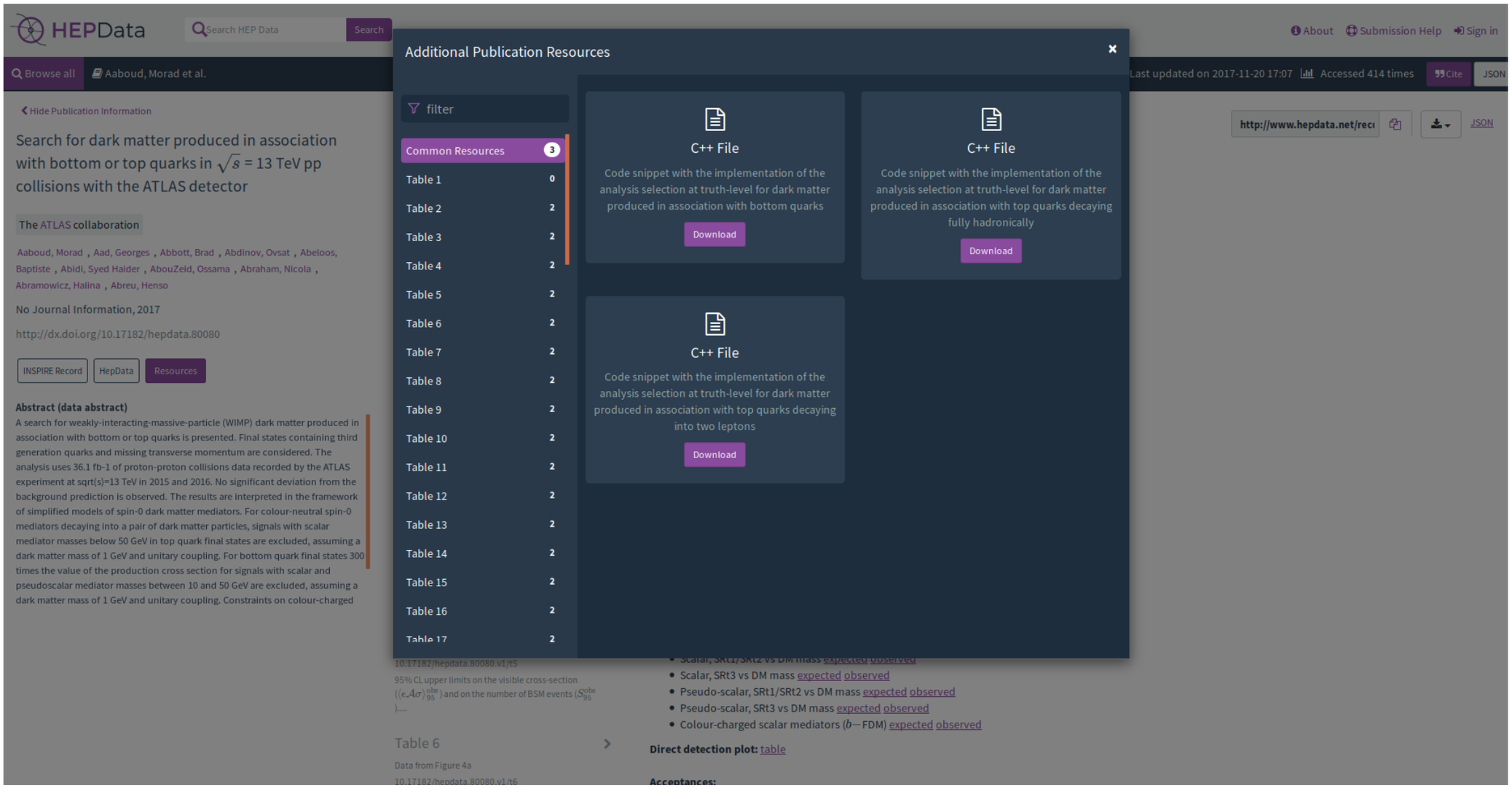


- ATLAS provides useful informations on HEPData
- all figures and tables are available in digitized form
- analysis code is provided



- the truth level analysis code for all signal regions is very useful for the implementation

- quick responses to email inquiries which greatly simplifies implementation



```cpp
#include "SimpleAnalysis/AnalysisClass.h"
#include "TMath.h"

DefineAnalysis(DMttZeroLepton2016)

void DMttZeroLepton2016::Init()
{
  addRegions({"SRHigh","SRLow"});
}

void DMttZeroLepton2016::ProcessEvent(AnalysisEvent *event)
{
    auto candJets   = event->getJets(20., 2.8); //jets
    auto electrons =  event->getElectrons(7, 2.47, EVeryLooseLH);

    //Muons
    auto muons      = event->getMuons(6, 2.5, MuLoose);

    // not doing overlap removal between electrons and muons with identical track
    candJets   = overlapRemoval(candJets,electrons,0.2,NOT(BTag85MV2c10));
    electrons  = overlapRemoval(electrons,candJets,0.4);
    candJets   = overlapRemoval(candJets, muons, 0.4, LessThan3Tracks);
    muons      = overlapRemoval(muons, candJets, 0.4);

    if (countObjects(candJets, 20, 2.8, NOT(LooseBadJet))!=0) return;

    candJets = filterObjects(candJets, 20, 2.8, JVT50Jet);

    auto signalElectrons = filterObjects(electrons, 25, 2.47, ETightLH|ED0Sigma5|EZ05mm|EIsoGradientLoose);
    auto signalMuons     = filterObjects(muons, 25, 2.5, MuMedium|MuD0Sigma3|MuZ05mm|MuIsoGradientLoose);
    auto signalLeptons   = signalElectrons + signalMuons;

    auto metVec     = event->getMET();
    double met   = metVec.Et();

    auto signalJets      = filterObjects(candJets, 20);
    auto signalBjets     = filterObjects(signalJets, 20., 2.5, BTag77MV2c10);
```

Conference Notes

- only little material is provided for conference notes
- it is hard for us to validate searches since no cutflows are published in some cases, e.g. ATLAS-CONF-2017-081
- we wanted to implement ATLAS-CONF-2016-070 which searches for light resonances in association with ISR
- we could not reproduce the cutflow due to problems with MC event generation, however, we did not receive any useful informations from ATLAS
- here, MC run cards would have been very useful

Wish List

- SLHA files
- input files for MC event generations, e.g. MG run cards
- code snippets
- efficiency maps
- cutflows for all signal regions
- more informations for conference notes

in the near future

- currently, we use subversion control but we plan to migrate to github

- docker image of CheckMATE -> talk from Lukas

- CKKW-L matching within CM

- in CM, we mainly implement ATLAS searches and the ATLAS detector tune is optimized, however, we did not optimize the CMS one... but slowly improving on the CMS detector tune, e.g. tau tagging and b tagging

Summary

- our collaboration is very large now
- we have a few members concentrating on analysis implementations only
- we have started with LLP searches and jet substructure searches
- we will have a LC module in CM
- CKKW-L matching within CM in the near future
- we want to migrate to github