



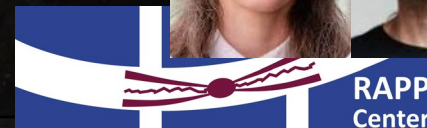
**CRC 1491**



**Cosmic Interacting Matters (CIM)  
From Source to Signal  
It's (almost) half-time!**

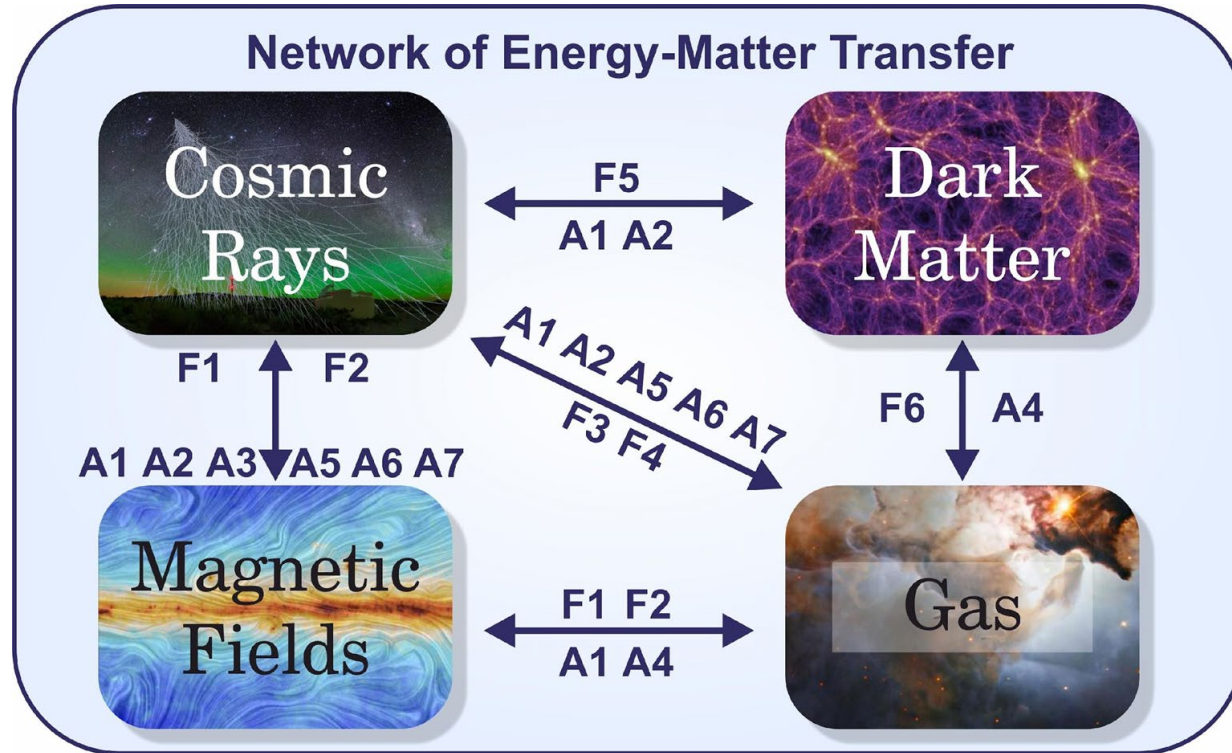


Julia Tjus | 18.09.2023



**RAPP  
Center**

# Our proposal: Creating a unifying view on Cosmic Interacting Matters

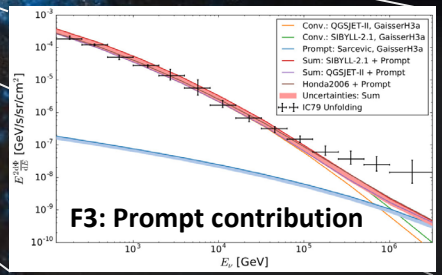
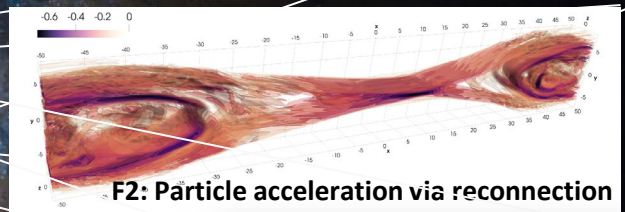
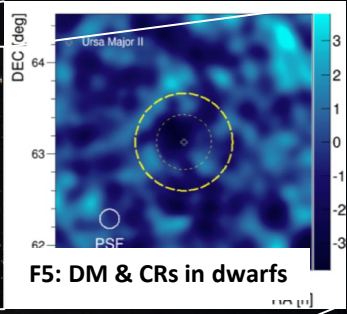
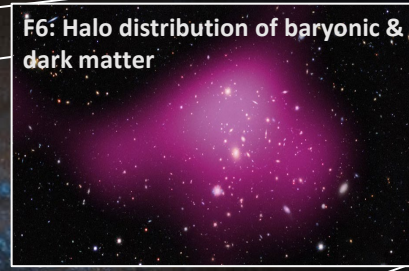
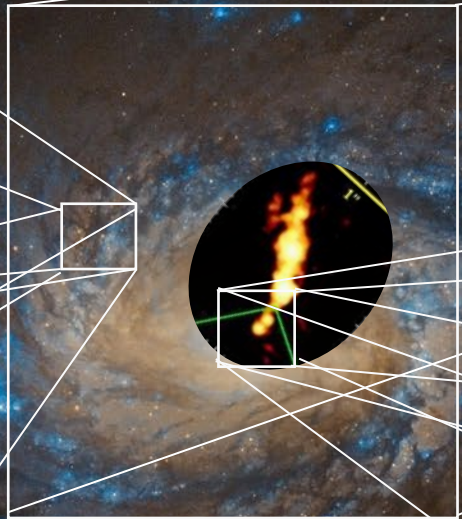
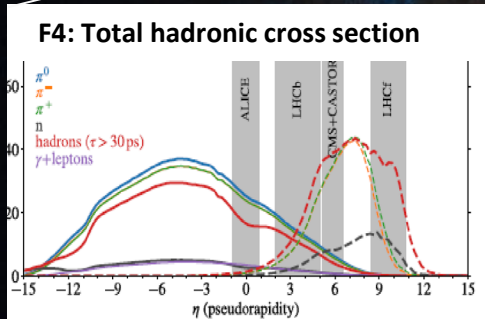
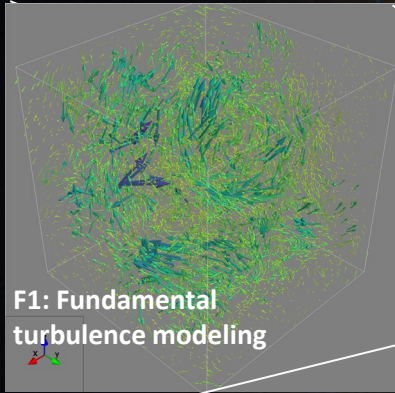


**Research area A (A1-A7):**  
Transport phenomena in astrophysical plasmas

**Research area F (F1-F6):**  
Fundamental properties of matter



# Our proposal: combine fundamental physics with astrophysics



Connecting plasma- & astrophysics @ RUB

Connecting particle- and astroparticle physics, existing network RUB-TUDO-BUW

# Promises for Phase 1



End of:	2022	2023	2024	2025	Collaborating Projects
1.P1		A4.M1 F1.M1 F2.M2	A4.M4 A4.M3	KM1	(A1, A2, A3, A4, F1)
1.P2		A4.M2 F2.M1		KM2	(A5, A6, A7, F2)
2.P3		A7.M1 F3.M1	A7.M1	KM3	(A5, A7, F3)
2.P4		F4.M1	A7.M1 A7.M2	KM3	(A1, A2, A3, A5, A7, F4)
3.P5		F6.M1	A2.M1	KM4	(A1, A2, A4, F5, F6)

# Trans-disciplinary structure of the CRC



Astrophysical signatures		PIs	
A1	Galactic Center	<a href="#">Fichtner</a>	Franckowiak
A2	Dwarf galaxies	Bomans	<a href="#">Tjus</a>
A3	Knee-to-ankle region	Kampert	<a href="#">Tjus</a>
A4	Starburst galaxies	<a href="#">Fichtner</a>	Dettmar
A5	Starburst-AGN-composits	Dettmar	<a href="#">Eichmann</a>
A6	Tidal Disruption Events	Franckowiak	<a href="#">Dettmar, Kuiper</a>
A7	Multimessenger modeling of AGN	Rhode	<a href="#">Tjus</a>

Fundamental properties		PIs	
F1	Intermittency and diffusion	<a href="#">Grauer</a>	<a href="#">Fichtner</a>
F2	Plasma Instabilities	<a href="#">Innocenti</a>	<a href="#">Grauer</a>
F3	Prompt muons	Albrecht*	Rhode
F4	Hadronic cross sections	Kampert	<a href="#">Kröniger* + Albrecht</a>
F5	Dark matter in dwarfs	Hildebrandt	Elsässer
F6	Dark matter and gas	Bomans	Wright
F7	Scale-bridging plasma dynamics to understand relativistic astrophysical jets	<a href="#">Kormann</a>	

New in A: Welcome Rolf Kuiper (A6, MERCUR-review)

New in F: Welcome Katharina Kormann (F7, DFG-approved)



Particle   Astroparticle   **Astro/Cosmo**   Plasma



# New projects: A6-2 and F7



- Rolf Kuiper/Anna Franckowiak: Modeling Tidal Disruption Events and their Observational Signatures (added to A6)

▪ Doctoral Researcher:  
Luke Comny



- Katharina Kormann: Skalenübergreifende Plasmadynamik für die Untersuchung relativistischer kosmischer Jets (new number F7)

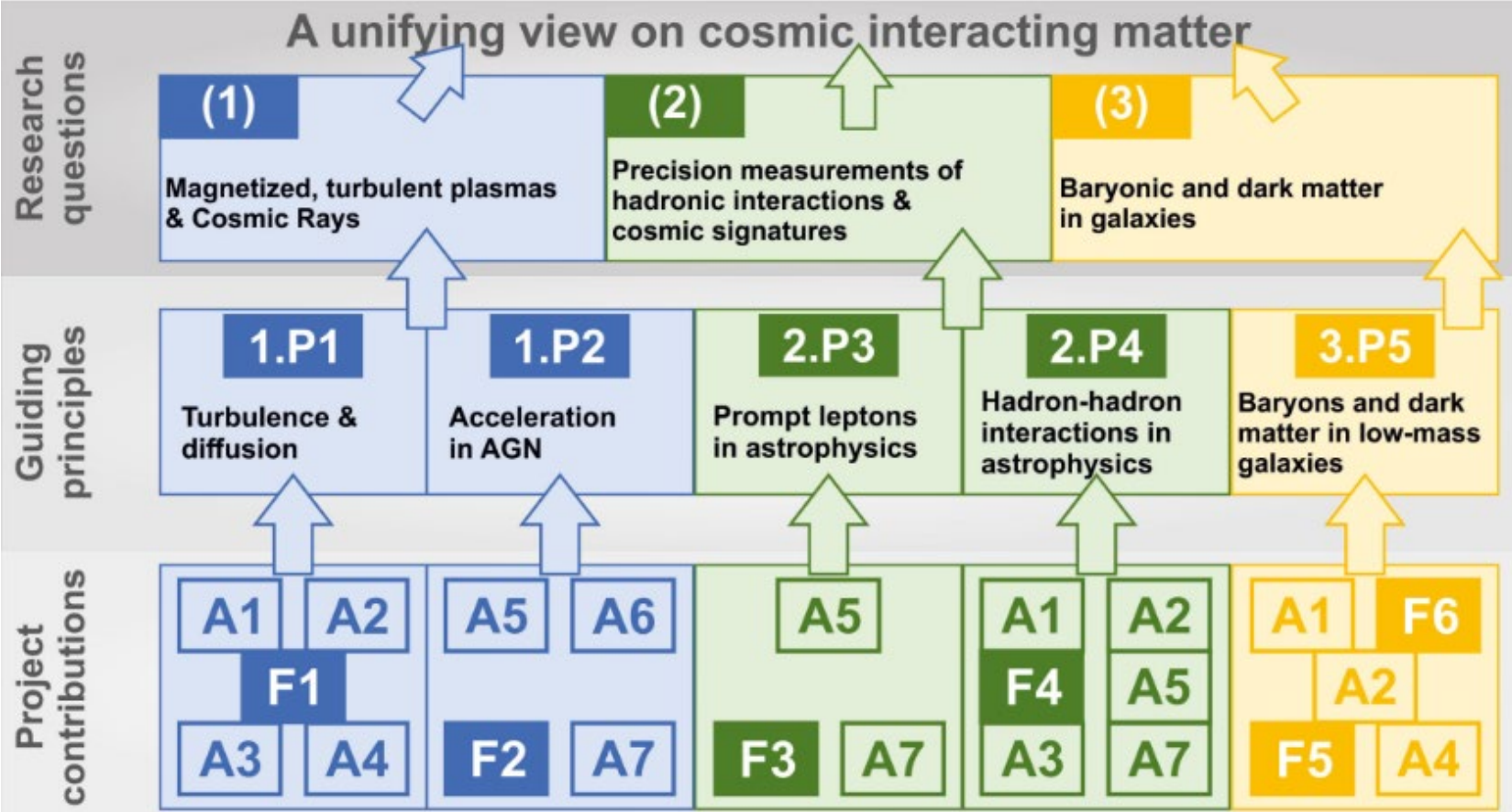
▪ Doctoral Researcher:  
Tileuzhan Mukhamet



## Welcome!



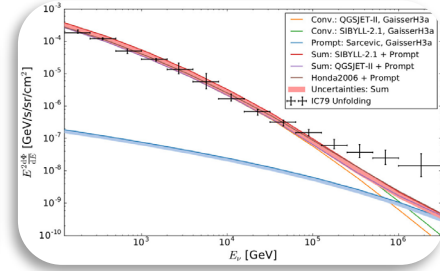
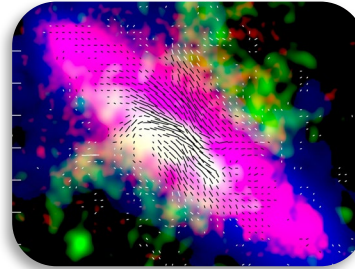
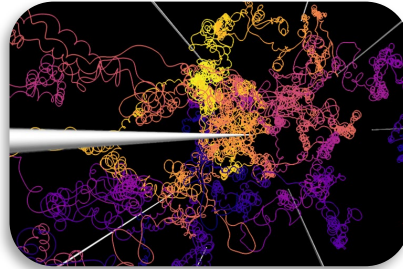
# Working Groups follow guiding principles



# This talk: Where we are and where we want to go:



## (1) Physics Program



## (2) Program implementation and structural elements in CIM

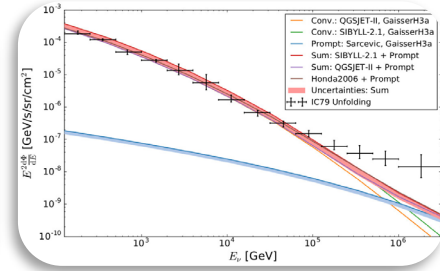
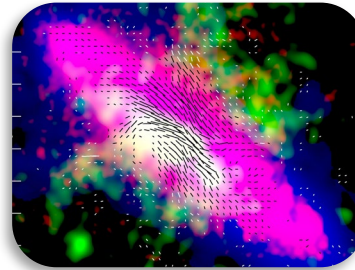
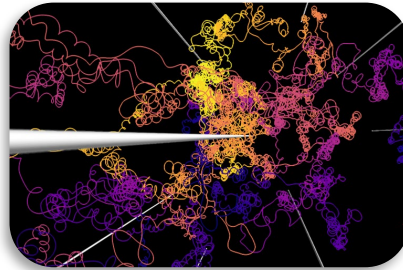




# This talk: Where we are and where we want to go:



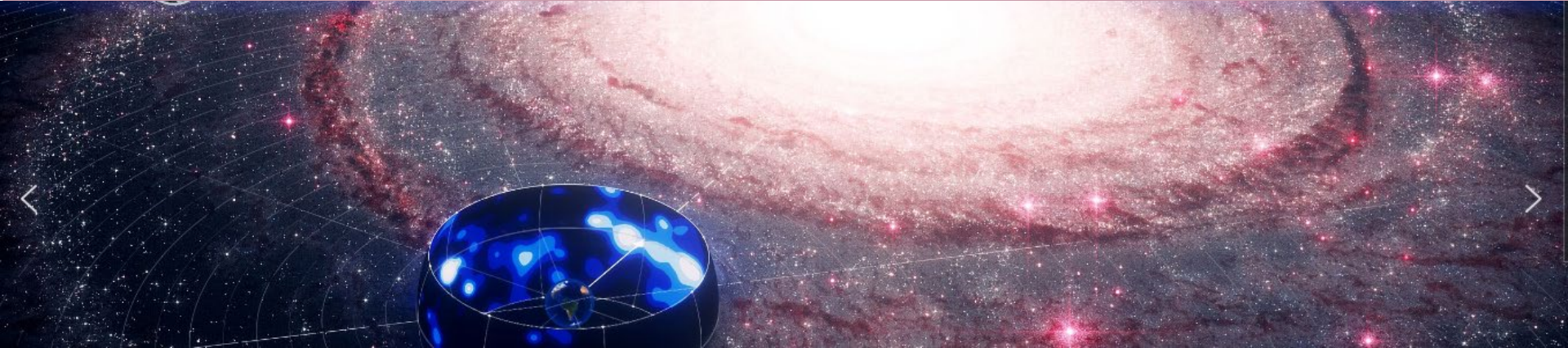
## (1) Physics Program



## (1) Program implementation and structural elements in CIM

# Some physics highlights

## Examples



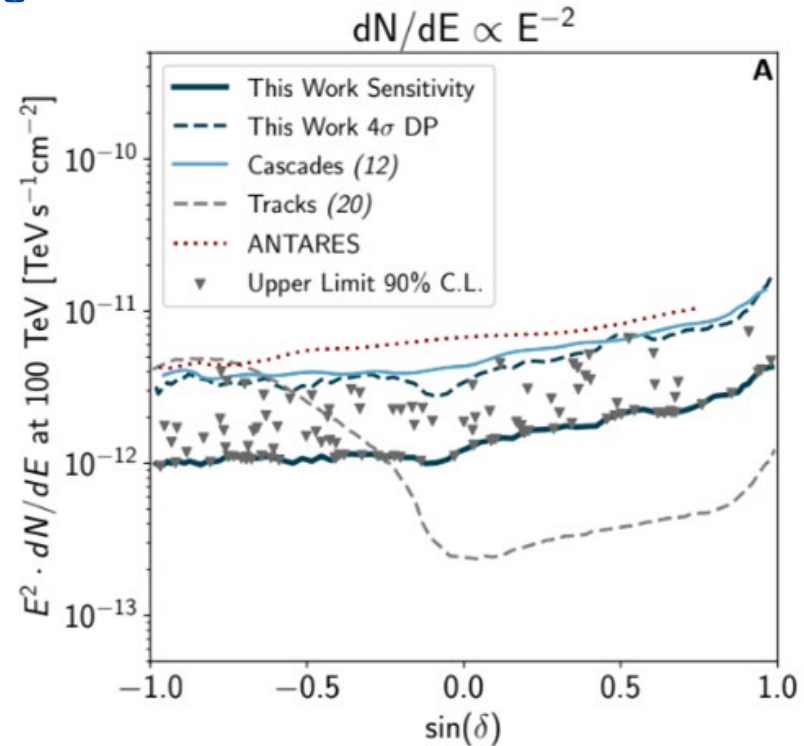
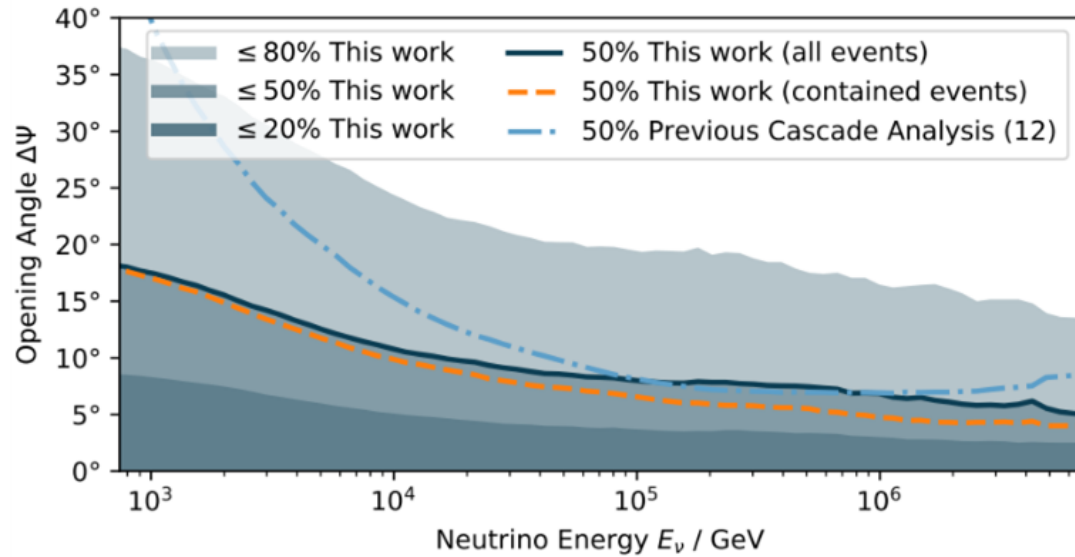
- Unexpected result (A1/F3)
  - Detection of Galactic Plane in Neutrinos
- Methodological Highlight (A1, A2, A3, A5, A7, F1, F2, F4)
  - CRPropa 3.2 paper
- Collaborative Highlight (F3, F4)
  - Review paper on Muon Puzzle

Examples - far from giving a complete overview!

# Scientific Highlight: Neutrino search with DNN reconstruction



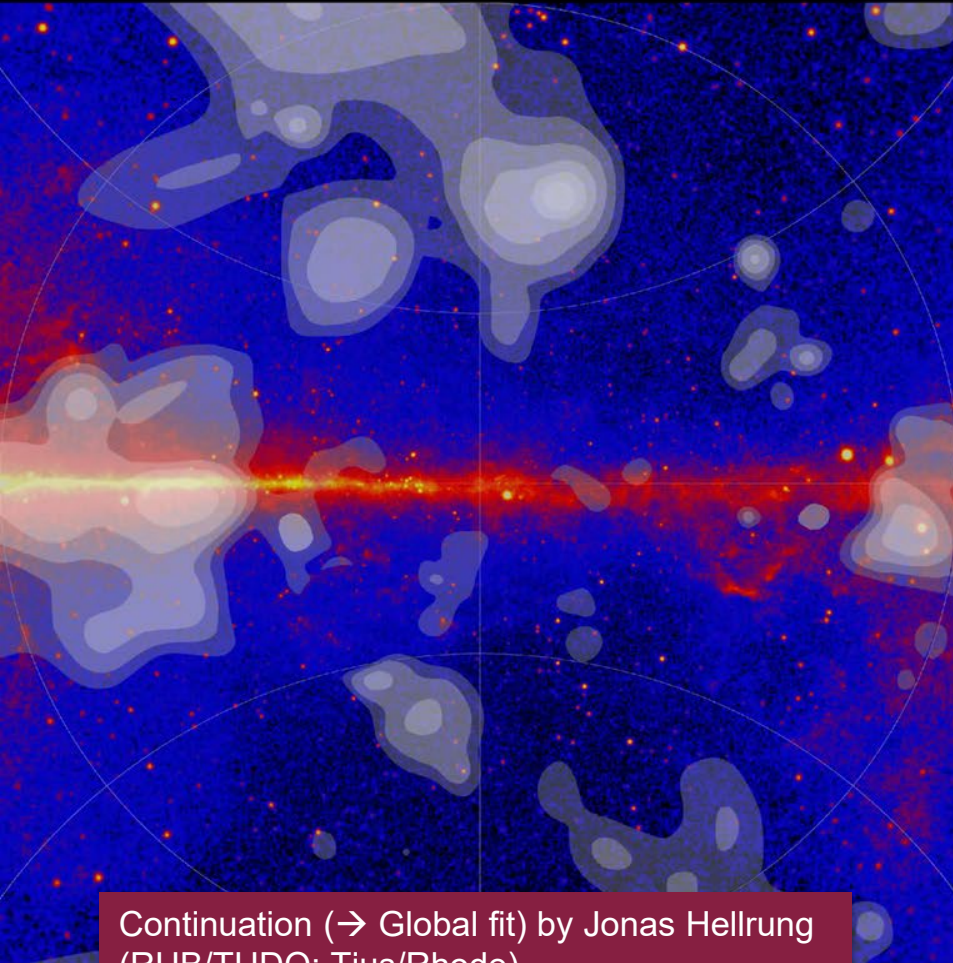
- Significant improvement of angular resolution  $\Rightarrow$
- Improvement of sensitivity by factor of 4-5



Mirco Hünnefeld, Wolfgang Rhode, TU Dortmund (F3)



# Detection of Galactic Plane in Neutrinos



Continuation (→ Global fit) by Jonas Hellrung  
(RUB/TUDO; Tjus/Rhode)

Relevant for A1, F1, F4  
Produced by F3



Abbasi et al (IceCube Coll )  
Science (Jun 2023)

# Methodological Highlight

## CRPropa 3.2



Julien Dörner

A1 (F1)

Julia Tjus,  
Lukas Merten

A2, A3, A7

Björn  
Eichmann

A5

Antonius  
Frie

F1

Mario Hoerbe,  
Leander Schlegel

A7

Patrick  
Reichherzer

A7 (F1, A6)

Karl-  
Heinz

A3, F4

Kampert

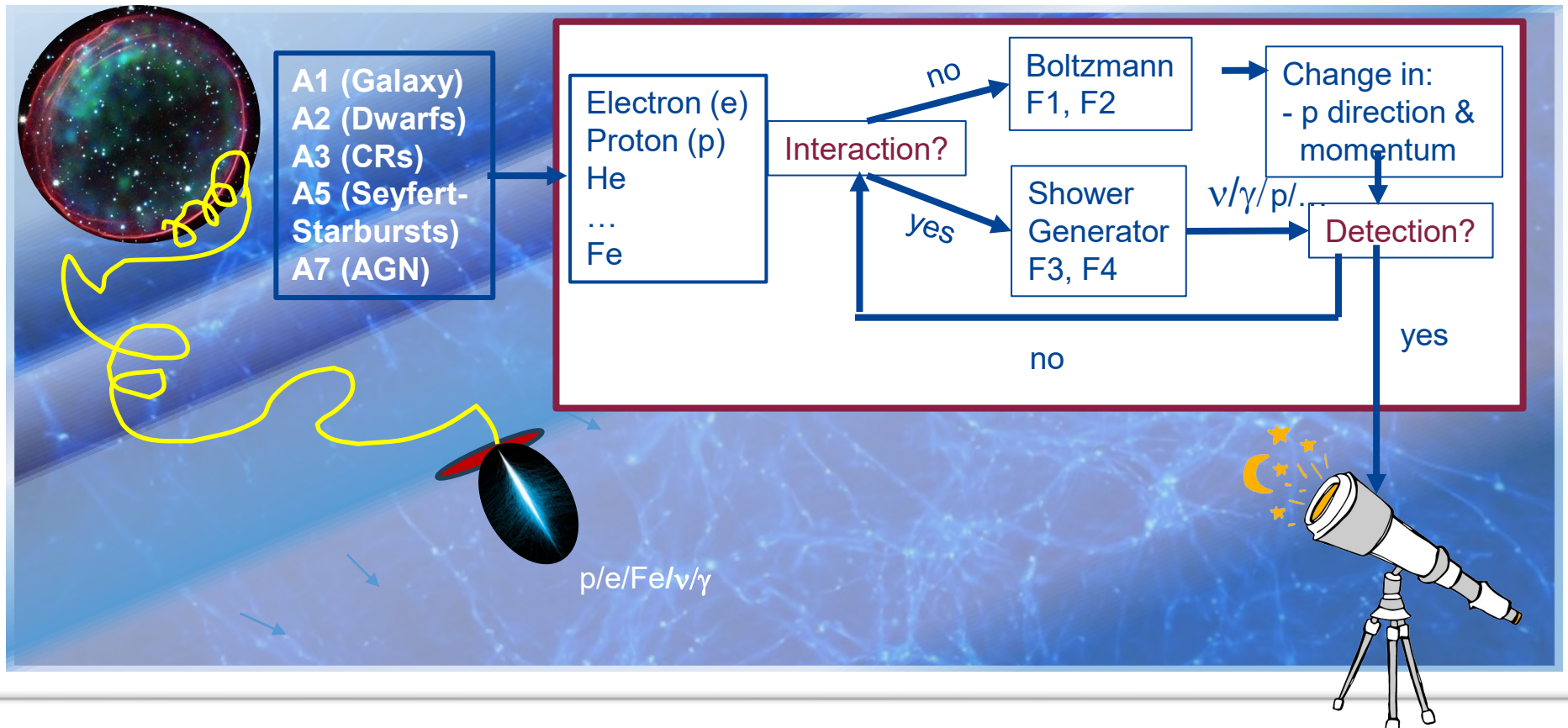
**3 PIs, 6 ECRs from CIM,  
Bochum & Wuppertal**

**J**ournal of **C**osmology and **A**stroparticle **P**hysics  
An IOP and SISSA journal

### CRPropa 3.2 — an advanced framework for high-energy particle propagation in extragalactic and galactic spaces

Rafael Alves Batista,<sup>a,b</sup> Julia Becker Tjus,<sup>c,d</sup> Julien Dörner,<sup>c,d</sup>  
Andrej Dundovic,<sup>e,f</sup> Björn Eichmann,<sup>c,d</sup> Antonius Frie,<sup>c,d</sup>  
Christopher Heiter,<sup>g,h</sup> Mario R. Hoerbe,<sup>c,i,d</sup> Karl-Heinz Kampert,<sup>j,k</sup>  
Lukas Merten,<sup>k,c,d</sup> Gero Müller,<sup>g</sup> Patrick Reichherzer,<sup>c,d,l</sup>  
Andrey Saveliev,<sup>m,n</sup> Leander Schlegel,<sup>c,d</sup> Günter Sigl,<sup>o</sup>  
Arjen van Vliet<sup>p</sup> and Tobias Winchen<sup>q,h</sup>

# CRPropa 3.2: input from F1/F2 (plasma) and F3/F4 (particle)



- A1 (Galaxy)
- A2 (Dwarfs)
- A3 (CRs)
- A5 (Seyfert-Starbursts)
- A7 (AGN)

- Electron (e)
- Proton (p)
- He
- ...
- Fe

Interaction?

no  
Boltzmann  
F1, F2

yes  
Shower  
Generator  
F3, F4

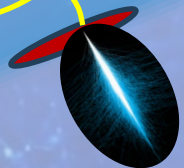
$v/\gamma/p/...$

Change in:  
- p direction &  
momentum

Detection?

yes

no



$p/e/Fe/v/\gamma$





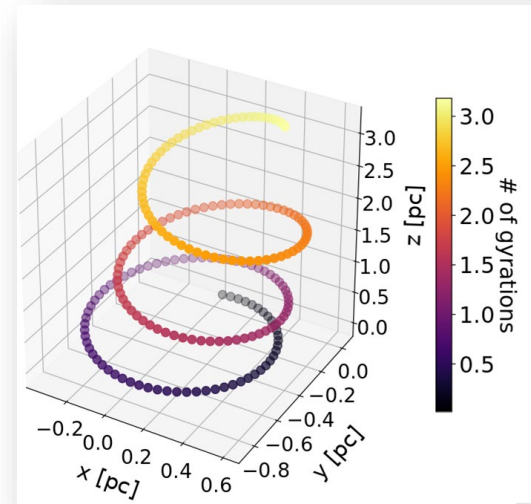
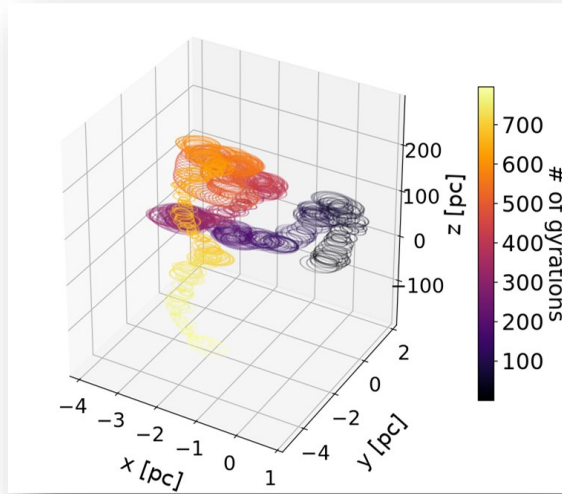
# CRPropa 3.2

## (1) Cosmic-ray Transport



$$\frac{\delta n}{\delta t} = \nabla \cdot (\widehat{D} \cdot \nabla n) - \vec{u} \cdot \nabla n + Q$$

$$\frac{dp}{dt} = q(\mathbf{v} \times \mathbf{B})$$



conversion into Stochastic Differential Equation (SDE):

$$dr_{\nu} = A_{\nu} dt + D_{\nu\mu} d\omega^{\mu}$$

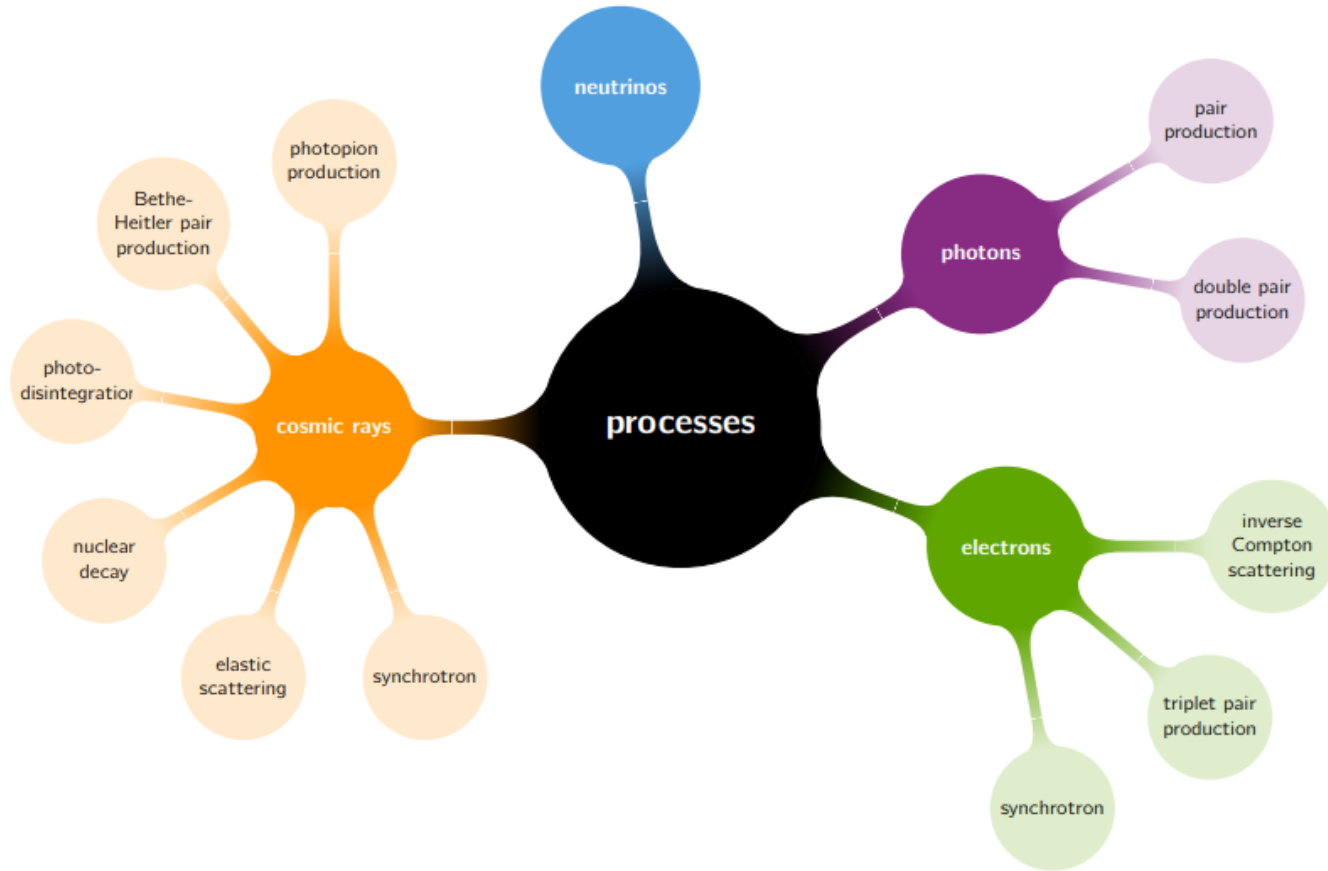
▣ treatment as quasi-particles

Numerical solution via Cash-Karb or Boris-Push

Treatment in one framework  $\Rightarrow$  CRPropa 3.2

# CRPropa 3.2

## (2) Cosmic-ray interactions



# Collaborative Highlight

## The muon puzzle

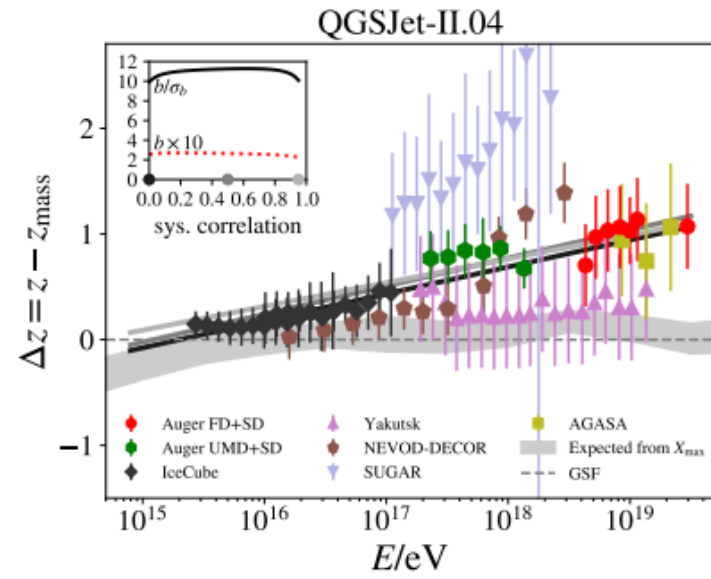
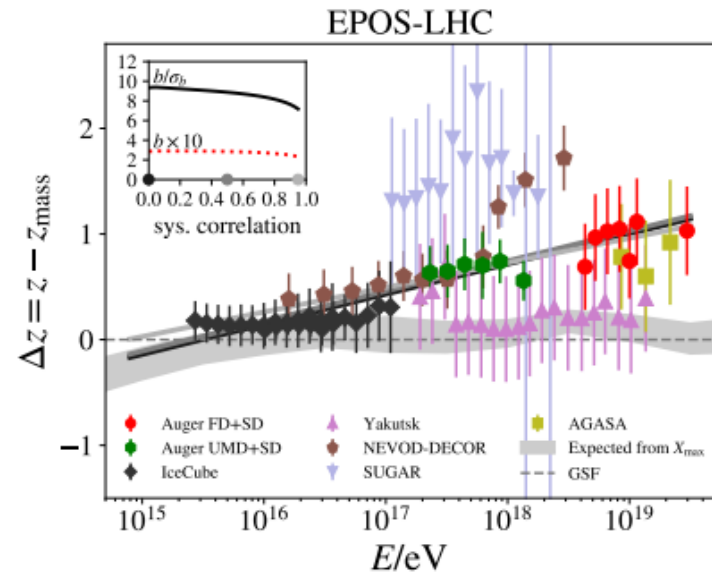


### The Muon Puzzle in cosmic-ray induced air showers and its connection to the Large Hadron Collider

#1

Johannes Albrecht, Lorenzo Cazon, Hans Dembinski, Anatoli Fedynitch, Karl-Heinz Kampert, Tanguy Pierog, Wolfgang Rhode, Dennis Soldin, Bernhard Spaan, Ralf Ulrich, Michael Unger

Published in: *Astrophys. Space Sci.* 367 (2022) 3, 27 • e-Print: [2105.06148](https://arxiv.org/abs/2105.06148) [astro-ph.HE]



73 citations

4 PIs, 1 ECR  
from CIM,  
Dortmund &  
Wuppertal



# Publications 2022

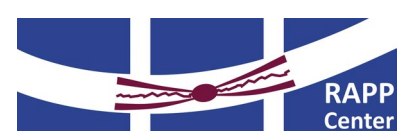
## 27 publications



				ASAS-SN follow-up of IceCube high-energy neutrino alerts	August 2022	Necker, J., de Jaeger, T., Stein, R., Franckowiak, A., et al.	
Simulation of deflection uncertainties on directional reconstructions of muons using PROPOSAL	December 2022	Gutjahr, P., Alameddine, J.-M., Sandrock, A., Soedingreko, J., Hünnefeld, M. and Rhode, W.	F3	Electron-Driven Instabilities in the Solar Wind	August 2022	Verscharen, D., ..., Innocenti, M. E., et al.	F2
Neutrino Cadence of TXS 0506+056 Consistent with Supermassive Binary Origin	December 2022	Becker Tjus, J., Jaroschewski, I., Ghorbanietamad, A., Bartos, I., Kun, E., Biermann, P. L.	A7	Magnetic fields and hot gas in M 101	August 2022	Wezgowiec, M., ..., Dettmar, R.-J., et al.	A4
Multimessenger Picture of J1048+7143	December 2022	Kun, E., Jaroschewski, I., Ghorbanietamad, A., ..., Becker Tjus, J., ..., Kiselev, V., Schlegel, L., Schroller, M., Reichherzer, P., et al.	A7	Multiwavelength Search for the Origin of IceCube's Neutrino	August 2022	Kun, E., Bartos, I., Becker Tjus, J., Biermann, P. L., Franckowiak, A., Halzen, F.	A7
Constraining the sources of ultra-high-energy cosmic rays across and above the ankle with the spectrum and composition data measured at the Pierre Auger Observatory	November 2022	Pierre Auger Collaboration: Abdul Halim, A., ..., Kääpä, A., Kampert, K.-H., et al.	A3	Nearby galaxies in the LOFAR Two-metre Sky Survey. I. Insights into the non-linearity of the radio-SFR relation	August 2022	Heesen, V., ..., Stein, M., ..., Adebahr, B., ..., Bomans, D. J., Dettmar, R.-J., et al.	A4, A5, A6
Characterising the Apertif primary beam response	November 2022	Dénes, H., ..., Adebahr, B., et al.	A6	Nearby galaxies in the LOFAR Two-metre Sky Survey II. The magnetic field-gas relation	August 2022	Heesen, V., ..., Stein, M.	A4
Continuum source catalog for the first APERTIF data release	November 2022	Kutkin, A. M., ..., Adebahr, B., et al.	A6	A nonlinear model of diffusive particle acceleration at a planar shock	July 2022	Walter, D., Effenberger, F., Fichtner, H., Litvinenko, Y.	F1, F2
First release of Apertif imaging survey data	November 2022	Adams, E. A. K., Adebahr, B., ..., Berger, A., et al.	A6	CRPropa 3.2 -- an advanced framework for high-energy particle propagation in extragalactic and galactic spaces	July 2022	Alves Batista, R., ..., Becker Tjus, J., Dörner, J., ..., Eichmann, B., Frie, A., ..., Hörbe, M. R., Kampert, K.-H., Merten, L., ..., Reichherzer, P., ..., Schlegel, L., et al.	A1, A2, A3, A5, F1
Solving the Multimessenger Puzzle of the AGN-starburst Composite Galaxy NGC 1068	November 2022	Eichmann, B., Oikonomou, F., Salvatore, S., Dettmar, R.-J., Becker Tjus, J.	A5	The Apertif science verification campaign. Characteristics of polarised radio sources	July 2022	Adebahr, B., Berger, A., et al.	A6
Lepto-hadronic jet-disc model for the multi-wavelength SED of M87	October 2022	Boughelliba, M., Reimer, A., Merten, L.	A7	Interaction between electrostatic collisionless shocks generates strong magnetic fields	June 2022	Boella, E., ..., Innocenti, M. E., et al.	F2
Hot magnetic halo of NGC 628 (M74)	September 2022	Wezgowiec, M., ..., Dettmar, R.-J., et al.	A4	PropPy - Correlated random walk propagation of cosmic rays in magnetic turbulence	June 2022	Reichherzer, P., Becker Tjus, J.	F1
Anisotropic cosmic ray diffusion in isotropic Kolmogorov turbulence	August 2022	Reichherzer, P., Becker Tjus, J., Zweibel, E. G., Merten, L., Pueschel, M.J.	A1, A3, F1	Propagation of Cosmic Rays in Plasmoids of AGN Jets-Implications for	April 2022	Becker Tjus, J., Hörbe, M., Jaroschewski, I., Reichherzer, P., Rhode, W., Schroller, M., ...	A7
						Propagation of Cosmic Rays in Plasmoids of AGN Jets-Implications for	A7
						The extended HI halo of NGC 4945 as seen by MeerKAT	A5
						The Muon Puzzle in cosmic-ray induced air showers and its connection to the Large Hadron Collider	F4
						Measurement of prompt charged-particle production in pp collisions at a centre-of-mass energy of 13 TeV	F4
						Propagation of Cosmic Rays in Plasmoids of AGN Jets-Implications for	A7
						Propagation of Cosmic Rays in Plasmoids of AGN Jets-Implications for	A7

# Publication 2023

## 18 publications



Evidence for a large off-centered galactic outflow and its connection to the extraplanar diffuse ionized gas in IC 1553	August 2023	Dirks, L., Dettmar, R.-J., Bomans, D. J., Kamphuis, P., Schilling, U.	A2, A4, F6
A Three-dimensional Model for the Evolution of Magnetohydrodynamic Turbulence in the Outer Heliosphere	August 2023	Kleimann, J., Oughton, S., Fichtner, H., Scherer, K.	A4
Energy Conversion by Magnetic Reconnection in Multiple Ion Temperature Plasmas	June 2023	Dargent J., Toledo-Redondo S., Divin A., Innocenti M. E.	F2
Observation of high-energy neutrinos from the Galactic plane	June 2023	Abbasi R., et al. (IceCube Collaboration)	F3, A1
Unsupervised classification of fully kinetic simulations of plasmoid instability using self-organizing maps (SOMs)	May 2023	Köhne S., Boella E., Innocenti M. E.	F2
Ultra-High-Energy Cosmic Rays - The Intersection of the Cosmic and Energy Frontiers	May 2023	Coleman A., ..., Dembinski, H.P., ..., Kampert, K.-H., et al.	F4
Particle-in-cell simulations of Alfvén wave parametric decay in a low-beta plasma	April 2023	González, C.A., Innocenti, M.E. and Tenerani, A.	F2
Lyman continuum leaker candidates among highly ionised low-redshift dwarf galaxies selected from He II	April 2023	Enders, A. U., Bomans, D. J., Wittje, A.	F6
Detection of a Peculiar Drift in the Nuclear Radio Jet of the TeV Blazar Markarian 501	February 2023	Britzen, S., ..., Kun, E., et al.	A7
Search for Gamma-Ray Spectral Lines from Dark Matter Annihilation up to 100 TeV toward the Galactic Center with MAGIC	February 2023	Abe, H. et al. (MAGIC Collaboration)	F5

Stochastic interpolation of sparsely sampled time series by a superstatistical random process and its synthesis in Fourier and wavelet space	February 2023	Lübke, J., Friedrich, J., Grauer, R.	F1
Astro-COLIBRI 2—An Advanced Platform for Real-Time Multi-Messenger Discoveries	January 2023	Reichherzer, P., ..., Becker Tjus, J., et al.	A6, A7
Cosmic-ray electron transport in the galaxy M51	January 2023	Dörner, J., Reichherzer, P., Becker Tjus, J., Heesen, V.	A1, A2, A4, F1
Multiwavelength Analysis of the IceCube Neutrino Source Candidate Blazar PKS 1424+240	January 2023	Kun, E., Medveczky, A.	A7
Optical/γ-ray blazar flare correlations: understanding the high-energy emission process using ASAS-SN and Fermi light curve	January 2023	de Jaeger, T., ..., Franckowiak, A., et al.	A7
Symmetries and Zero Modes in Sample Path Large Deviations	January 2023	Schorlepp, T., Grafke, T., Grauer, R.	F1

**MOST IMPORTANT:**  
Put SFB1491 in your acknowledgements!

**MOST IMPORTANT:**  
Please report every publication to Eva!

Total number of reported papers: 45

SFB-first-author: 19

Publications with more than 1 PI:

Becker Tjus, Franckowiak, Rhode (A1, A3, F3)

Eichmann, B., Dettmar, R.-J., Becker Tjus, J. (A5+A7)

Becker Tjus, J., & Franckowiak, A., (A6+A7)

Bomans, D. J., Dettmar, R.-J. (A6+F6)

Becker Tjus, J., Eichmann, B., Kampert, K.-H. (A1, A2, A3, A5, F1, F2, F4)

Becker Tjus, J., Rhode, W., (A7)

Albrecht, J., Kampert, K.-H., Rhode, W. (F3, F4)

⇒ total of **8 PIs** show **connected work** ⇒ needs to be improved (all 18 PIs)

⇒ **ECRs/PIs: please start working toward collaborative publications early-on!**

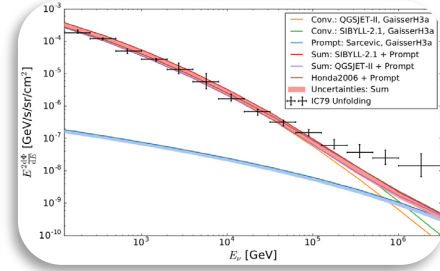
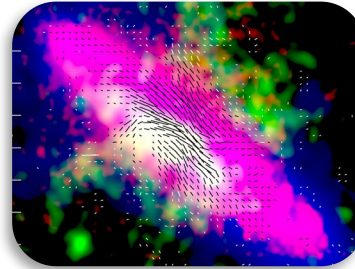
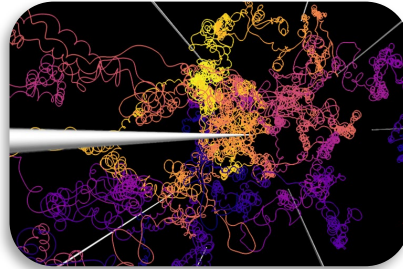
**MOST IMPORTANT:**  
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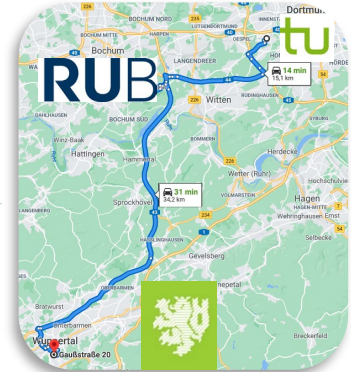
# This talk: Where we are and where we want to go:



## (1) Physics Program






## (2) Program implementation and structural elements in CIM











CIM git: <https://gitlab.ruhr-uni-bochum.de/sfb1491>

- C **CompSchool2023**  Maintainer
- P **Part-F**   
Science area F - Fundamental properties of matter
- P **Part-A**   
Science area A - Astrophysical signatures of cosmic-ray transport and interaction

Rainer Grauer  
Kevin Kröninger  
Angus Wright  
Andreas Schramm  
Jürgen Möllenhoff

Numerical Simulations  
Experimental Data  
Observational Data  
Data Steward  
CIM-Cluster

## Publication RDM:

- P **Part-F**   
Science area F - Fundamental properties of matter
- F **F1**   
Propagation of fast charged particles in artificially generated MHD turbulence: implications for cosmi...
  -  L **Luebke et al 2023**  ★ 0
  -  W **Walter et al 2023**  ★ 0

**See Rainer's talk**

Compute Cluster: [galileo.cim.ruhr-uni-bochum.de](https://galileo.cim.ruhr-uni-bochum.de)

(used heavily in the CompSchool 2023)

# Status of Ö: Homepage and internal page



- new homepage concept with internal page and underlying database has been developed by Jonas Hackfeld, Vladimir Kiselev and Johannes Just
- Status of first release:
  - development phase ended
  - user test phase (including PIs) has just been ended  
<https://test-sfb.tp4.rub.de>
  - currently: preparation of go-live
    - feedback is incorporated
    - final hardware solution for server under discussion with Bernd
  - go-live planned for early October
- Updates are already under development/planned (in particular a semi-automated publication list)

*See Susanne's talk*

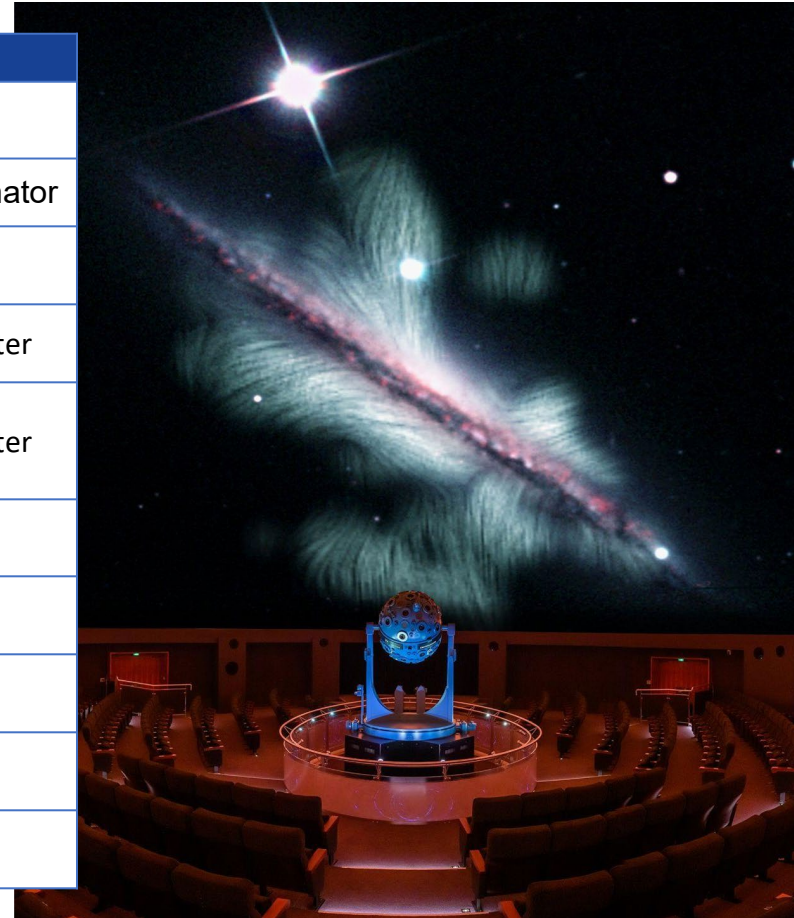
# Status of Ö: Planetarium Show



See Susanne's talk

- concept & script in prep
- 2 scenes externally (in prep)
- "Universe on Tour" roadshow → trailer/teaser!

Name	Position
Susanne Hüttemeister	PI
Eva Jütte	Scientific Coordinator
Yelena Stein	DLR
Tobias Jogler	Planetarium Münster
Björn Voss	Planetarium Münster
Christian Theiss	Planetarium Mannheim
Mathias Jäger	Planetarium Mannheim
Thomas Niemann	Planetarium Mannheim
Jurek Völp	WHK RUB
Marcel Mielach	WHK RUB



# Status of Ö: Social Media



Twitter & Insta running  
[Input to → Marissa]  
LinkedIn new

## Nu Galactic Plane:

- movie & still
- Webinar + Press conference

→ >2000 views live, 12.5k views  
(24 hours), 25k views (Aug 31, 23)

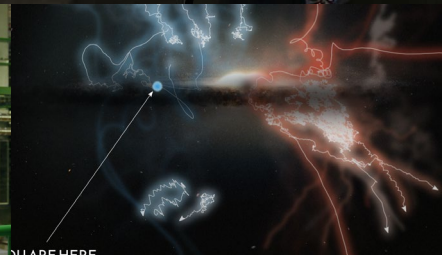
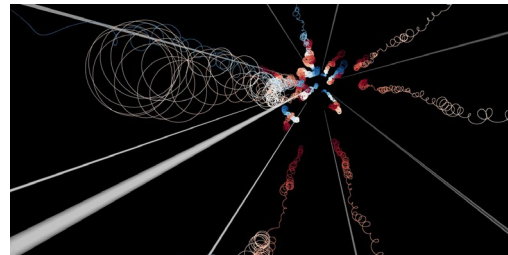
See Susanne's talk



Science Communication Lab:  
<https://scicom-lab.com/>



- Experiment on MS Wissenschaft
- Participation in
  - Mars on Tour
  - opening Year of the Universe @ Planetarium
  - Jugend Forscht
  - Schülerinnen-projektwoche
- An incredible calendar 2023



- Hendrik → Johannes
- Successful PhD school at Bad Honnef (Jan 2023) - 4th edition; next in Jan 2025
- Everybody should meet once a year with their PhD students and fill out the SMART sheet
- ECRs are very active, organize many conferences themselves, organize themselves in sub-groups, very positive atmosphere as far as I can tell
- More activities:
  - best paper award
  - ECR meeting



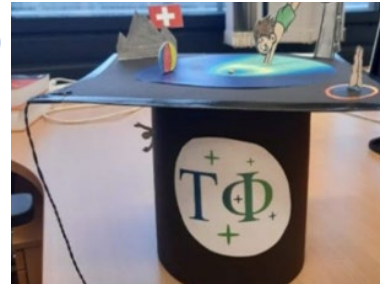
**See Anna's talk**

# MGK: Successful PhD thesis defence



- **Mirco Huennefeld:** High-energy neutrino observation from the Milky Way, Sept 2023
- **Ancla Müller:** Polarized radio emission of cluster galaxies: clue to the physics of ram-pressure stripping and its influence on galaxy evolution, Feb 2023
- **Lennart Baalman:** Examining simulated MHD shock structures of astropheres, March 2022
- **Alex Käätä:** Propagation in the Galactic magnetic field – Effects on the spectrum, composition and anisotropy of Galactic and extragalactic cosmic rays, Jan 2022

**MOST IMPORTANT:**  
*Please tell Eva for each  
successful defence*



**If PhD student agrees, we will  
put a note on Twitter**



# CRC 1491: Breaking new grounds

(status so far: ship sailed  
down the Ruhr all the way  
to IB and Duisburg to pick  
up new Pis  
[Kormann/Kuiper])







# Cosmic Interacting Matters – From Source to Signal CRC 1491

Julia Tjus | 06.11.2023

