DarkSide Materials Weekly Meeting:
Update on Ar activation

Goal: to update the first estimates of cosmogenic activation on **Argon,** mainly of ^{39}**Ar**:

- Including a more realistic exposure history during Ar storage and transportation.
- Considering production by sources other than cosmic neutrons.

- Correction factors for cosmic ray fluxes: new altitude
- Exposure history: Aria
- Results for activity: update

- Outline of a possible publication

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Answers to pending questions

- Questions to be clarified to complete the study:
  - *Urania:* storage of UAr is made at surface when being extracted?

    "While at the Urania site, the UAr will always be on the surface while being processed and once in the skids."

    → OK with assumption
  - *Urania:* altitude of facilities in Cortez?

    "According to Google Maps the elevation of the Urania plant will be approximate 7100 ft."

    → Higher than Cortez altitude (6191 ft), correction factors updated

Thanks to Vance Strickland and Federico Gabriele

Correction factors

Exposure to cosmic rays will happen at different altitudes and latitudes
→ correction factors are needed to the assumed cosmic rays fluxes at sea level, different for different components

J.F. Ziegler, Terrestrial cosmic ray intensities, IBM J. Res. Develop. 42 (1998) 117.

- **Protons, muons**

$$I_2 = I_1 \exp\left(\frac{A_1 - A_2}{L}\right),$$

where I_1 is the cascade flux at some altitude (pressure) and I_2 is the flux at altitude A_2, both altitudes being expressed in g/cm^2.

Table 3. Sea-level particle absorption lengths.

Particle	Length L (g/cm^2)
Electrons	100
Protons	110
Pions	113
Neutrons	136
Muons and muon capture	261

Location	H (ft)	A (g/cm2)		I ratio Cortez mu	I ratio Cortez p
Cortez (1887 m)	6191	823.480		**2.23**	**6.72**
New York	0	1033.000		I ratio Urania mu	I ratio Urania p
Urania (2164 m)	7100	795.467		**2.48**	**8.67**

- **Neutrons** Extrapolation for URANIA location of deduced factors f due to altitude and geomagnetic rigidity at Denver and Leadville.

Location	H (ft)	A (g/cm2)	f	I ratio Cortez	f at Cortez	I ratio Urania	f at Urania
Denver	5280	852.3	4.11	0.809	5.08	0.659	6.24
Leadville	10200	705.2	12.86	2.386	5.39	1.942	6.62
Cortez (1887 m)	6191	823.5			**5.23**		
Urania (2164 m)	7100	795.5					**6.43**

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    → OK with assumption
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  - *Aria:* total time spent there for UAr?

    "No, we have not any idea, also because we have to change the compressor for these new shipping containers." "I will say more or less 90 days for the entire production."

    "It will take URANIA 9-10 months to produce all the UAr for DS-20k (64T)"

    Depth when being stored after/before processing?

    "The containers will be on the surface."

    "As the UAr was processed at ARIA it would be put back into the skids. When 3 skids were full, 6T of UAr, they would be sent to LNGS for storage underground."

Assumption: 10 days of exposure at sea level for the processing at ARIA of 3 skids

Thanks to Vance Strickland and Federico Gabriele

Exposure history

- As realistic as possible exposure conditions:
  tentative **exposure times** and **places (altitude)** for shipping: URANIA → ARIA → LNGS

Urania exposure (d)	10	20	30
US trip exposure (d)	7		
Overseas trip exposure	67		
Aria exposure (d)	10		
Itay trip exposure (d)	20		

- Urania exposure: each third of Ar with different exposure time
- US trip exposure: average between maximal (from Cortez altitude) and minimal (sea level) flux
- Overseas and whole Italy exposure: at sea level

Total time for each set of 3 skids (6 T): 134 days
(since starting production at Urania to arrival at LNGS)

Total time for 10 sets of 3 skids: 404 days
(since starting production at Urania of first one to arrival at LNGS of last one)

Results

Induced activity *A* knowing the exposure history to cosmic rays at each step

$$A = R\left[1 - \exp(-\lambda t_{exp})\right] \exp(-\lambda t_{cool})$$

t_{exp} = exposure time

t_{cool} = cooling time

				Urania		US		Overseas		Aria, Italy		Total	
	R	err	f Urania	A	err	A	err	A	err	A	err	**A**	**err**
	(kg-1 d-1)			(kg-1 d-1)		(kg-1 d-1)		(kg-1 d-1)		(kg-1 d-1)		**(kg-1 d-1)**	
n	759	128	6.43	0.689	0.116	0.139	0.023	0.359	0.061	0.161	0.027	**1.348**	**0.136**
mu	172	26	2.48	0.060	0.009	0.015	0.002	0.081	0.012	0.036	0.006	**0.193**	**0.016**
p	3.6	2.2	8.67	0.004	0.003	0.001	0.001	0.002	0.001	0.001	0.000	**0.008**	**0.003**
g	112.8	20.9	1	0.016	0.003	0.006	0.001	0.053	0.010	0.024	0.004	**0.099**	**0.011**
total	(from R. Saldanha et		(from J. F.	**0.769**	**0.117**	**0.161**	**0.024**	**0.495**	**0.063**	**0.222**	**0.028**	**1.647**	**0.137**
(%)				46.7		9.7		30.1		13.5			

A (mBq/kg)	err
0.0191	**0.0016**

- Slight increase due to higher altitude in Urania and consideration of exposure in Aria
- Activity when arriving at LNGS each set of 3 skids; the effect of cooling underground up to collecting all sets has been checked to be negligible

Results

- Comparison to the very first estimate of induced ^{39}**Ar** activity:

R (kg-1 d-1)		Exposure	A (mBq/kg)	
1048	126	35 d Colorado + 41 d sea level	0.022	0.003

A (mBq/kg)	err
0.0191	0.0016

- The computation of the induced activity of ^{39}**Ar** in UAr for exposure in surface from Urania to LNGS has been completed assuming an exposure history as realistic as possible now.
- A residual level (at 2.6% of quantified activity in DS50, 0.73 mBq/kg) is confirmed.

Outline of a possible publication

Introduction
- DarkSide project and GADMC
- Problem of cosmogenic activation

The DarkSide-20K Project

Methodology: Production rates → Activity → Counting rates

Cosmogenic yields in Argon *(note at DocDB)*
- Relevant isotopes
- Production rates
- Activities for assumed exposure
- Underground activation by muons?

Cosmogenic yields in Copper and steel *(note at DocDB)*
- Relevant isotopes
- Production rates
- Activities for assumed exposure

Expected counting rates in DS
- Description of simulation framework
- Results
- Comparison with the whole DS model

Conclusions

For Astroparticle Physics?