Search for Ultra-high Energy Neutrinos with the Pierre Auger Observatory

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Overview of my work

- How does our measure for neutrinos work on the new electronics in Auger Prime

- Search for Ultra-High-Energy Neutrinos from GRBs with the Pierre Auger Observatory - Create upper limits of UHE neutrino luminosity

- Modelling the emission region of GRBs to study survival of UHECRs and emission of neutrinos and photons

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- **How does our measure for neutrinos work on the new electronics in Auger Prime**

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Why Search for UHE neutrinos?

- UHE neutrinos will tell us more about the composition of the UHECR primaries
- UHE neutrinos could be the only direct probe into the sources of UHECRs at distances farther than ~100 Mpc

Neutrino detection principle

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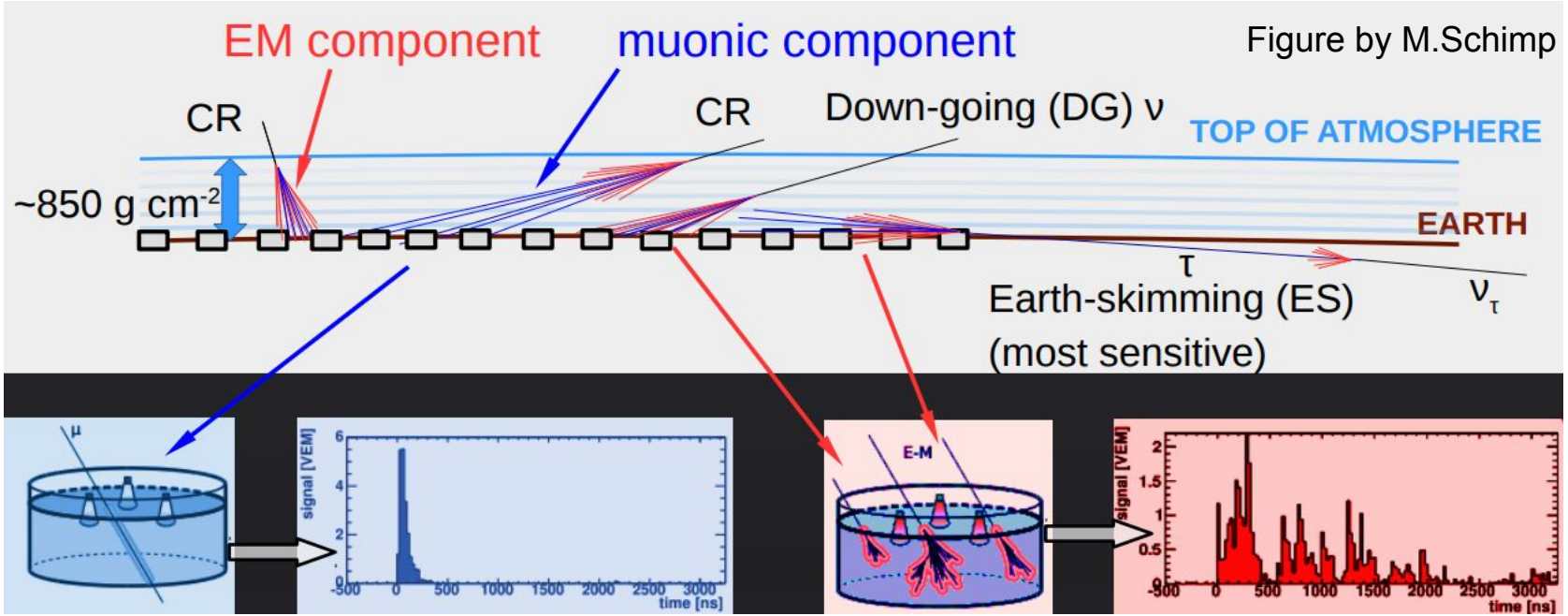
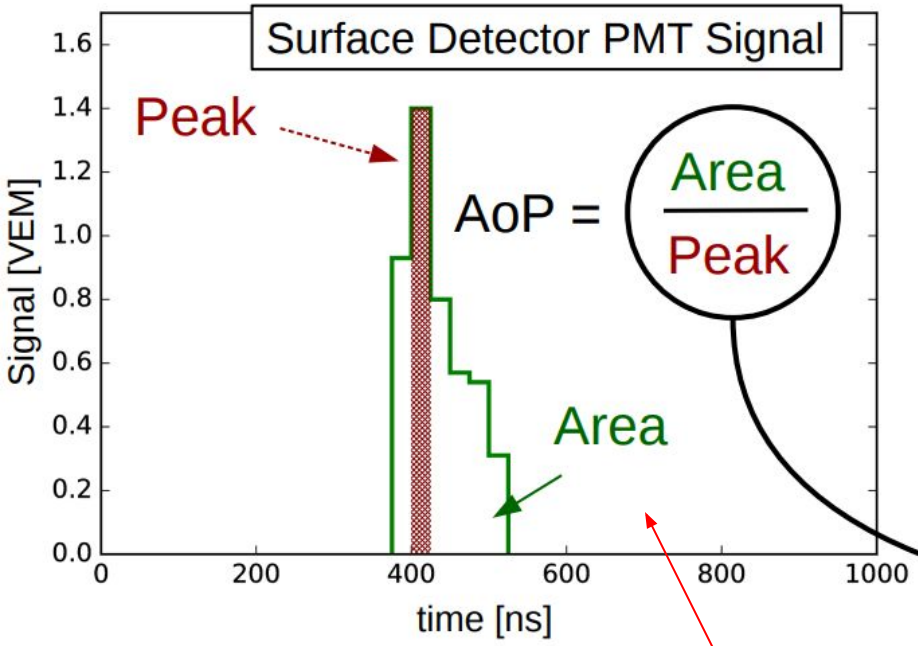
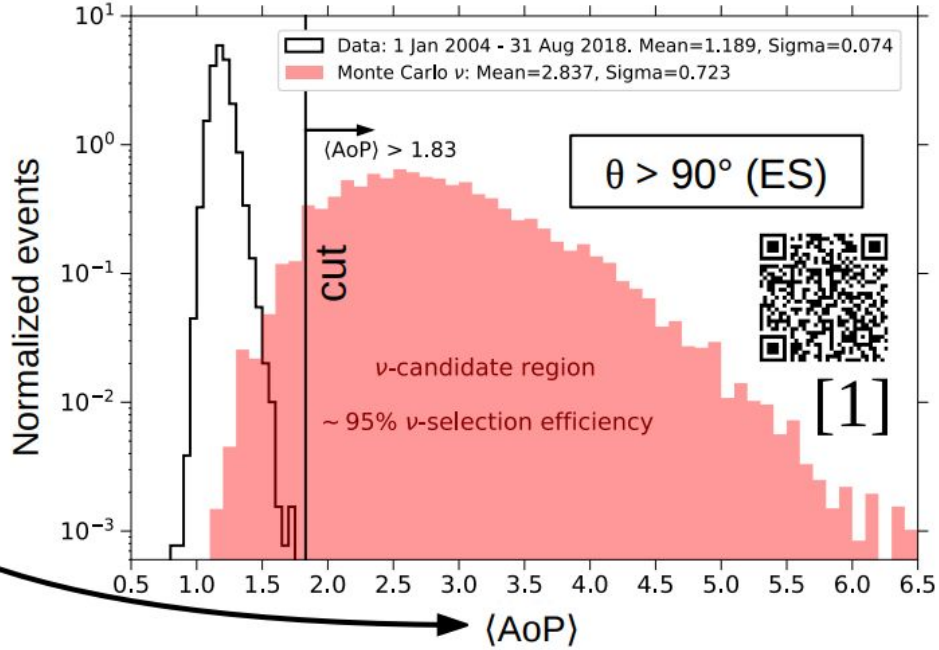
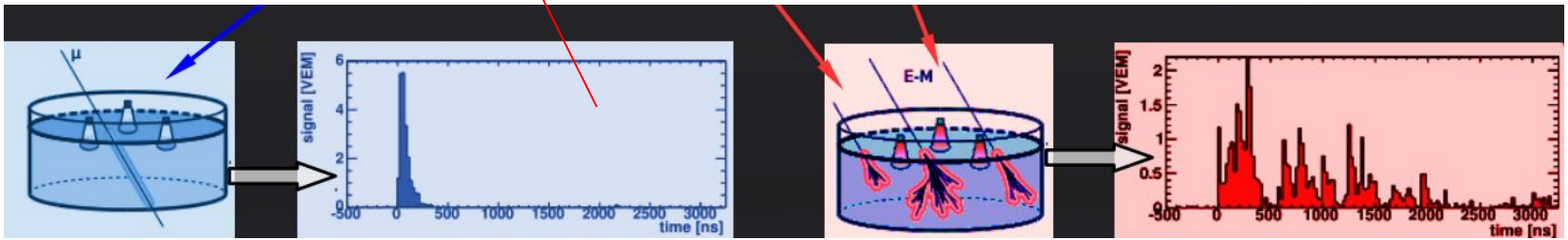
- Neutrino induced showers contains a significant electromagnetic component





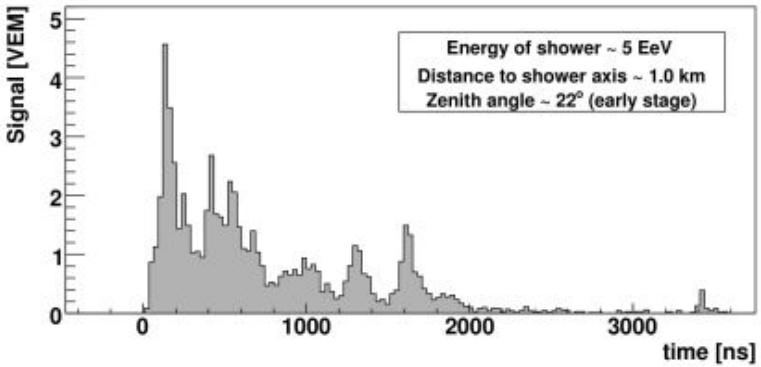




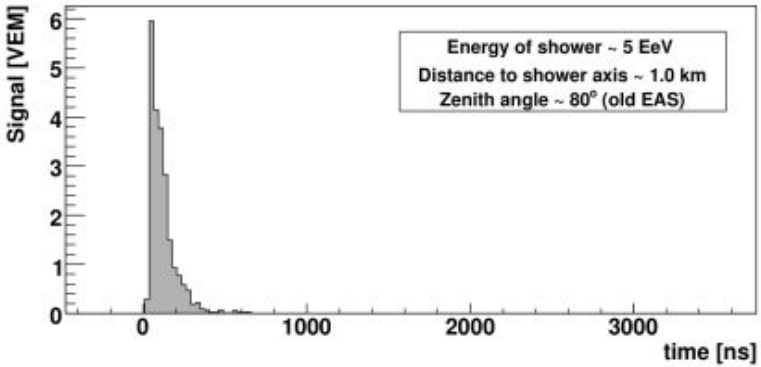
https://arxiv.org/abs/1906.07422

Measure for neutrino detection

- Current observable for detection of UHEv: ⟨AoP⟩
- AoP = The ratio of the integrated signal of the station (“Charge”) over the biggest value of the signal (“Peak”)
- For narrow signals: ⟨AoP⟩ ~ 1 For wide signals: ⟨AoP⟩ >> 1



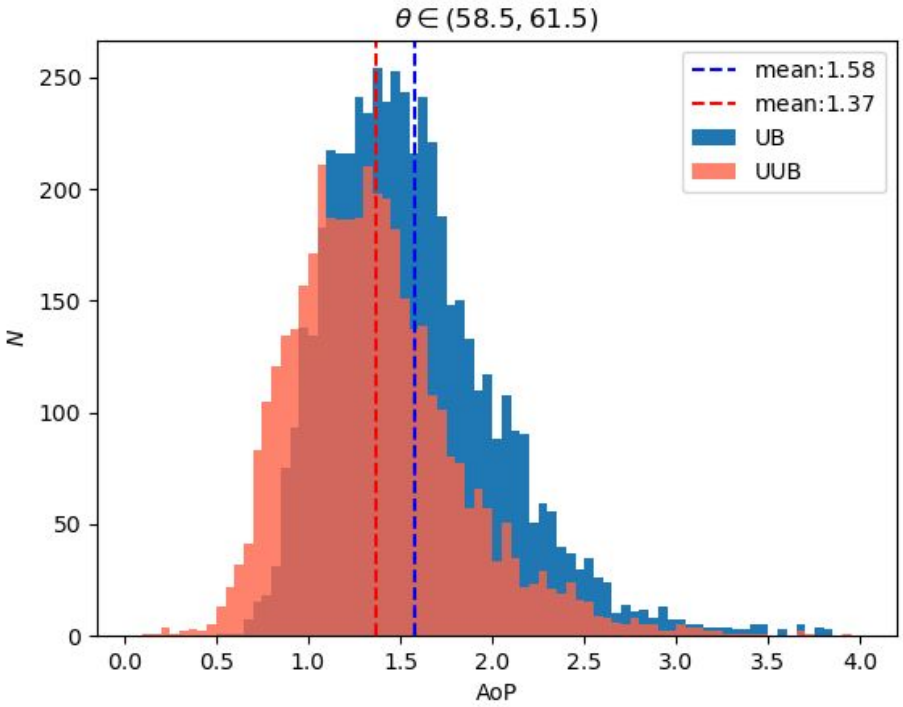
(a) Typical broad signal from a “young” EAS.



(b) Typical narrow signal from an “old” EAS.

What is the current issue with our values for ⟨AoP⟩?

- Since the change from the **Unified board** (UB) to the **Upgraded Unified Board** (UUB), we get lower values for ⟨AoP⟩
- For a angular bin in **Down Going Low** (DGL), in the period 09.2022-12.2022
- Always on-going neutrino searches → Need to adopt to the new electronics to be able to start unblinding



Current strategies of how to tackle unblinding with UUBs

- Temporary fix: Use a scaling factor (quotient of means of UB and UUB AoP distribution)
- Implement the downsampling

Implementing the Downsampling in DGL

- How we define ⟨AoP⟩ in DGL is the following:

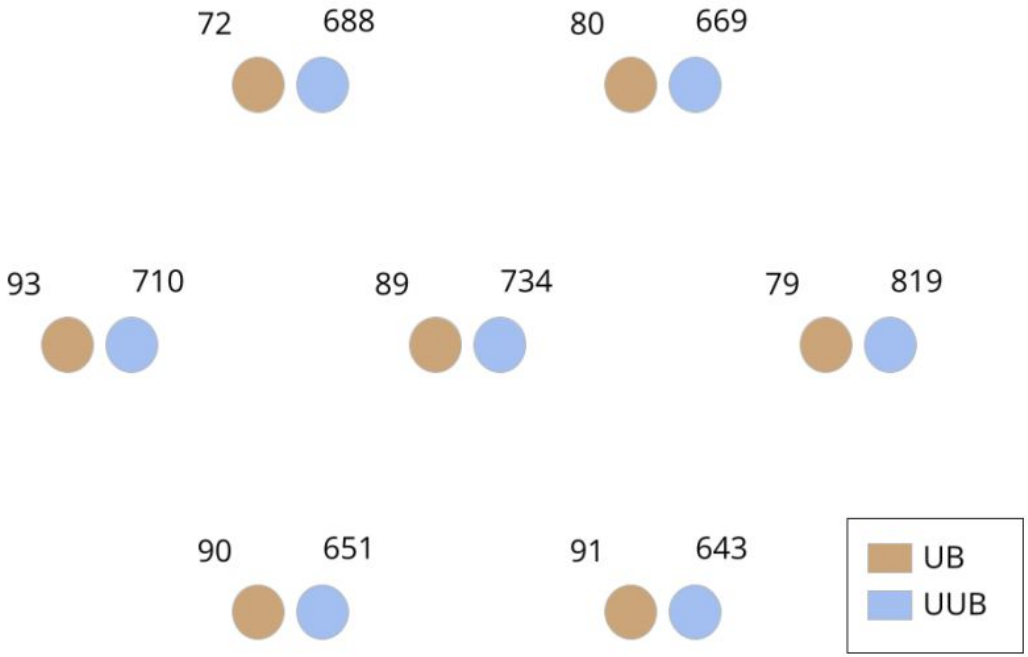
$$AoP = \frac{\sum_{i=1}^{\#PMTs} Charge_i \cdot \frac{Calib.Peak_i}{Calib.Chargei}}{\sum_{i=1}^{\#PMTs} Peak_i}$$

- Replace Charge and Peak by the ”Downsampled equivalence” by running the trace through a downsampling filter, ”UUBDownsampleFilter.h”

Current strategies of how to tackle unblinding with UUBs

- Temporary fix: Use a scaling factor (quotient of means of UB and UUB AoP distribution)
- Implement the downsampling
- Downside of scaling factor check: Measurements are not taken from the same events
- When looking at the doublet stations we can get the correction factor from the same event

Do a check on the doublet stations

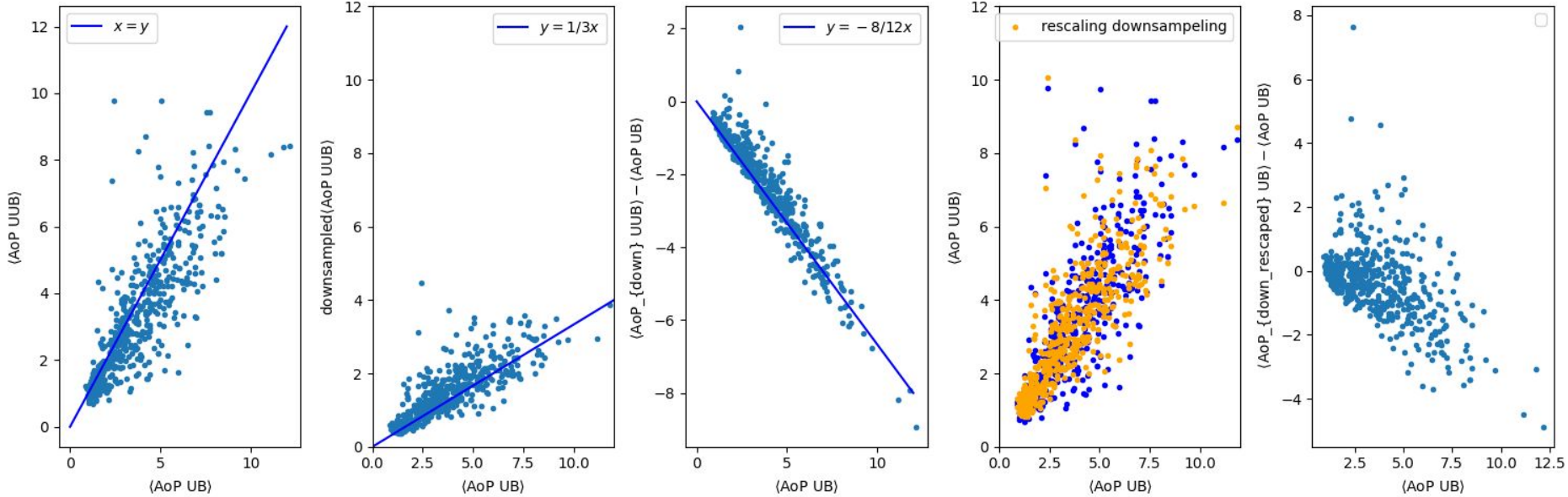


- When looking at the doublet stations we can get the correction factor between UUB and UB from the same event
- Currently: Applying a downsampling filter on the UUB traces, to see if this improves our issue

Picture taken from: GAP2023 033

Results - check on the doublet stations

Data taken between 01.2022 - 03.2024



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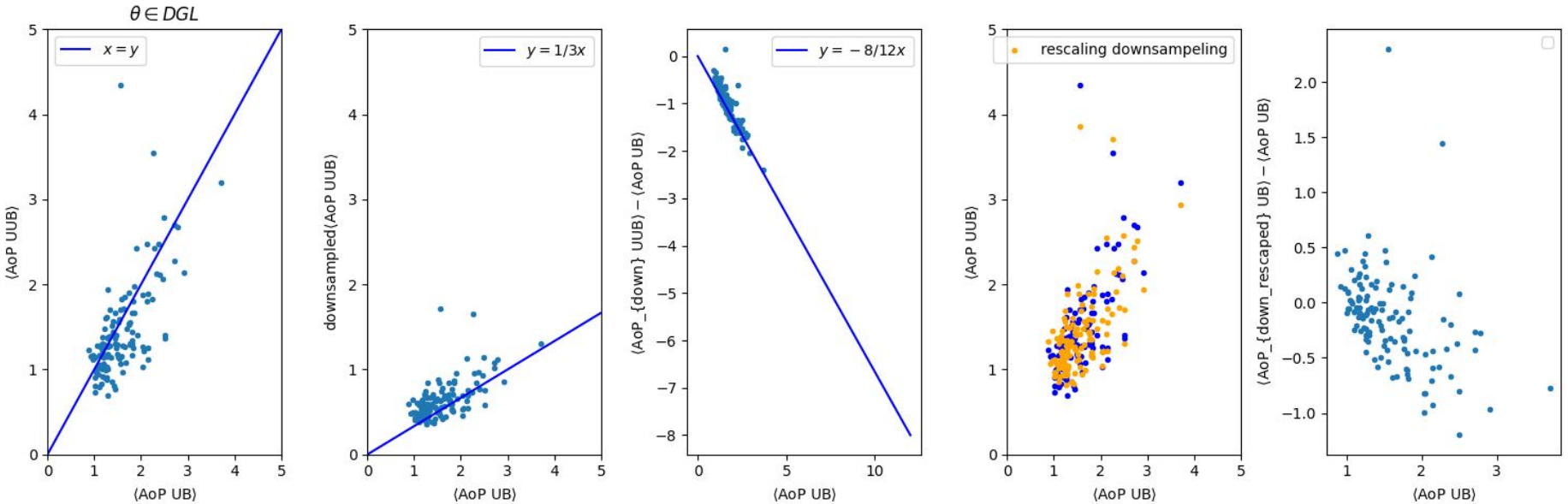
Results - check on the doublet stations



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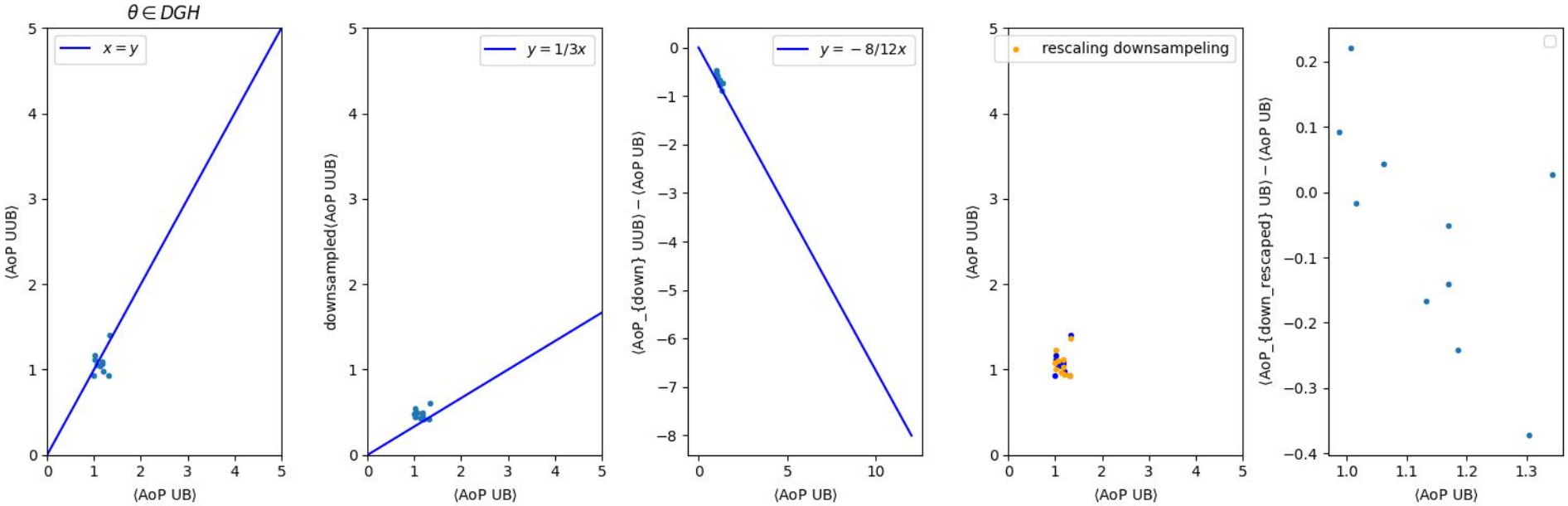
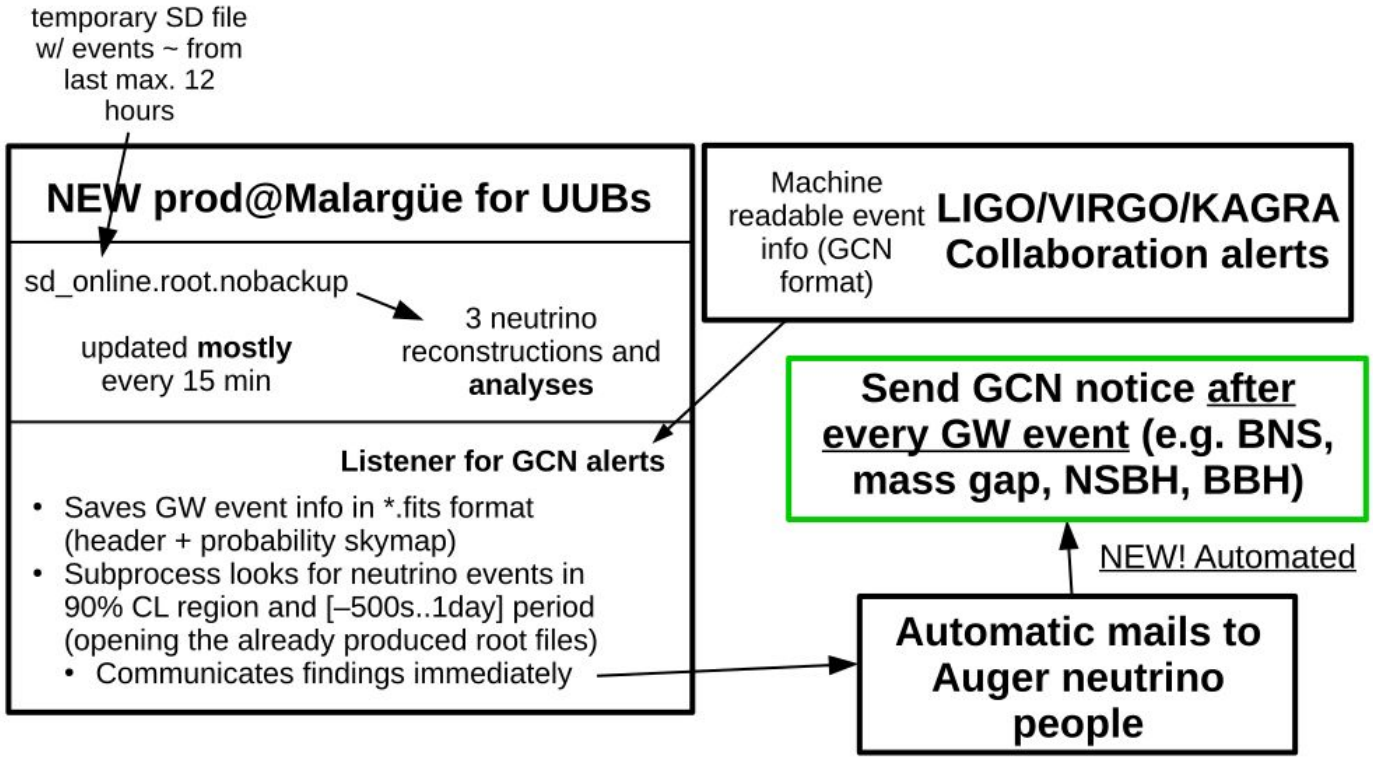


Further work

- Set up automation for General Coordinates Network (GCN) circulars following Gravitational wave (GW) events



Summary

- We want to set up the automation for the General Coordinates Network (GCN) circulars following GW events → We need a “ translation” between ⟨AoP⟩ for the UB and the UUB

- A future long-term goal of implementing a new v-analysis?

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Additional slides

Neutrino detection principle

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Selection	Earth-skimming (ES)	Downward-going *high* angle (DGH)	Downward-going *low* angle (DGL)
Flavours & Interactions	ν_τ CC	ν_e, ν_μ ,ν_τ CC & NC	ν_e, ν_μ ,ν_τ CC & NC
Angular range	$\theta > 90°$	$\theta \in (75°, 90°)$	$\theta \in (60°, 75°)$
N° of Stations ($N_{\rm st}$)	$N_{\rm st} \geq 3$	$N_{\rm st} \geq 4$	$N_{\rm st} \geq 4$

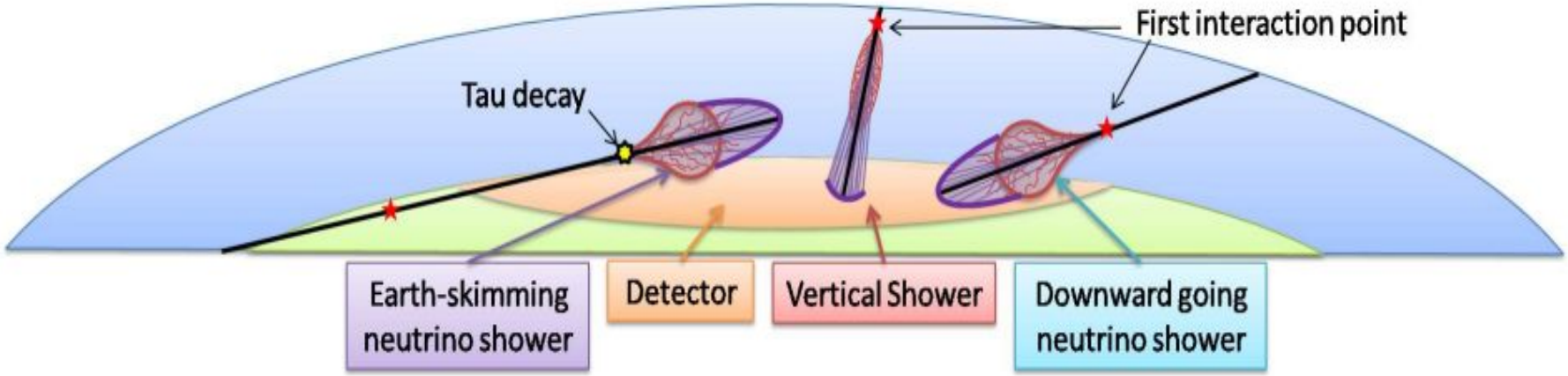

Figure by Jose Luis Navarro Quirante

Selection	Earth-skimming (ES)	Downward-going *high* angle (DGH)	Downward-going *low* angle (DGL)
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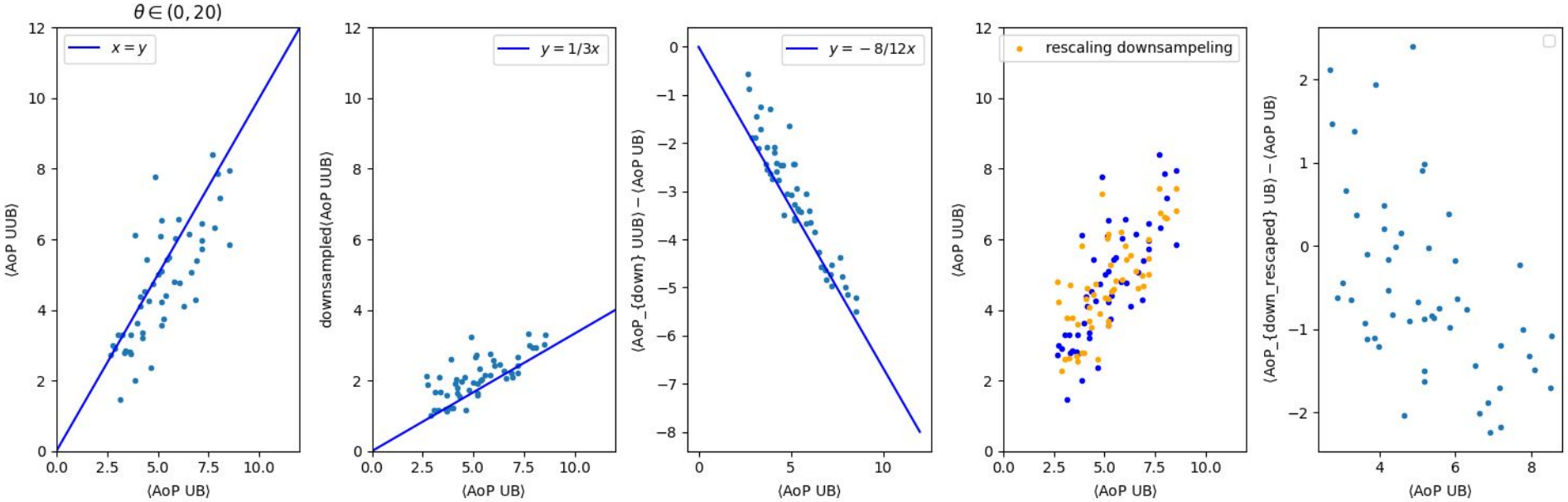
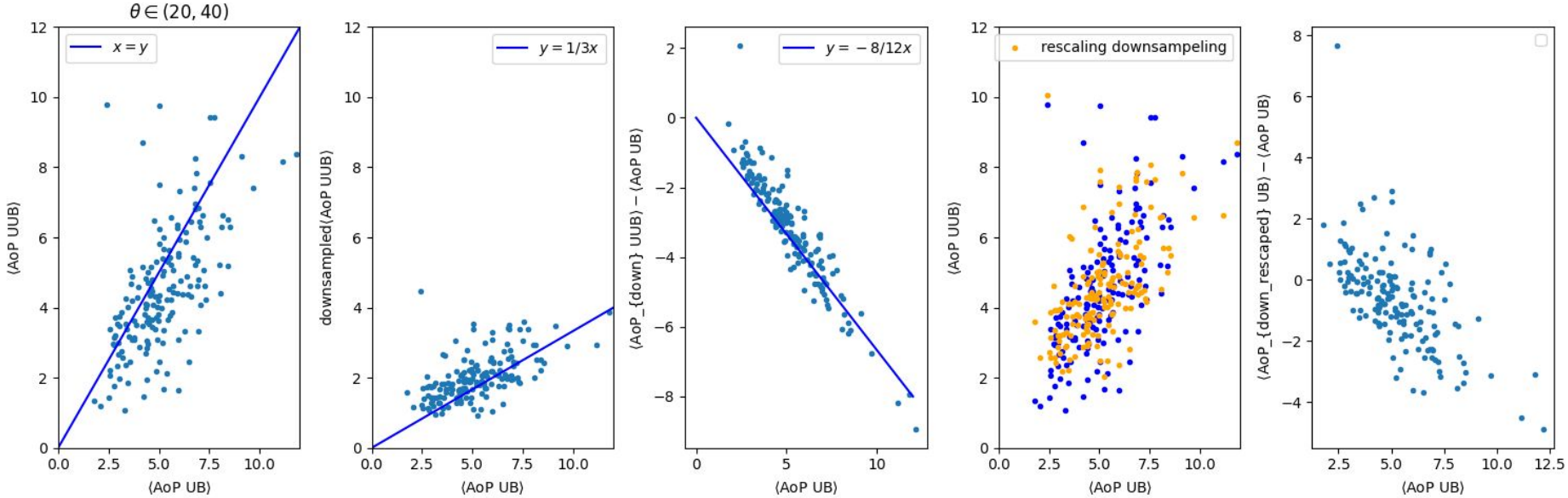
N° of Stations ($N_{\rm st}$)	$N_{\rm st} \geq 3$	$N_{\rm st} \geq 4$	$N_{\rm st} \geq 4$
	–	$\theta_{\rm rec} > 75°$	$\theta_{\rm rec} \in (58.5°,\ 76.5°)$
Inclined	$L/W > 5$	$L/W > 3$	–
Showers	$\langle V \rangle \in (0.29,\ 0.31)$ m ns^{-1}	$\langle V \rangle < 0.313$ m ns^{-1}	–
	RMS$(V) < 0.08$ m ns^{-1}	RMS$(V)/\langle V \rangle < 0.08$	–
	Data: 1 January 2004 - 31 May 2010		$\geq 75\%$ of stations close to
	$\geq 60\%$ of stations with		shower core with ToT trigger
Young	ToT trigger & AoP > 1.4	Fisher discriminant based	&
Showers	Data: 1 June 2010 - 20 June 2013	on AoP of *early* stations	Fisher discriminant based
	$\langle$AoP$\rangle > 1.83$		on AoP of *early* stations
	AoP$_{\rm min} > 1.4$ if $N_{\rm st}$=3		close to shower core


$\theta \in (0, 20)$
$x = y$
⟨AoP UUB⟩
⟨AoP UB⟩
$y = 1/3x$
downsampled⟨AoP UUB⟩
⟨AoP UB⟩
$y = -8/12x$
⟨AoP_{down} UUB⟩ − ⟨AoP UB⟩
⟨AoP UB⟩
rescaling downsampeling
⟨AoP UUB⟩
⟨AoP UB⟩
⟨AoP_{down_rescaped} UB⟩ − ⟨AoP UB⟩
⟨AoP UB⟩


$\theta \in (20, 40)$
$x = y$
⟨AoP UUB⟩
⟨AoP UB⟩
$y = 1/3x$
downsampled⟨AoP UUB⟩
⟨AoP UB⟩
$y = -8/12x$
⟨AoP_{down} UUB⟩ − ⟨AoP UB⟩
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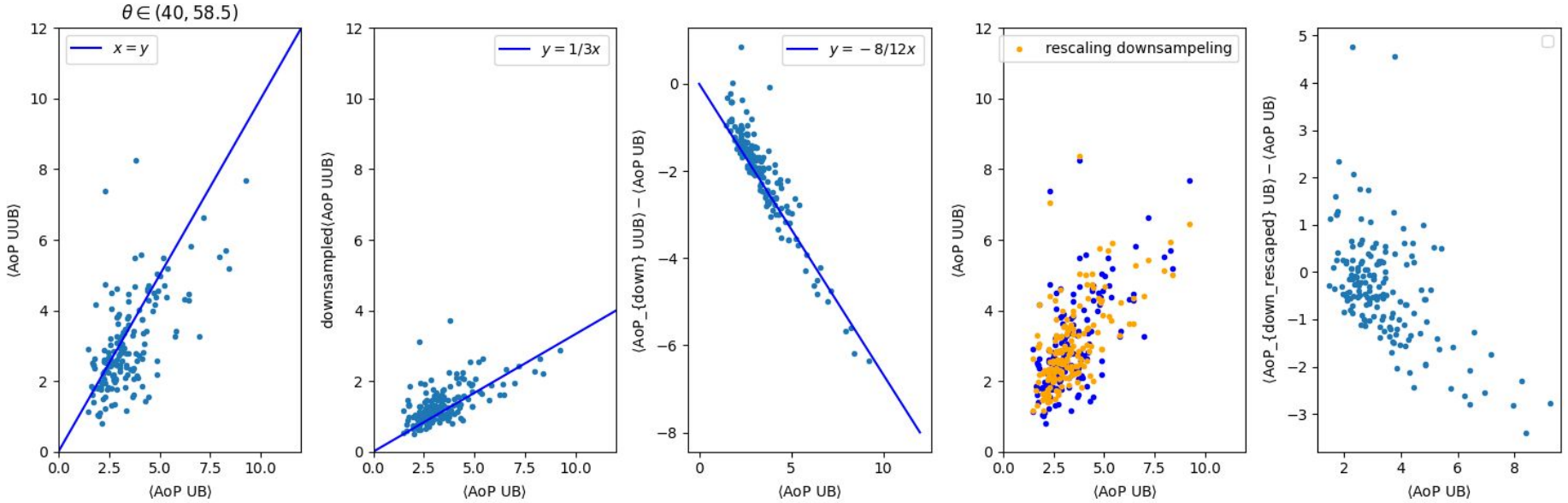
⟨AoP UB⟩


$\theta \in (40, 58.5)$
$x = y$
⟨AoP UUB⟩
⟨AoP UB⟩
$y = 1/3x$
downsampled⟨AoP UUB⟩
$y = -8/12x$
⟨AoP_{down} UUB⟩ − ⟨AoP UB⟩
rescaling downsampeling
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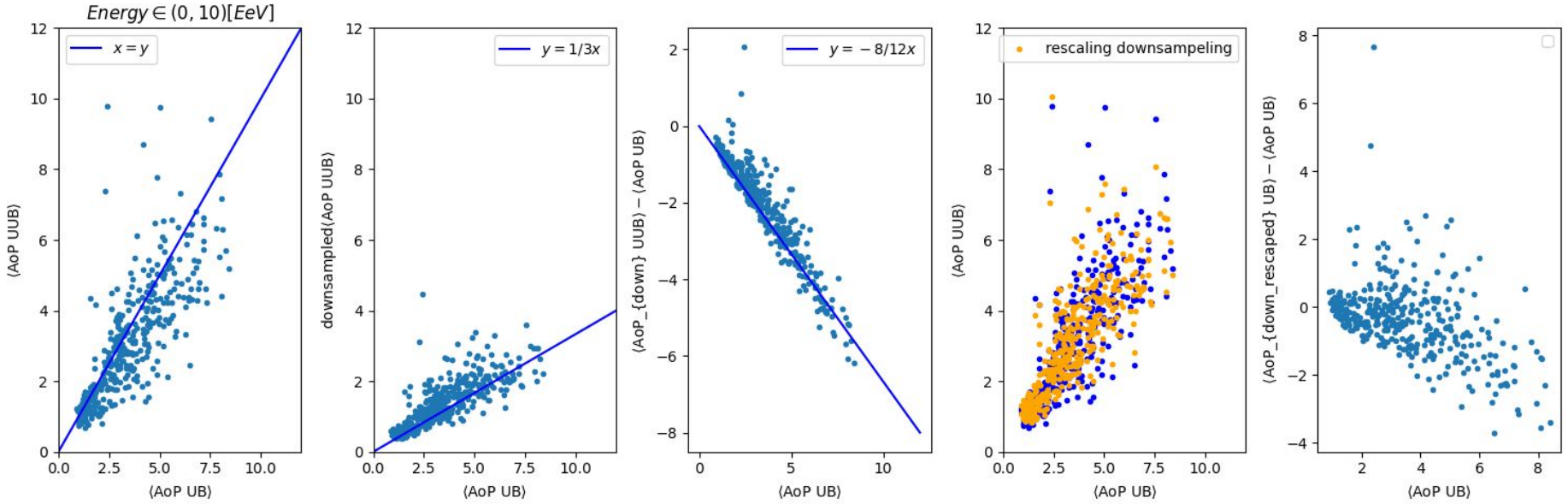
$Energy \in (0, 10)[EeV]$
$x = y$
⟨AoP UUB⟩
⟨AoP UB⟩
$y = 1/3x$
downsampled⟨AoP UUB⟩
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rescaling downsampeling
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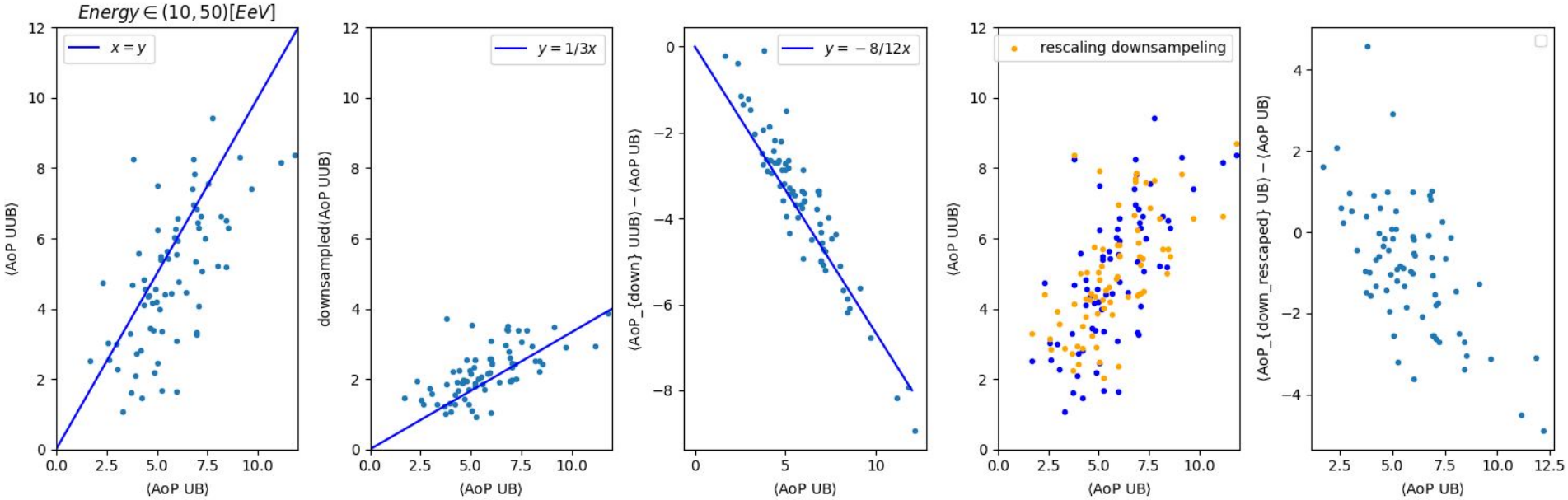
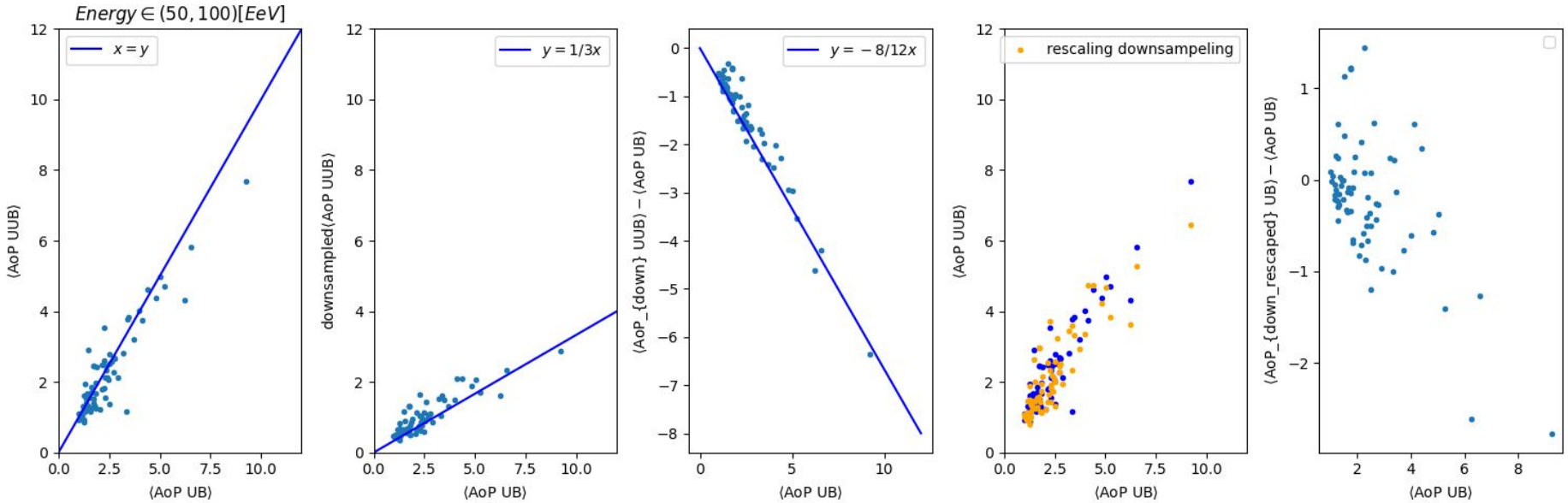

$Energy \in (10, 50)[EeV]$
$x = y$
⟨AoP UUB⟩
⟨AoP UB⟩
$y = 1/3x$
downsampled⟨AoP UUB⟩
⟨AoP UB⟩
$y = -8/12x$
⟨AoP_{down} UUB⟩ − ⟨AoP UB⟩
⟨AoP UB⟩
rescaling downsampeling
⟨AoP UUB⟩
⟨AoP UB⟩
⟨AoP_{down_rescaped} UB⟩ − ⟨AoP UB⟩
⟨AoP UB⟩


$Energy \in (50, 100)[EeV]$
$x = y$
⟨AoP UUB⟩
⟨AoP UB⟩
$y = 1/3x$
downsampled⟨AoP UUB⟩
$y = -8/12x$
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