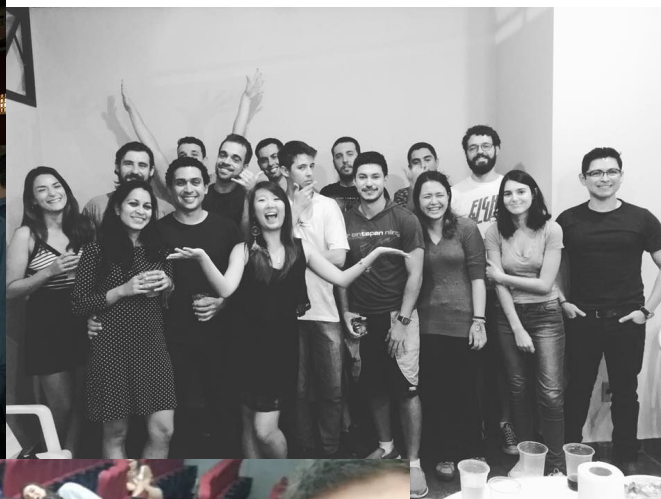
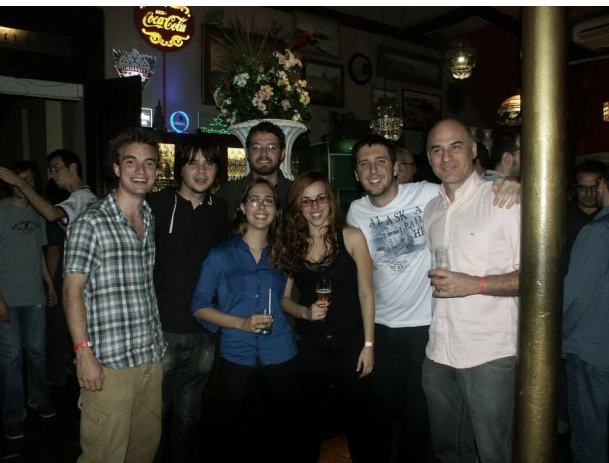


Event classes for IACT analysis

Rodrigo Guedes Lang

High-energy astrophysics in the multi-messenger era workshop, 09/05/2023

A little on both sides...



- Bachelor: 2010-2014
- Masters: 2015-2016
- PhD: 2017-2020



- Post-doc: 2021-...



Currently (let's talk!)

HESS

- Reconstruction and gamma/hadron separation;
- Event classes;
- Jelena: time cleaning;
- Tim: improvement of lowest energies for mono;

UHECR

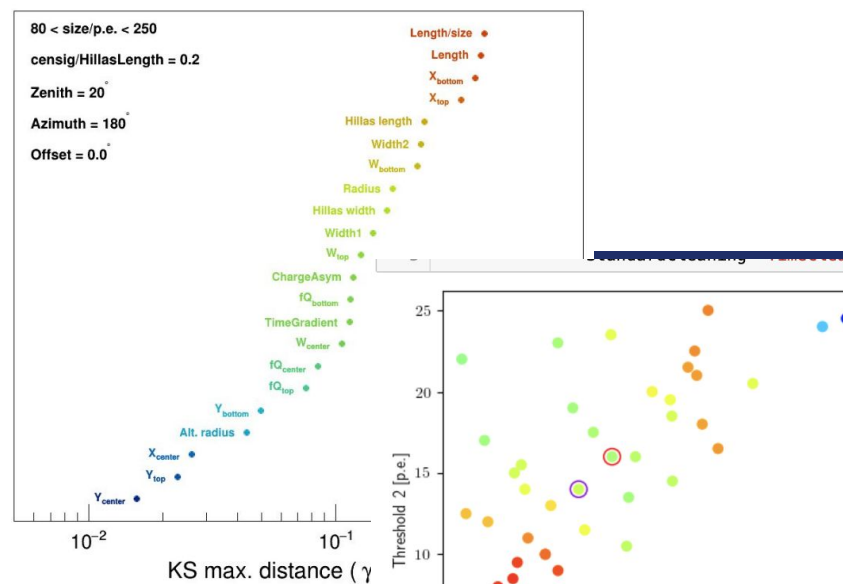
- Origin of UHECR;
- Anisotropy;
- Luciana & Vitor: modelling the dipole;
- Chaimongkol: mass-dependent composition;

SWGGO

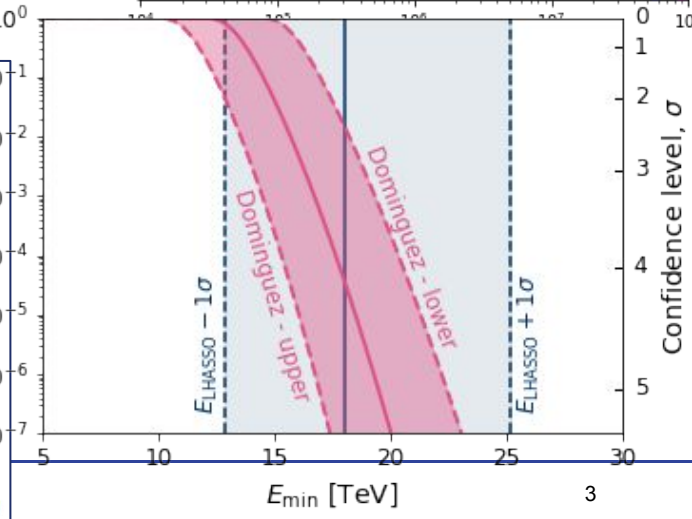
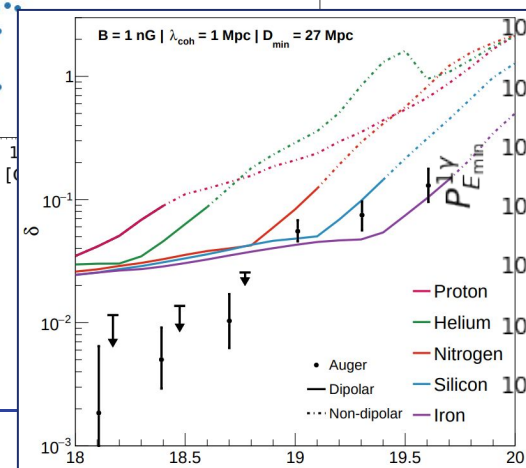
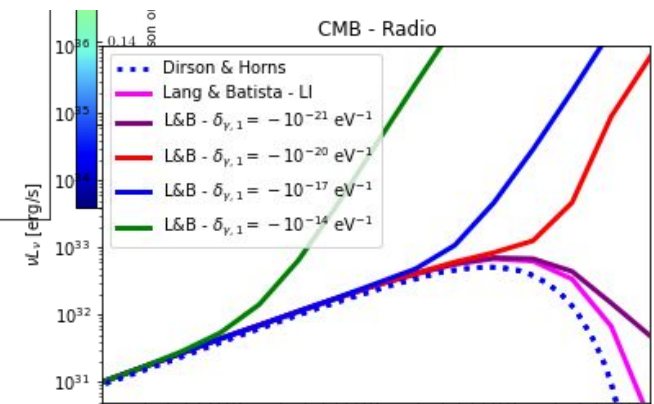
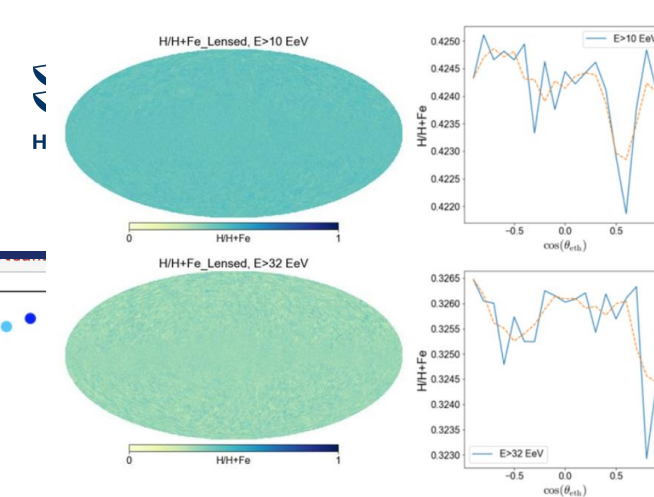
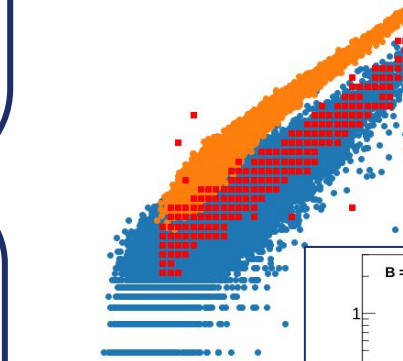
- Cosmic ray anisotropy and composition;
- Muon reconstruction;

LIV

- Testing LIV with gamma-rays and UHECR;
- EBL interaction;
- Inverse compton emission;



- True proton
- True iron
- Reconstructed proton



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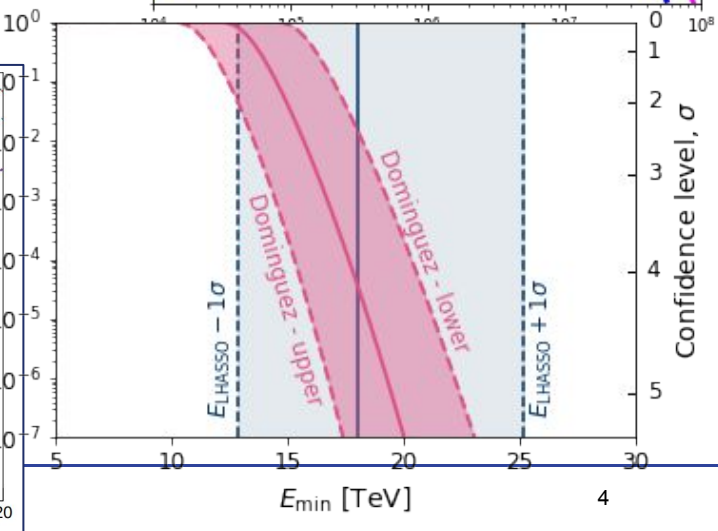
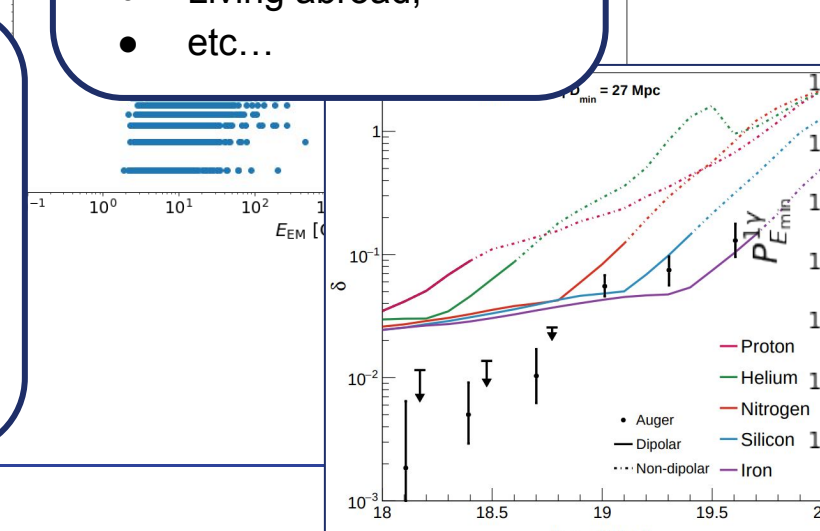
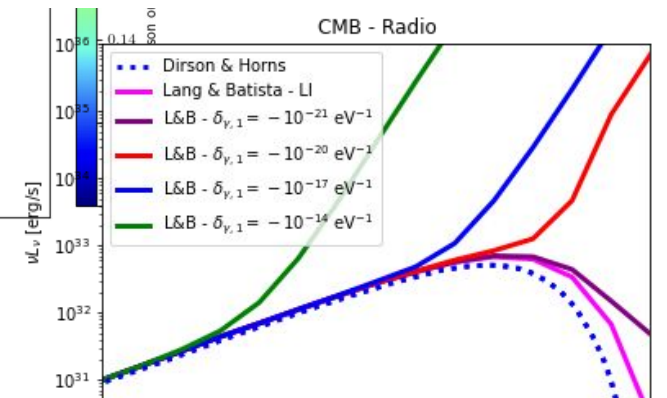
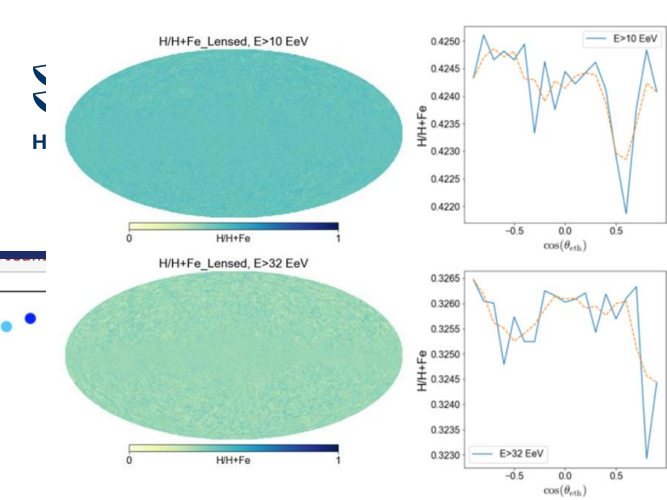
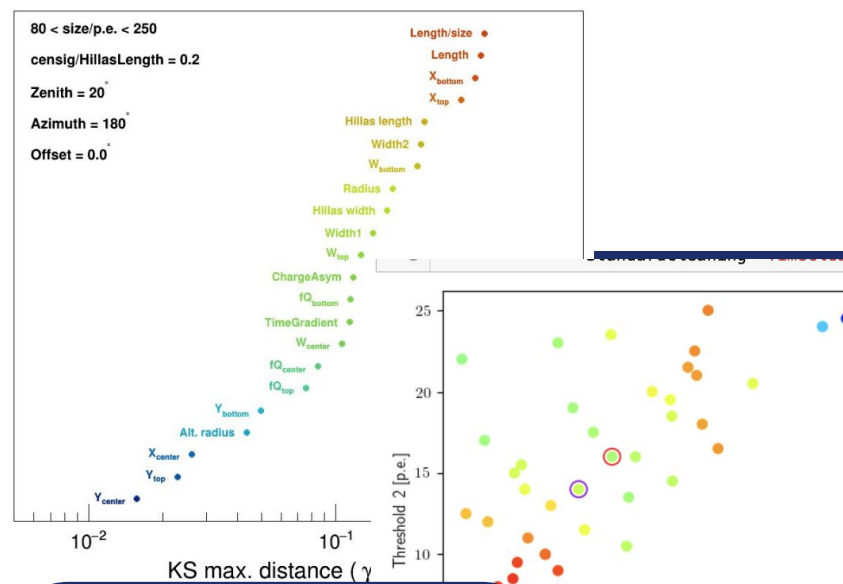
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also...

- Sharing a bit my experiences in both Brazil and Germany;
- Living abroad;
- etc...



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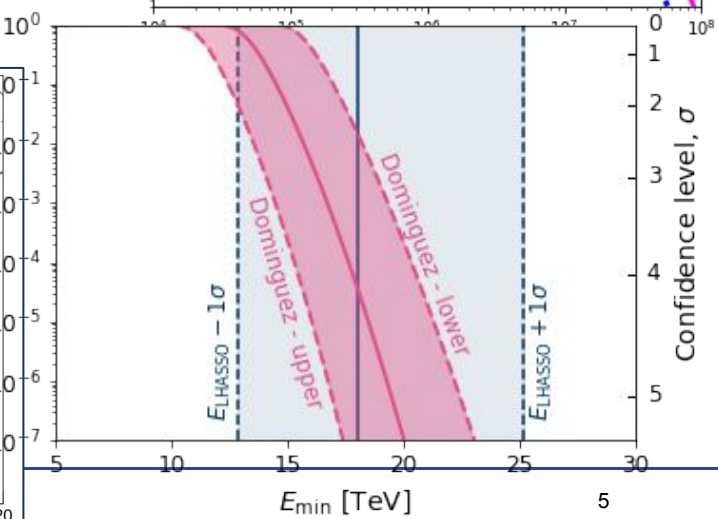
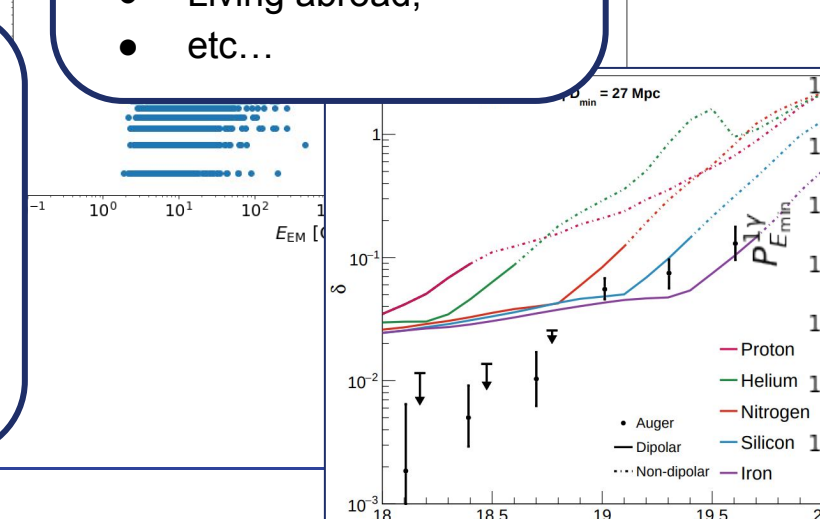
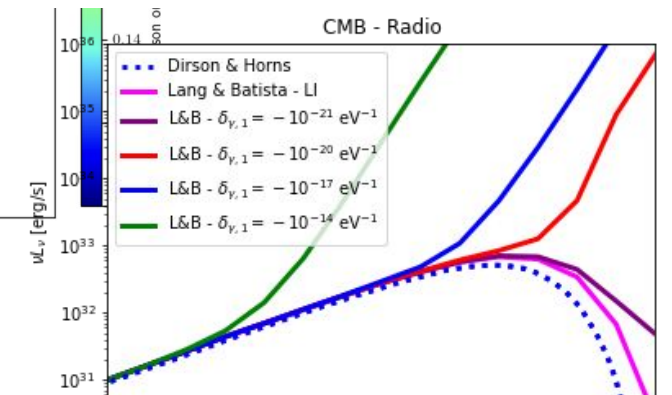
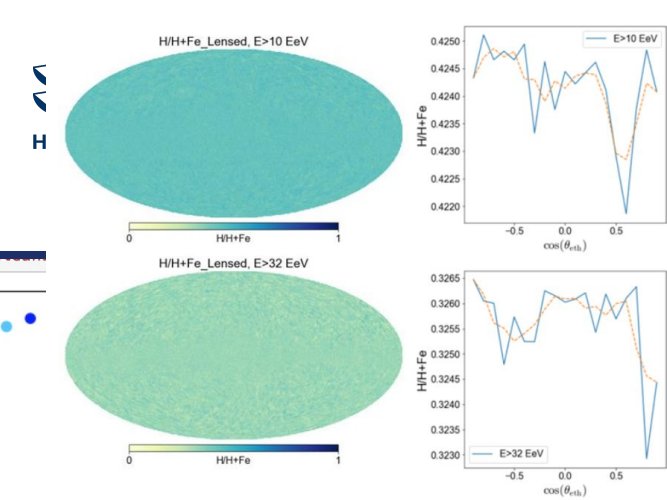
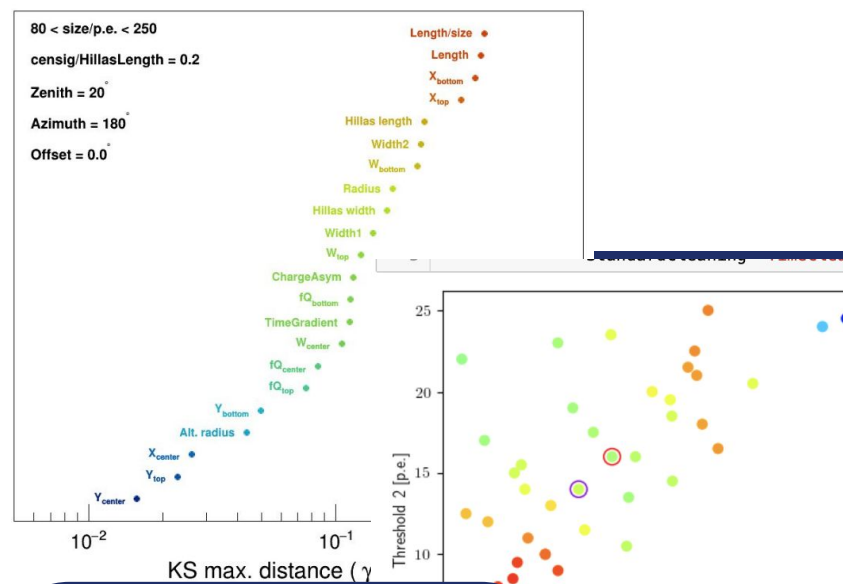
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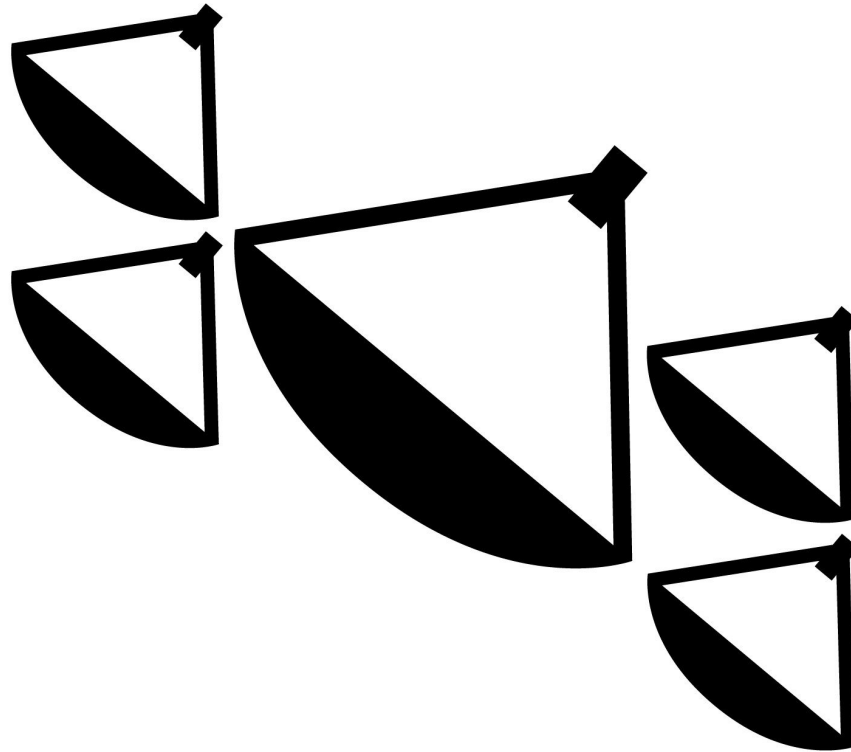
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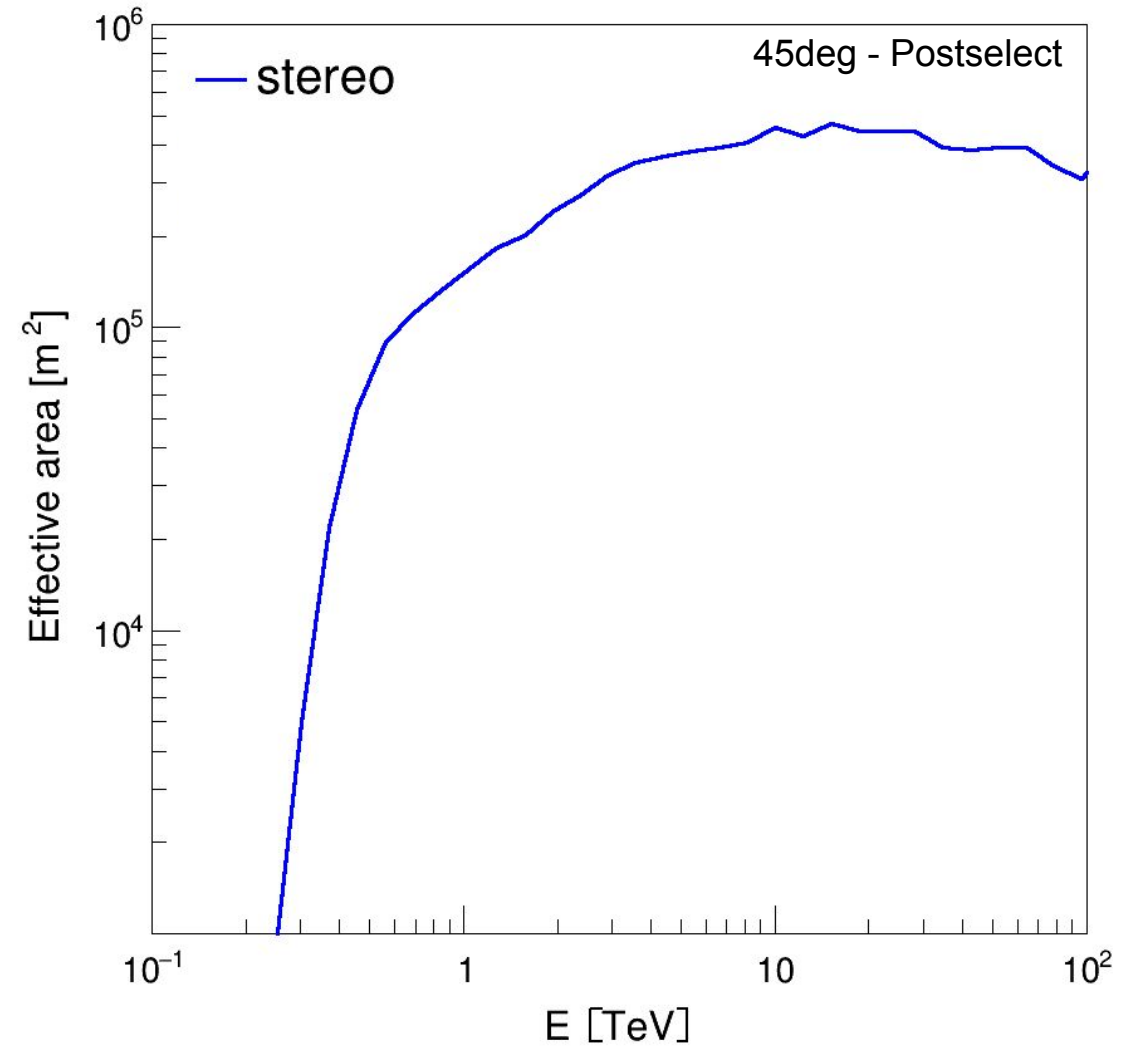
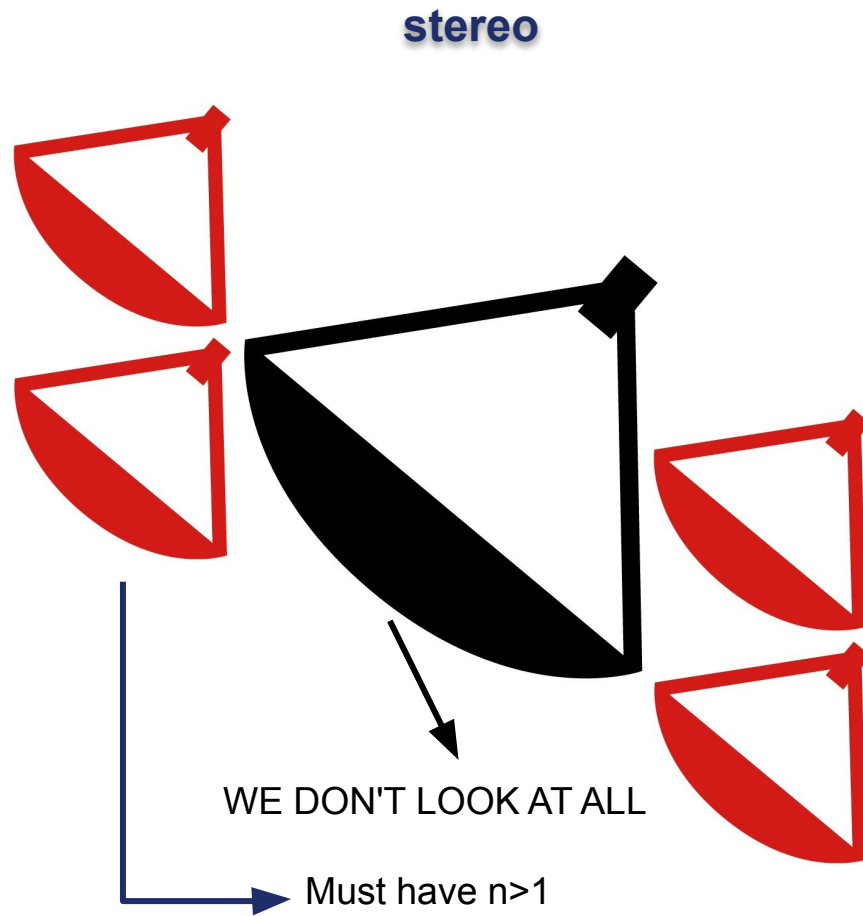


Current scheme



MULTIPLICITY

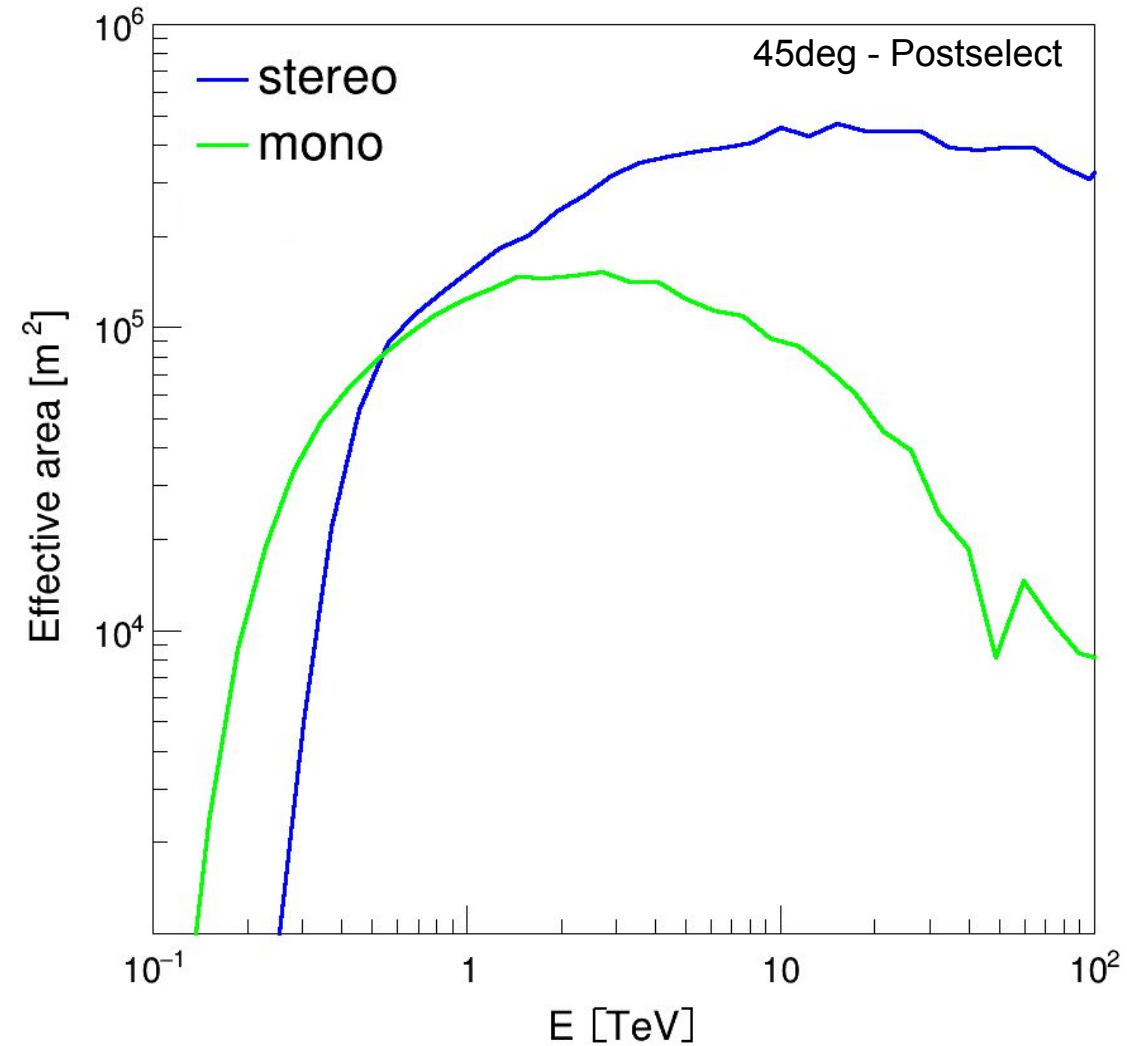
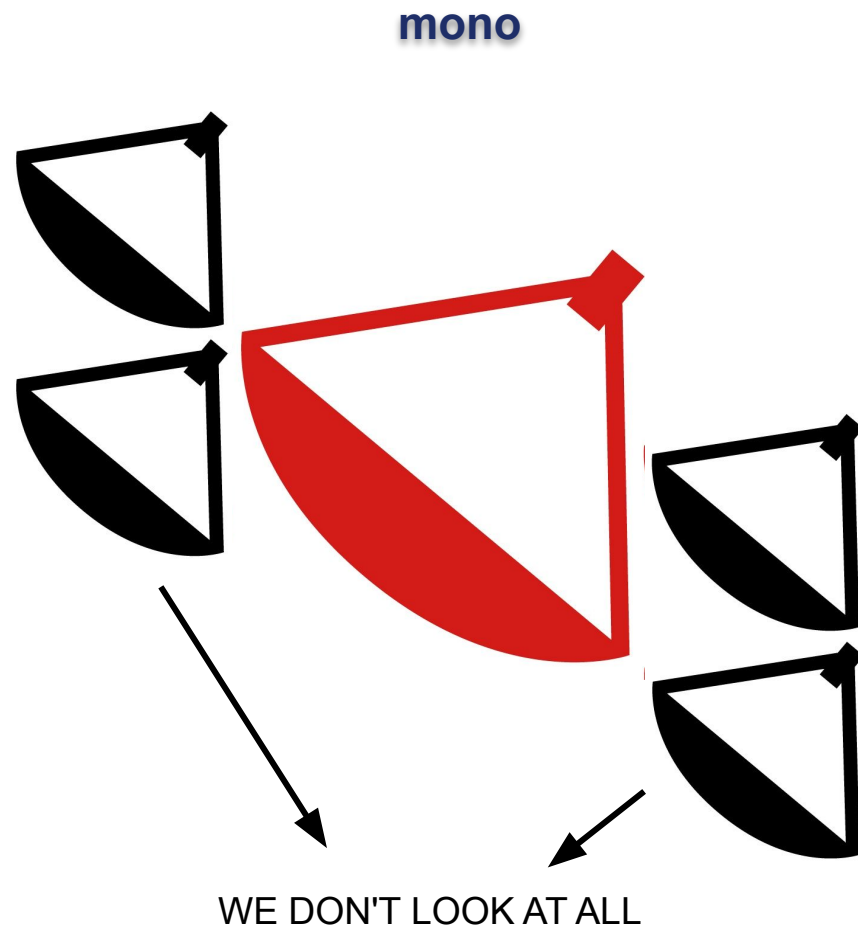
Current scheme



MULTIPLICITY

stereo

Current scheme

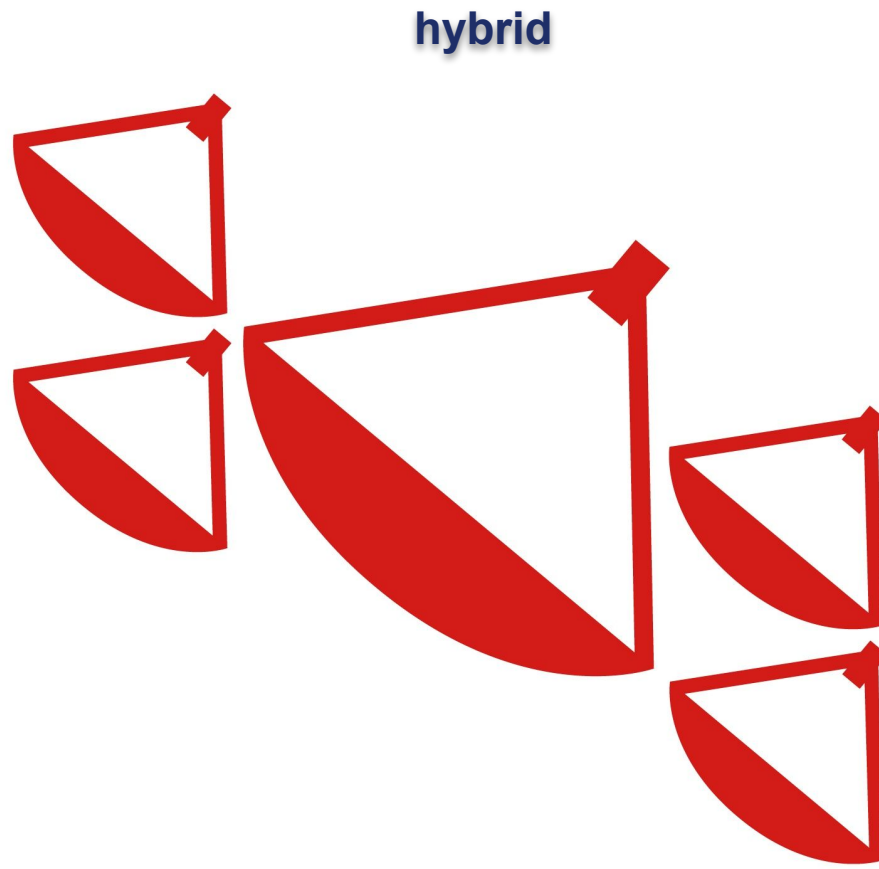


MULTIPLICITY

stereo

mono

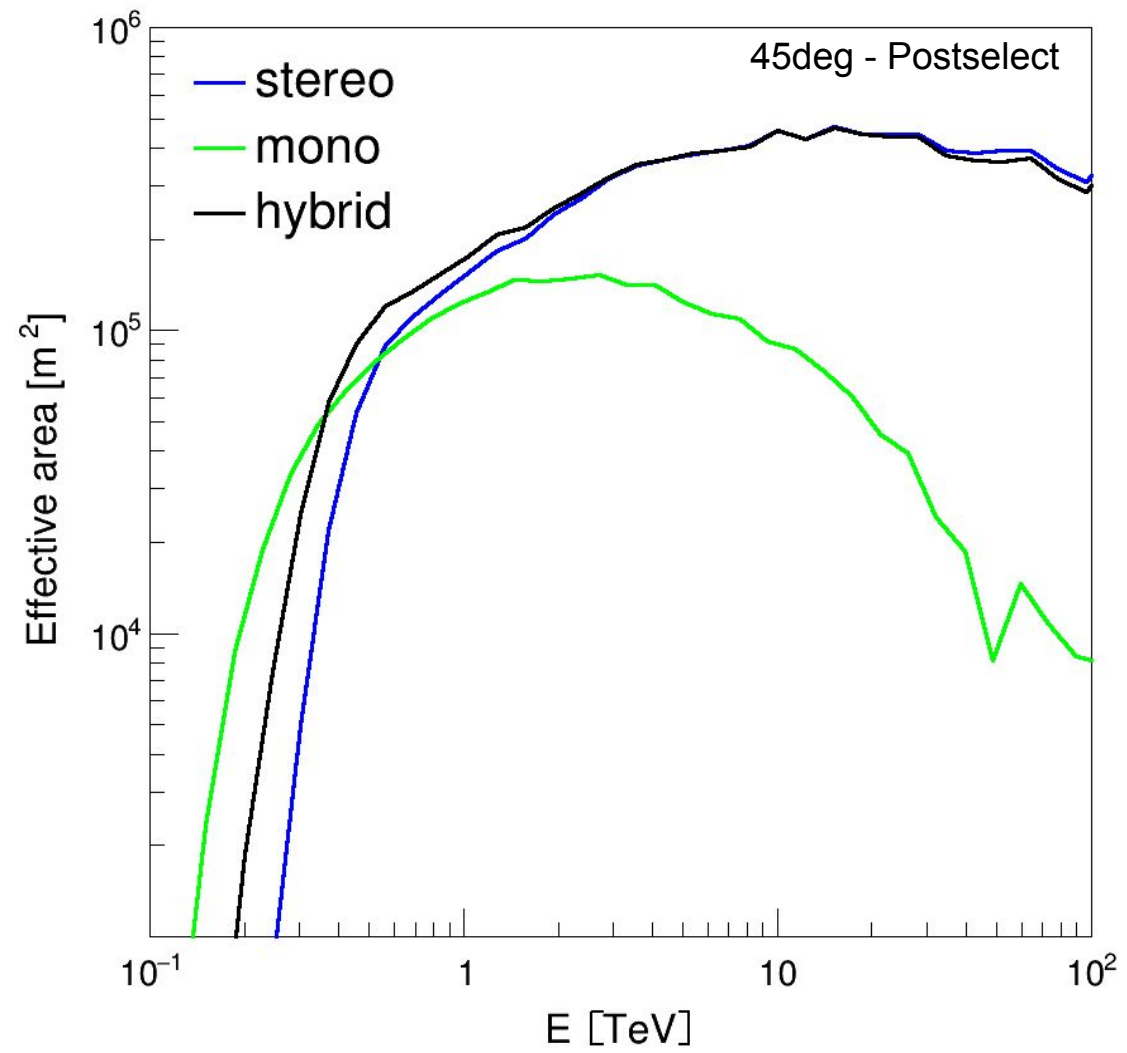
Current scheme



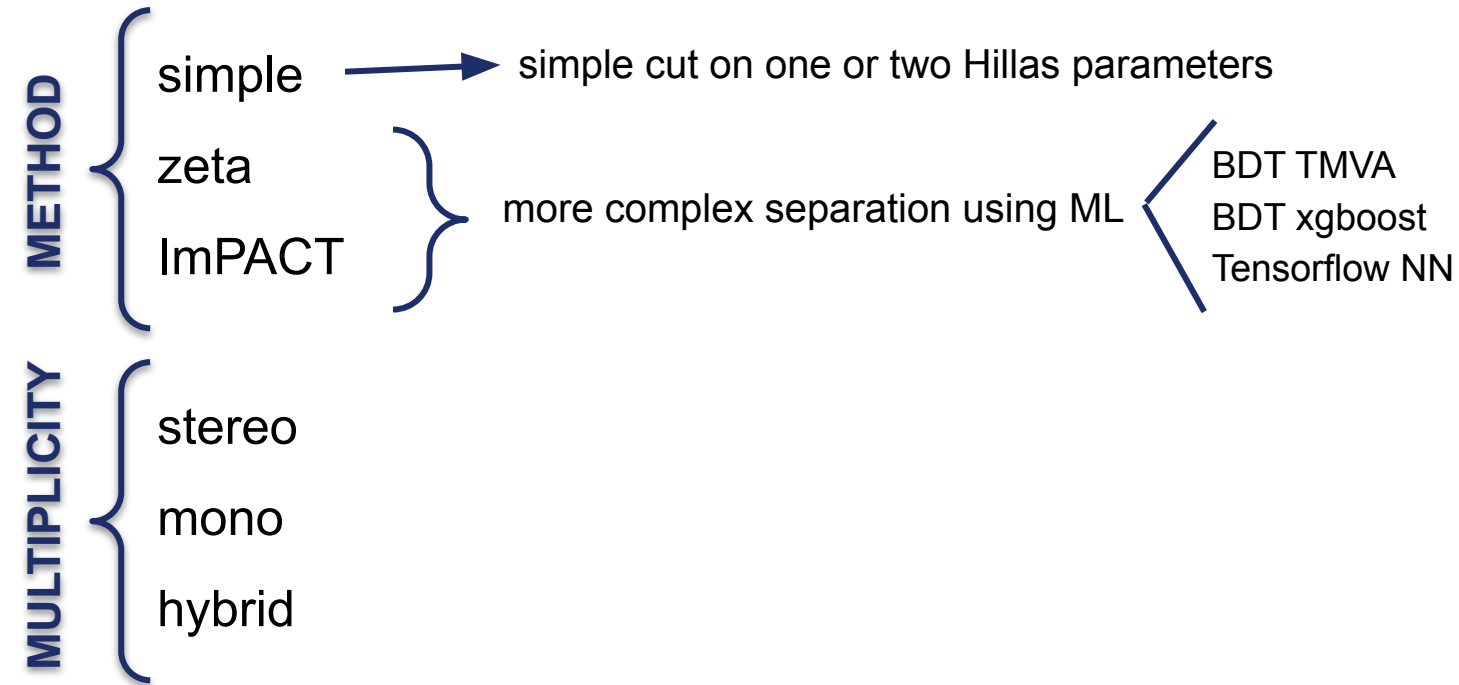
MULTIPLICITY

- stereo
- mono
- hybrid

Must have $n > 1$



Current scheme



Current scheme

QUALITY

- loose
- std
- hard
- safe

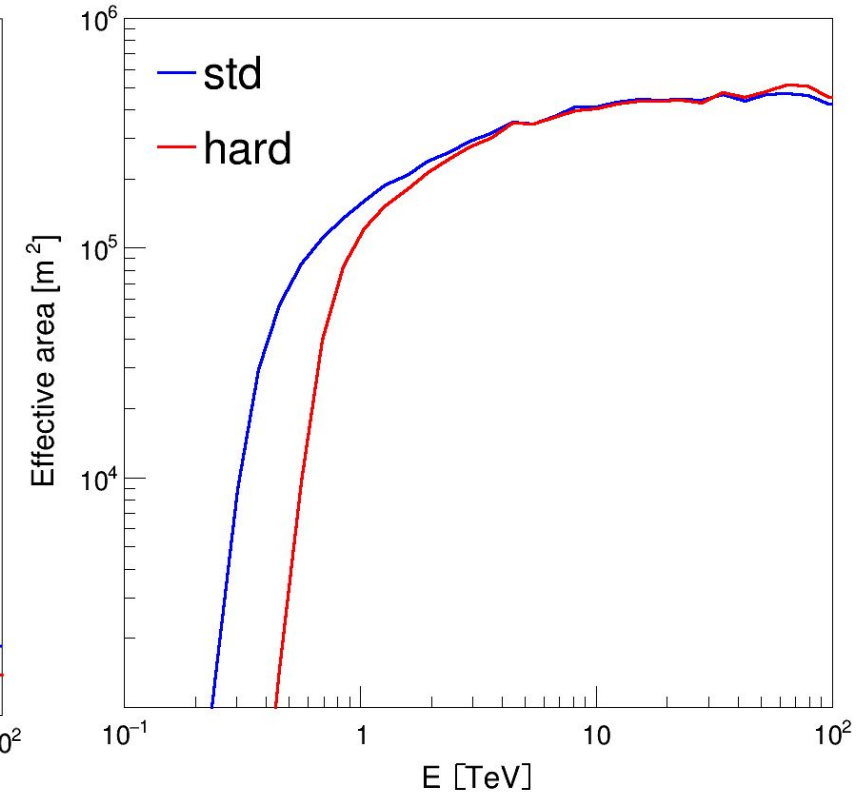
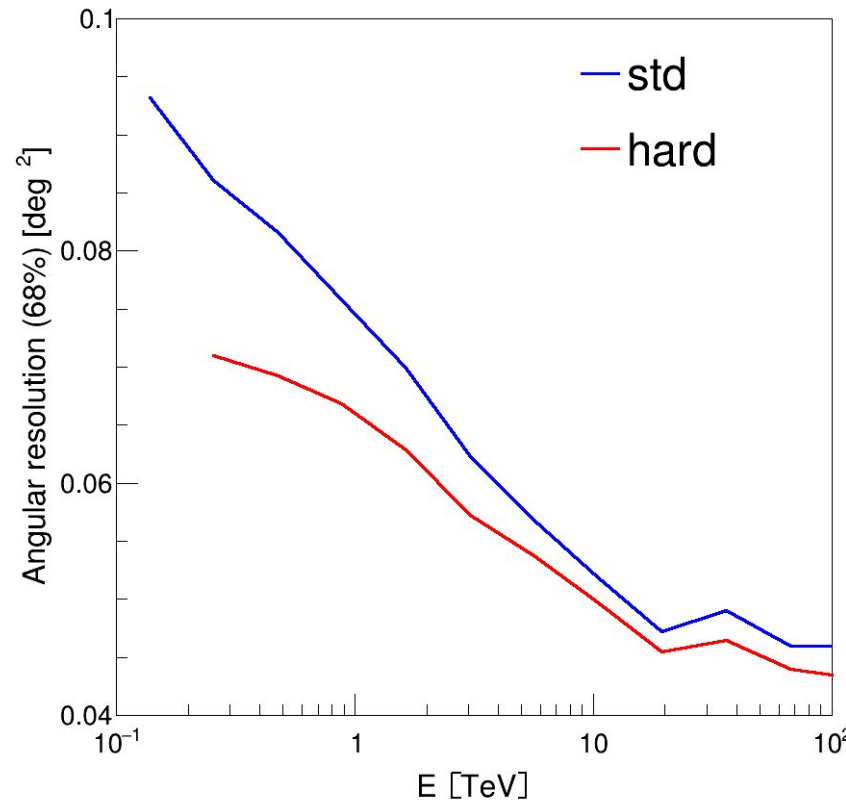
METHOD

- simple
- zeta
- ImPACT

MULTIPLICITY

- stereo
- mono
- hybrid

- How tight do we want to cut?
- Balance between resolution and statistics;
- Driven by science case;



Problems with current scheme

PRACTICAL

- Lack of an uniform framework;
- Discrepancies found;

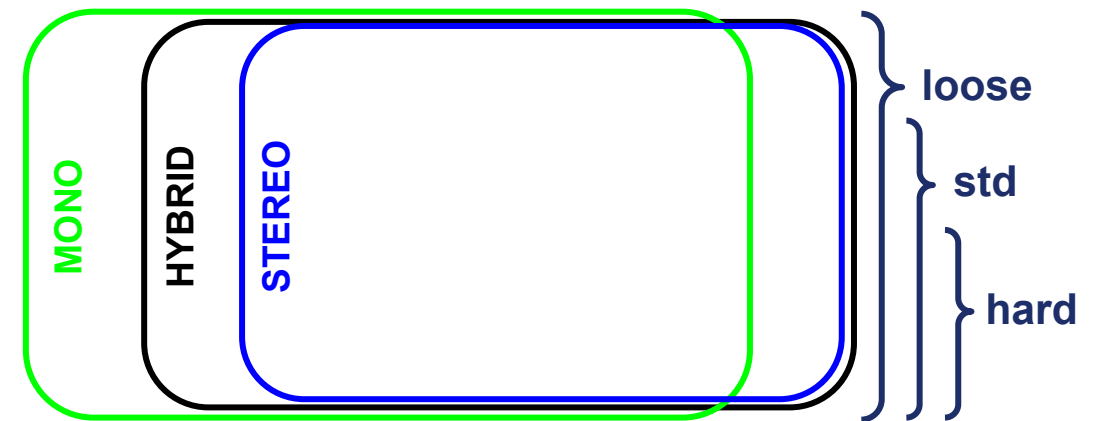
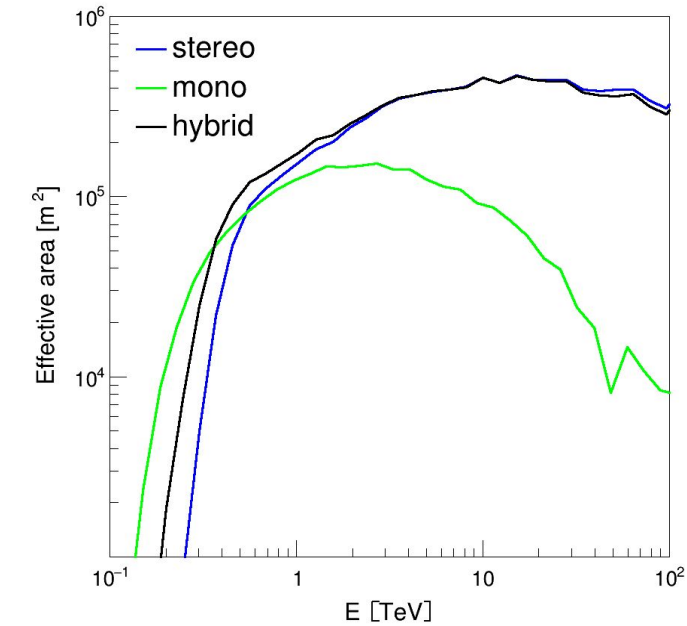
Problems with current scheme

PRACTICAL

- Lack of an uniform framework;
- Discrepancies found;

CONCEPTUAL

- Superimposed and not complimentary configs;
- Cannot exploit the full energy range with a single analysis;

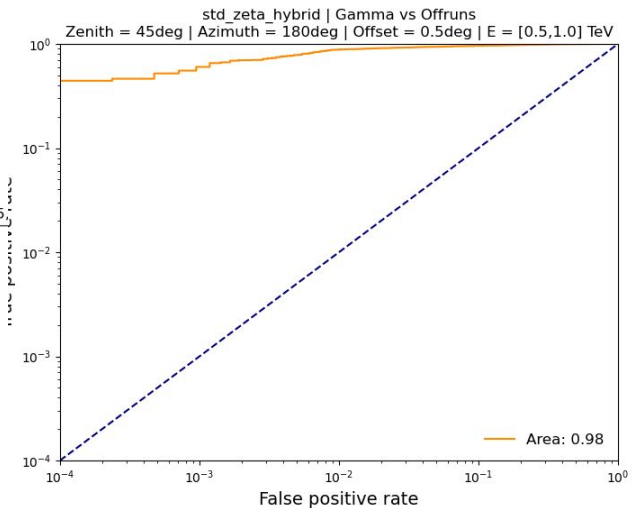
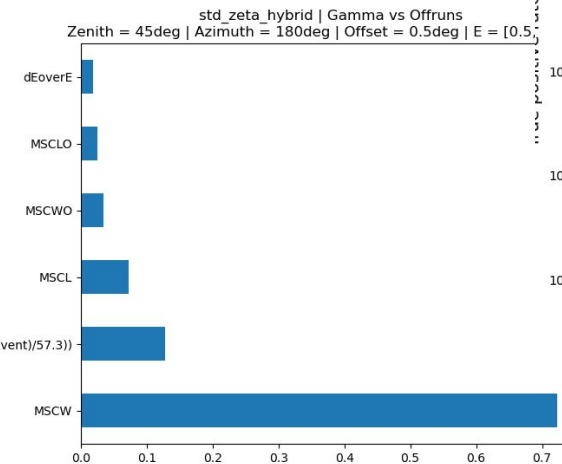
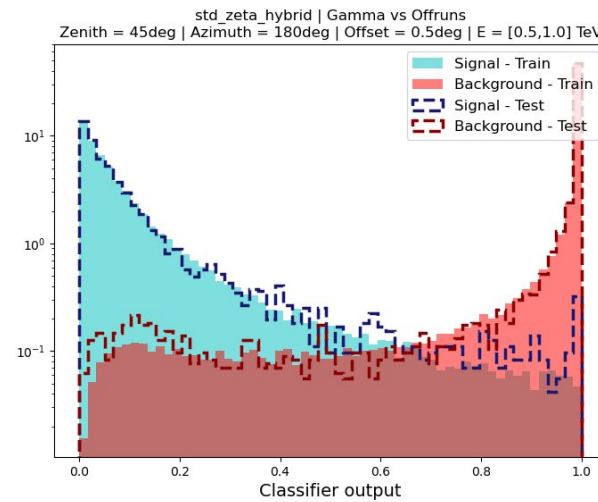
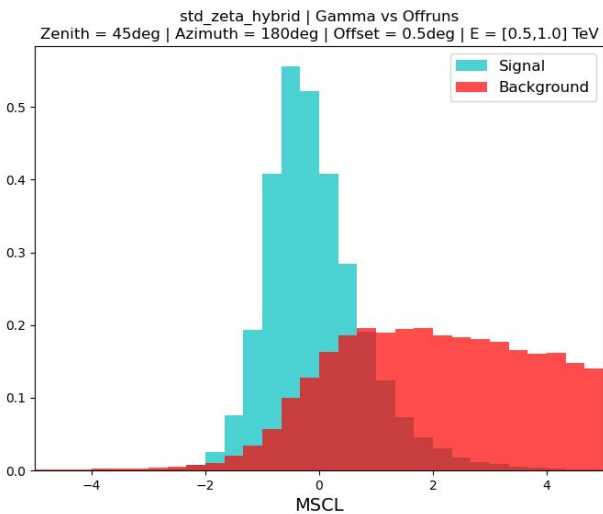


New scheme

PRACTICAL

- Uniform training for every config: BDT using xgboost on Python ;
- Master script covering the whole process;

- lookups generation;
- separation training;
- mono reconstruction training;
- cut optimization;
- diagnostic plots;



New scheme

PRACTICAL

- Uniform training for every config: BDT using xgboost on Python ;
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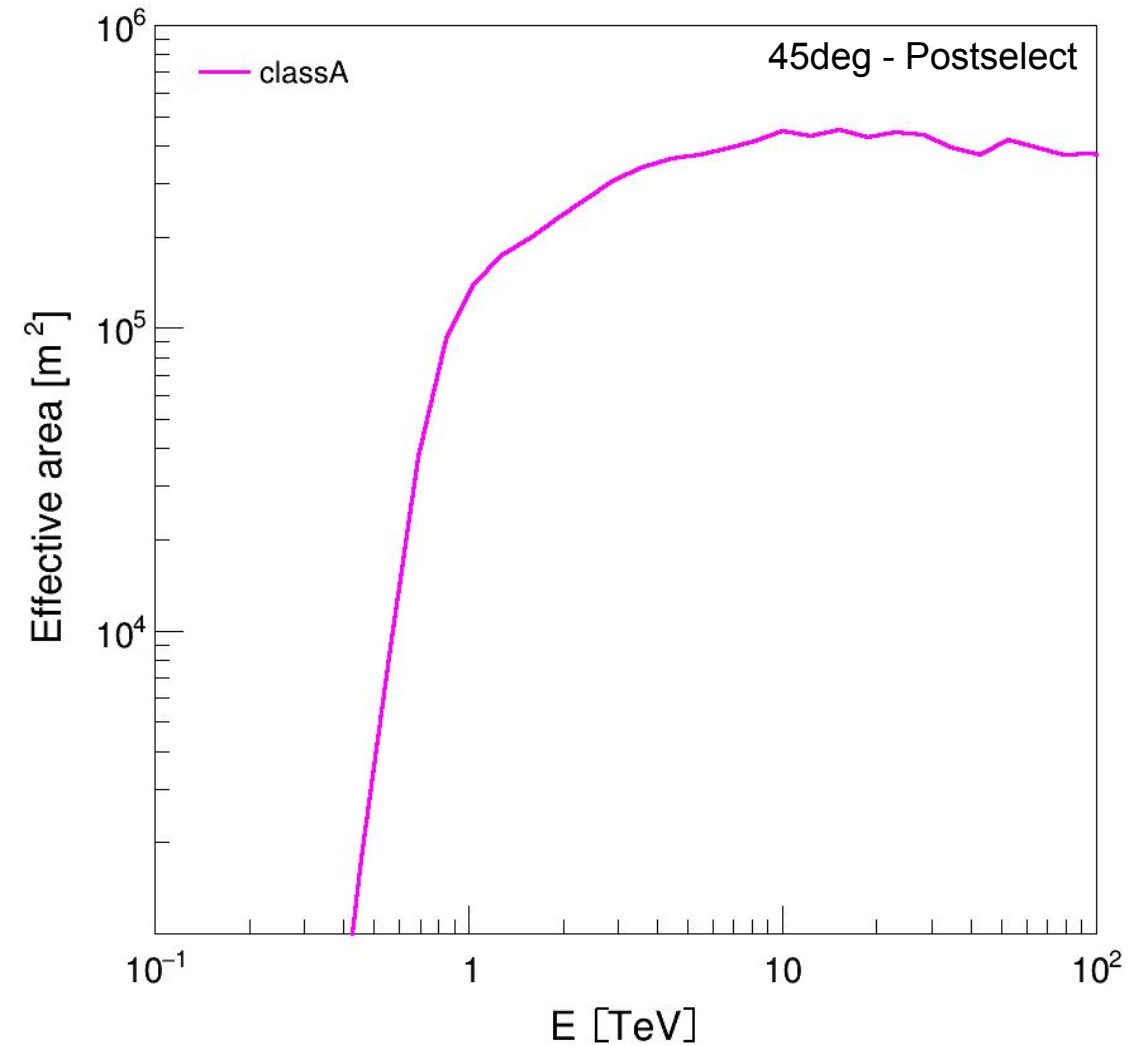
CONCEPTUAL

- Event classes!

Event classes

- Events divided into EXCLUSIVE and complementary classes according to "quality";

CT5 > 50 p.e. AND n≥2 CT1-4 > 200 p.e. ⇨ A



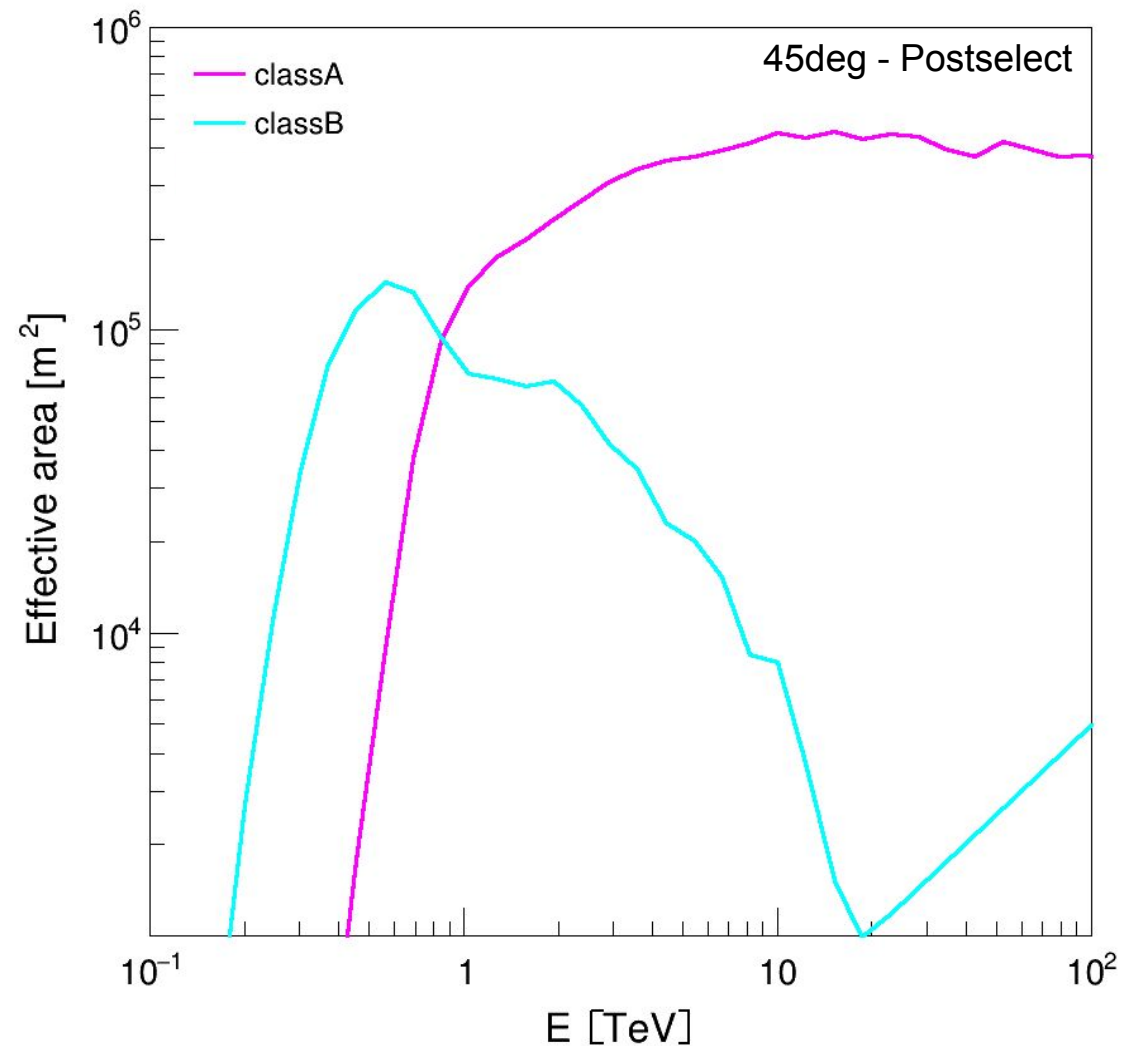
Event classes

- Events divided into EXCLUSIVE and complementary classes according to "quality";

CT5 > 50 p.e. **AND** $n \geq 2$ CT1-4 > 200 p.e. \Rightarrow **A**

if not

$(CT5 > 80$ p.e. **AND** $n \geq 1$ CT1-4 > 80 p.e.) \Rightarrow **B**
OR ($n \geq 2$ CT1-4 > 80 p.e.)



Event classes

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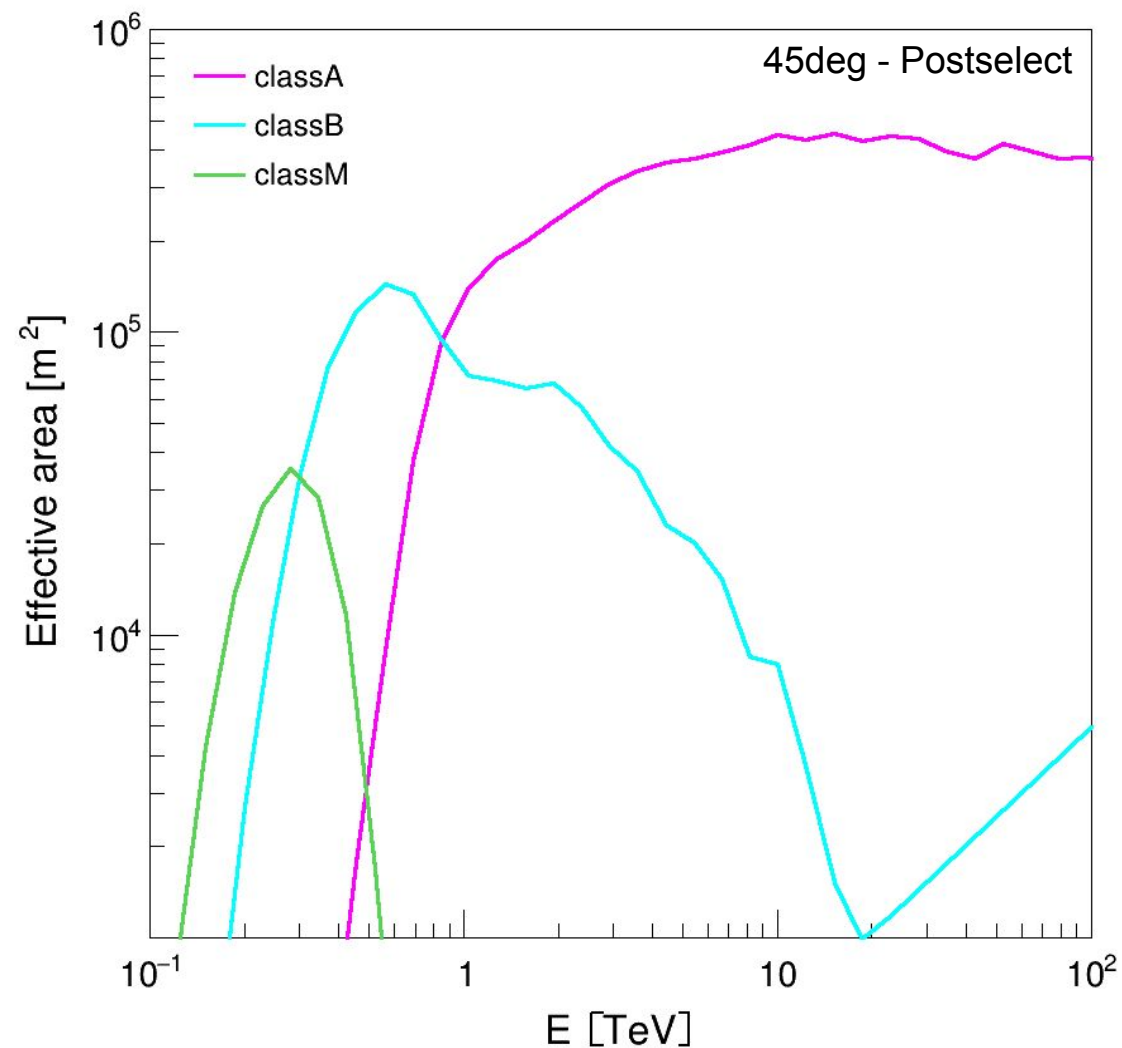
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Event classes

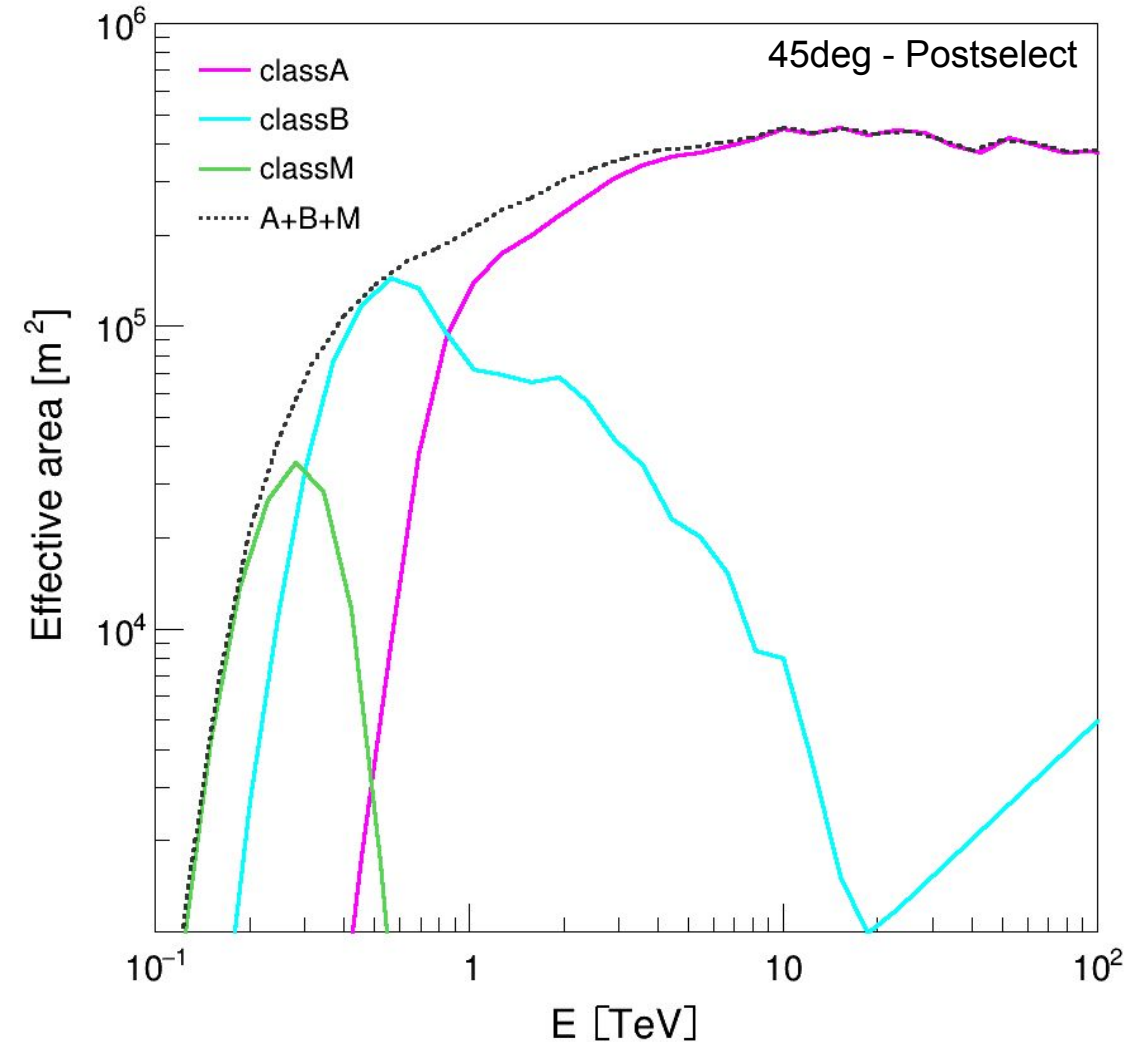
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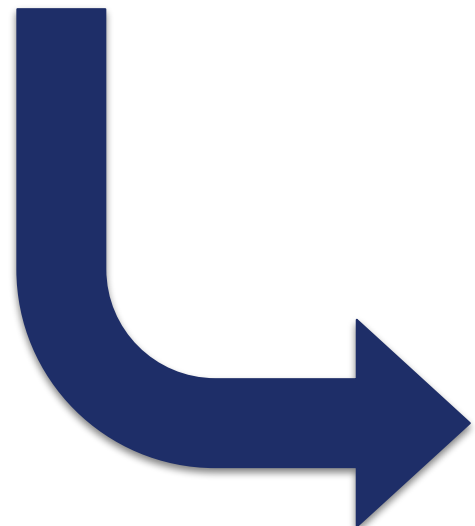
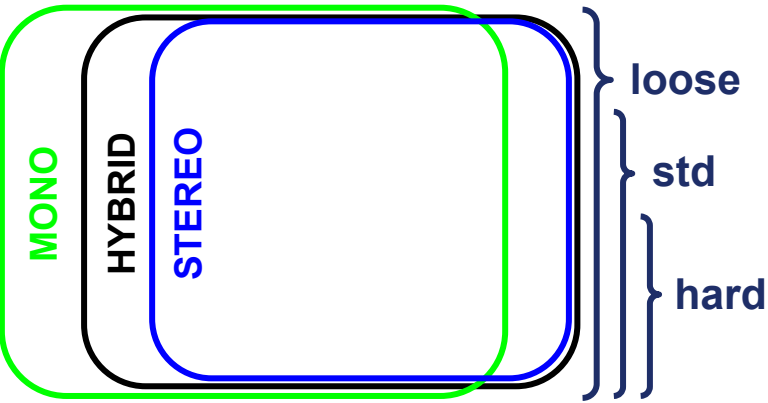
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if not
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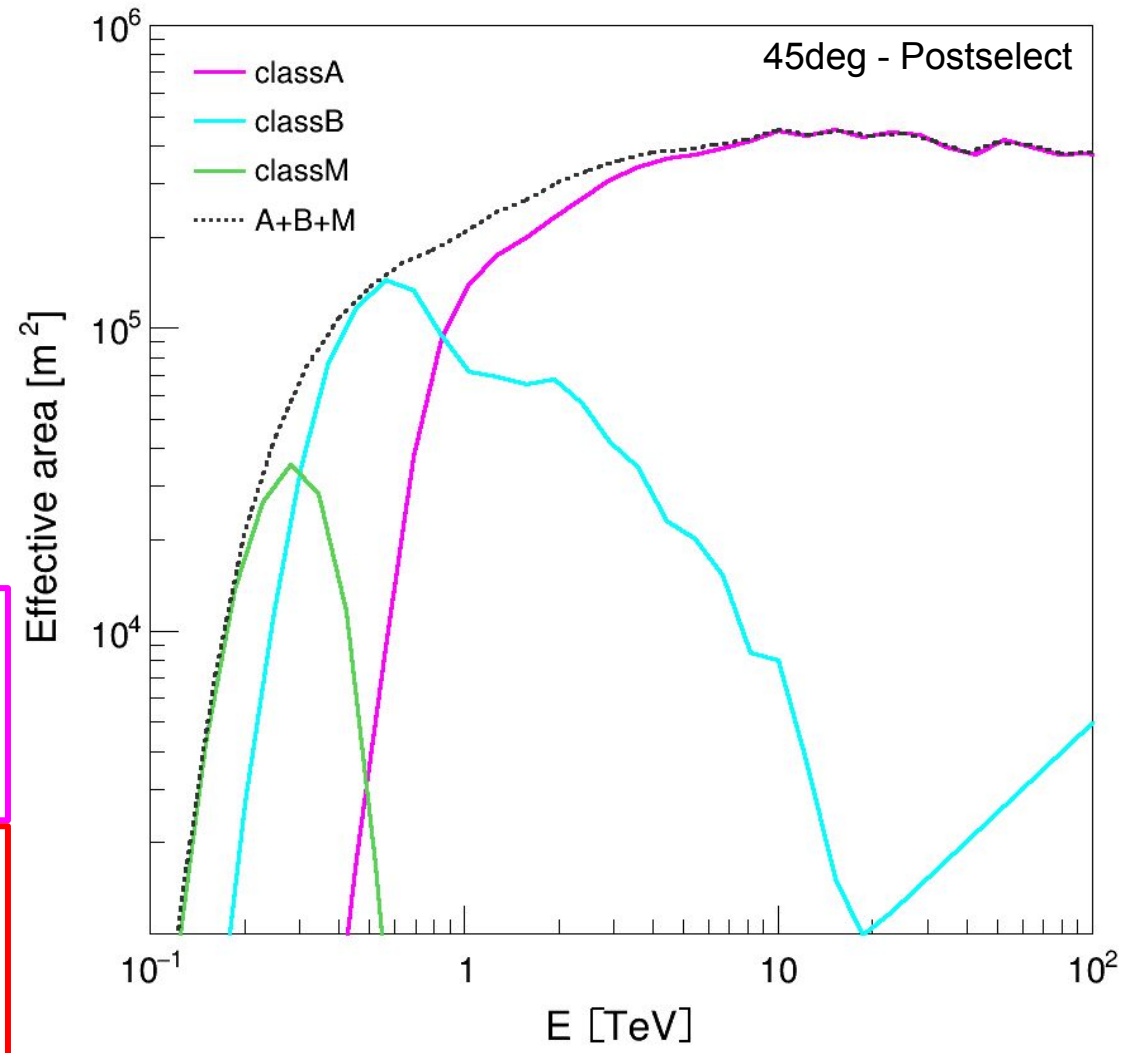
if not
C (still neglected \rightarrow very low quality events)



Event classes

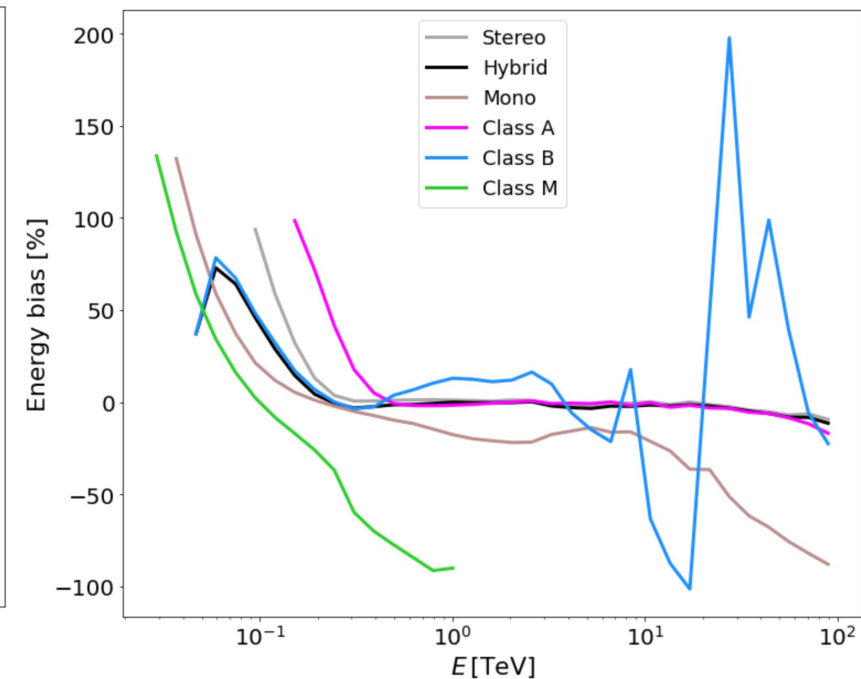
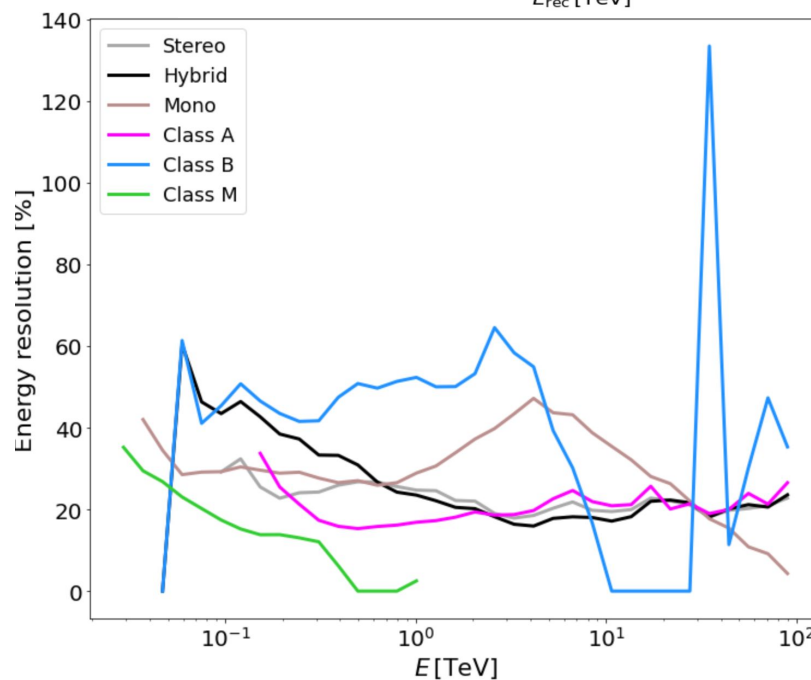
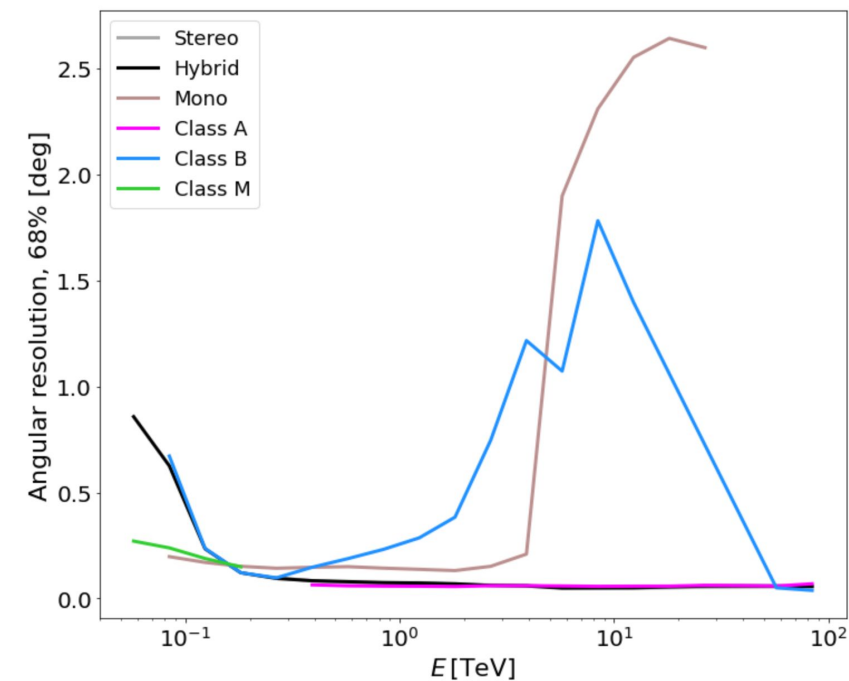
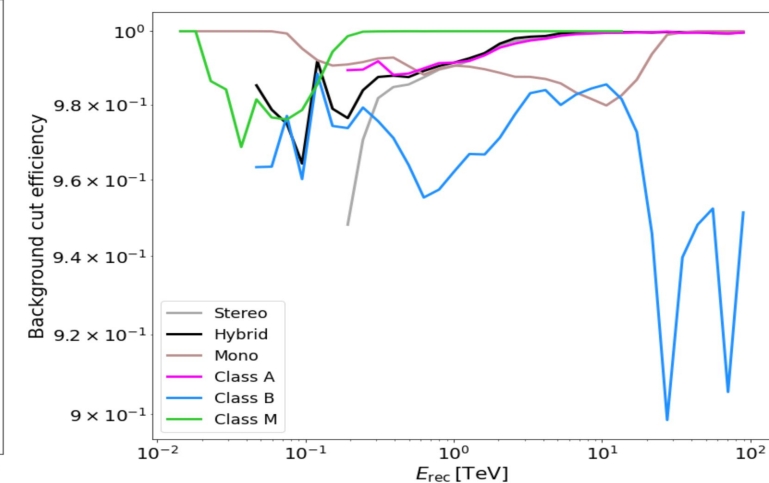
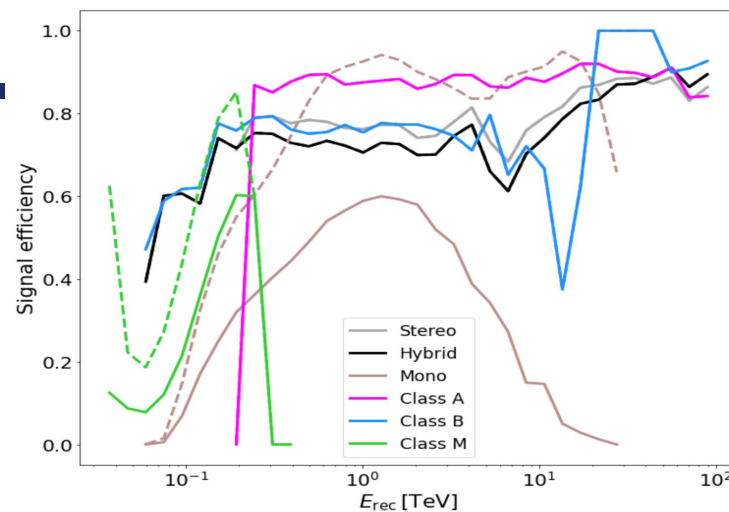


A+B+C+M exploits the full potential of the experiment

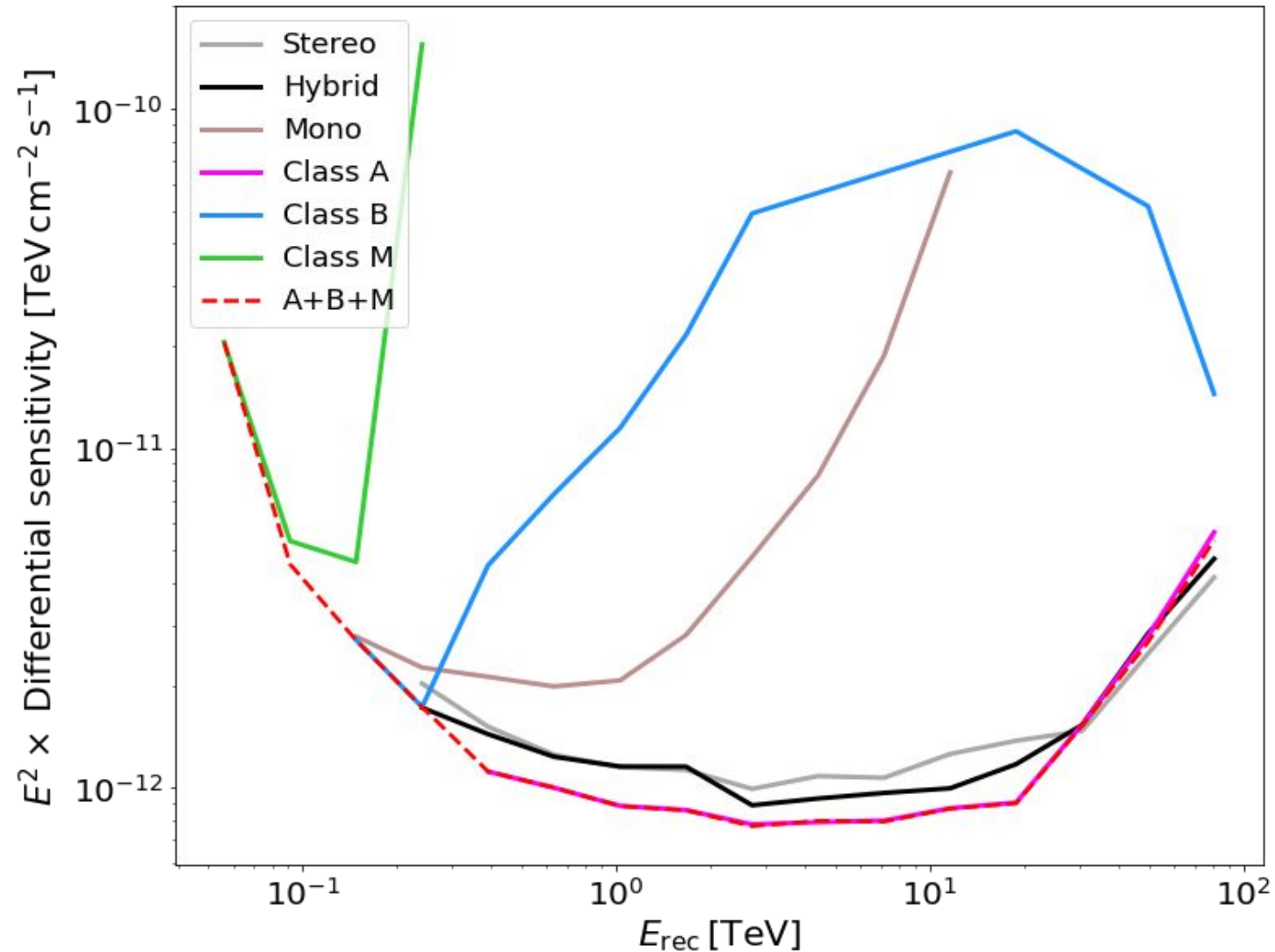


Event classes

- Implemented on HAP (HESS analysis package);
- Trained and optimized;
- Performance estimated on MC;

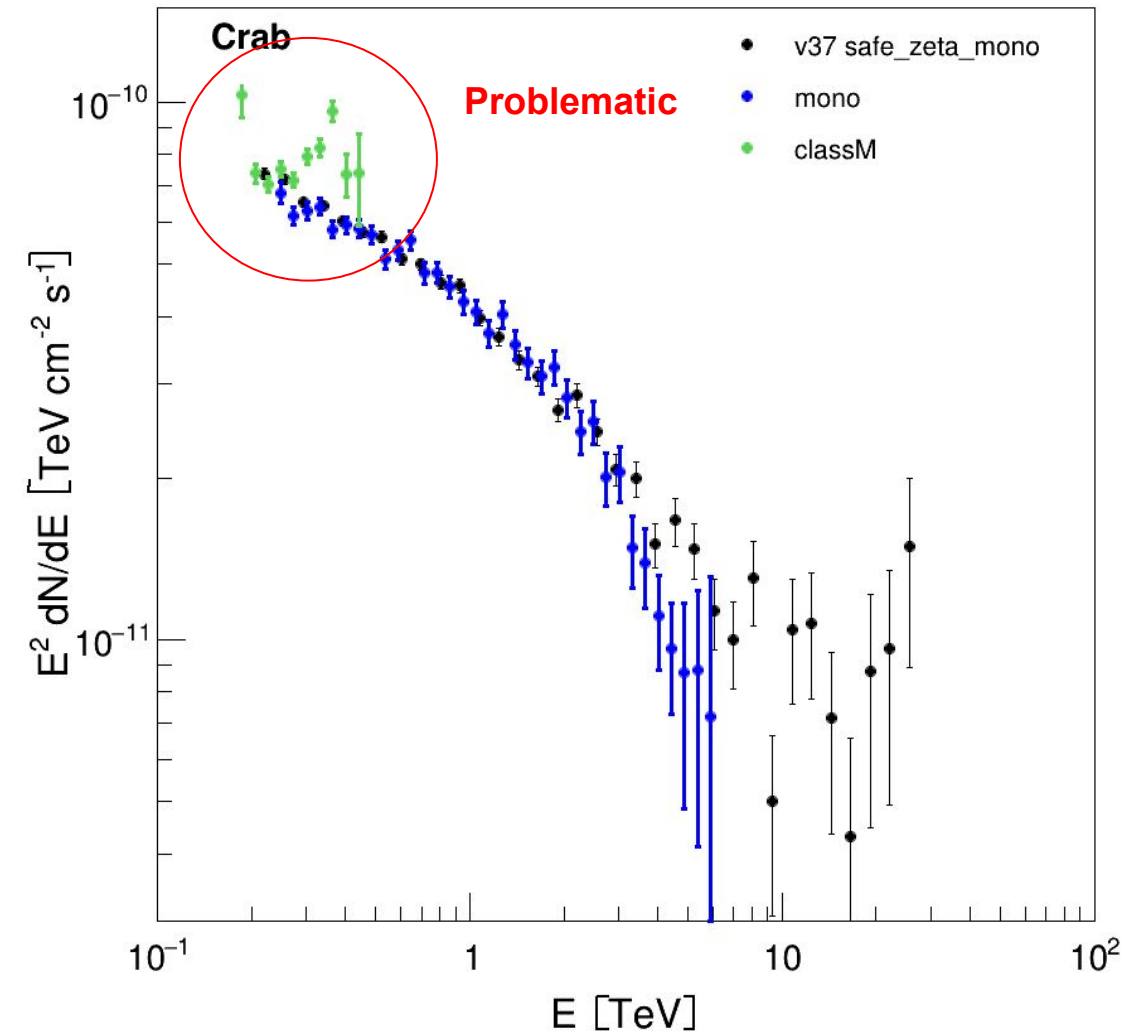


Event classes - sensitivity



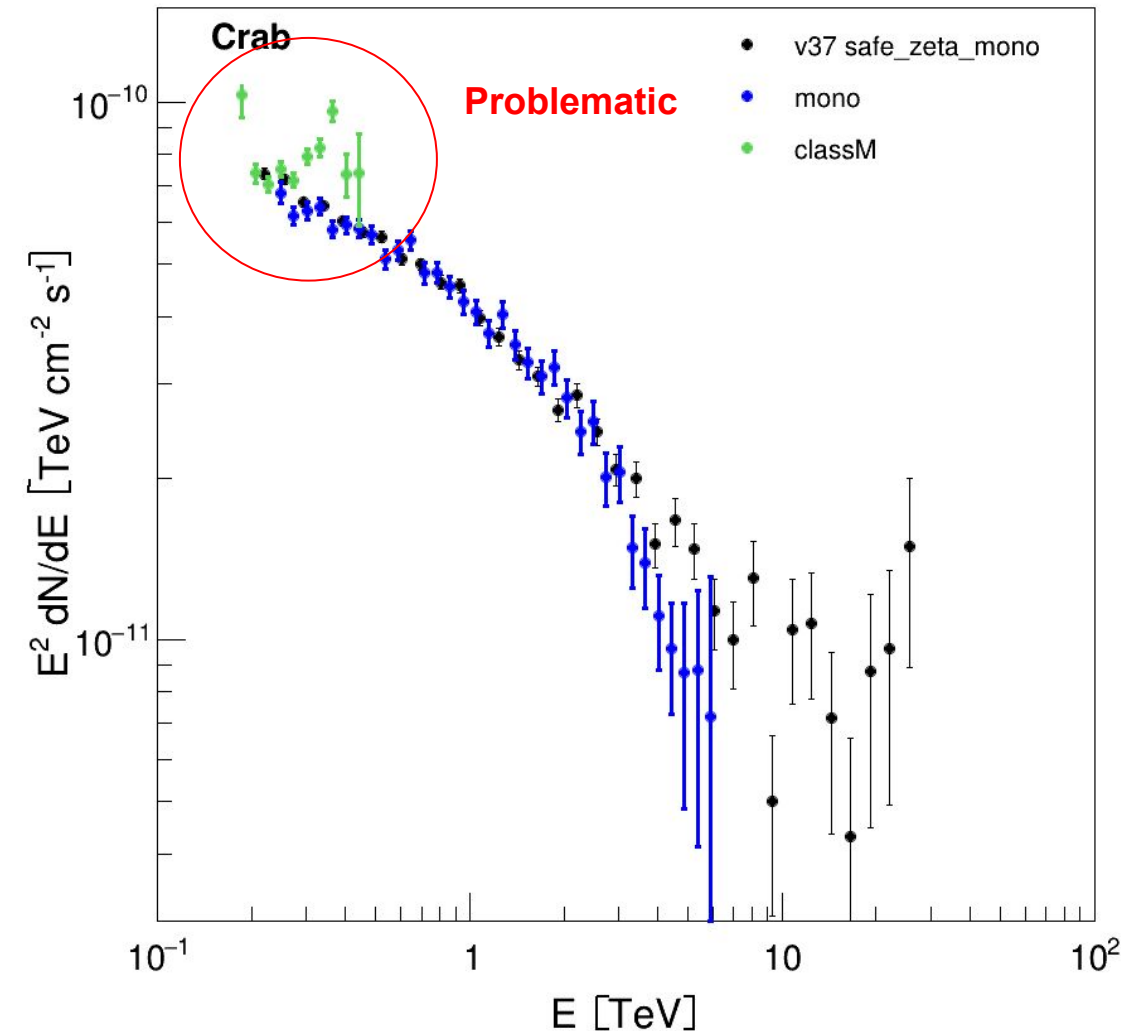
But real data can be a bit less willing to help (to be learned for CTA!)

- Tested implementation on Crab data;
- Unexpected structures on the spectrum in the energy range where the classes overlap;



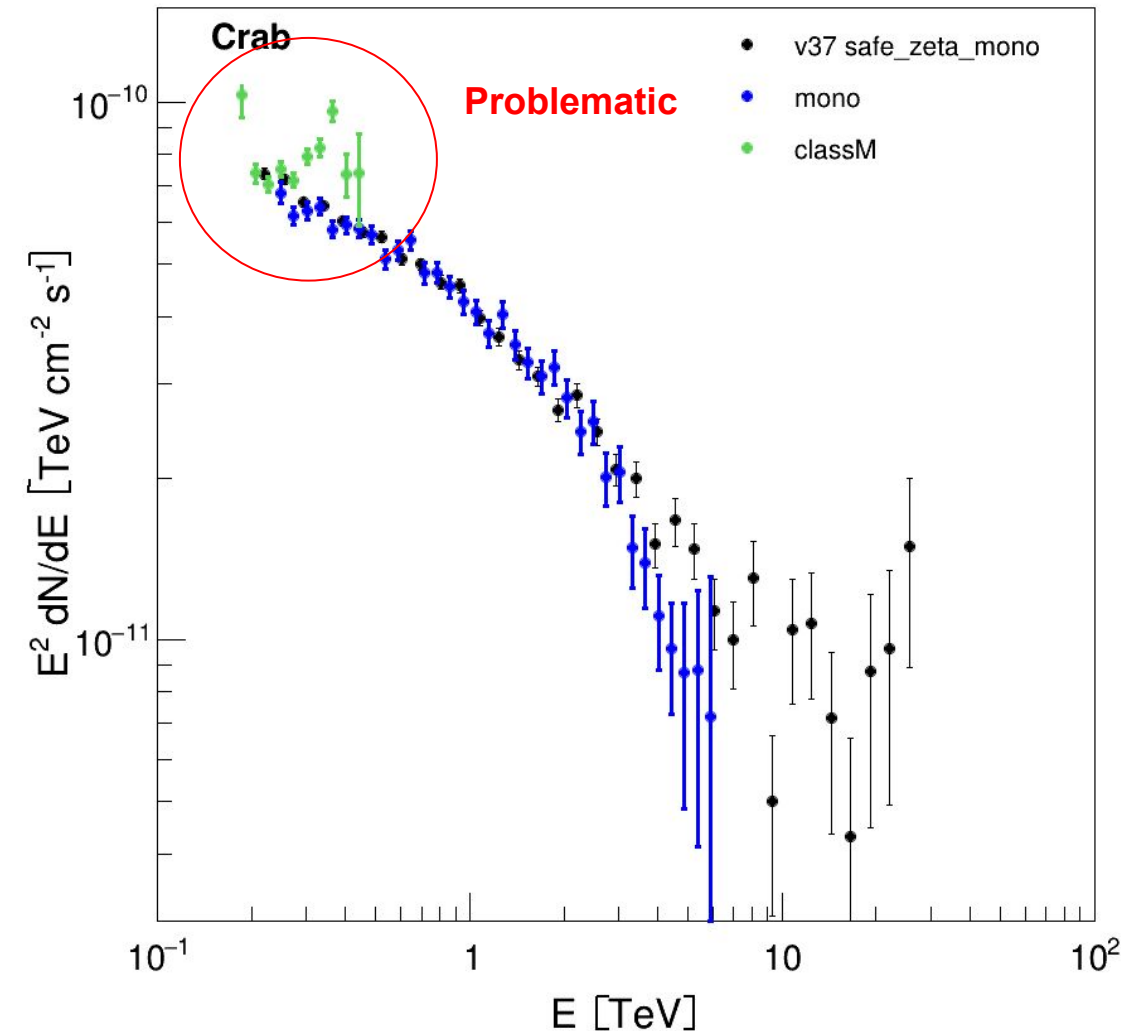
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- The separation of classes is done purely on image size, prior to any reconstruction;
- Size distributions are naturally affected by atmosphere and reflectivity (better conditions -> larger sizes);
- Different runs will then have a different class fraction;
- Calibration between different telescopes needs to be done with care!



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- Size distributions are naturally affected by atmosphere and reflectivity (better conditions -> larger sizes);
- Different runs will then have a different class fraction;
- Calibration between different telescopes needs to be done with care!
- Run by run atmospheric/reflectivity correction needed (Benedetta++)!



Conclusions and next steps

- Unified the gamma/hadron separation and reconstruction framework at HESS;
- Event classes as a possibility of exploiting the whole potential of IACTs;
- Sensitivity either as good as or better than the current scheme for the whole energy range!
- To always be kept in mind:
 - Applying new methods to real data will bring up new unexpected problems to be solved!
 - Using two (or three in the future) types of telescopes needs to be done with care!
- For HESS, we expect that after the run by run correction by Benedetta++ is implemented, classes will be fully usable;
- Then, classes++:
 - Several new ideas (how to better mix different telescopes, energy/zenith/etc dependent cuts, better mono direction reconstruction, etc);
 - Time cleaning (see Jelena's talk);
 - New variables to find muon on mono low energy events (with Tim);
- **Come talk to me about any of the topics (or more!) from the beginning of the talk!**

Muito obrigado
Vielen Dank
Thank you very much
:D

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