Scintillator and Reflectivity Optimization for the 4-Cell WOM-LS Prototype Detector

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Overview of WP 2.1 Projects in Mainz

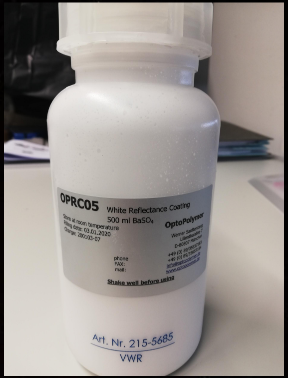
Motivation: enhanced detector light output

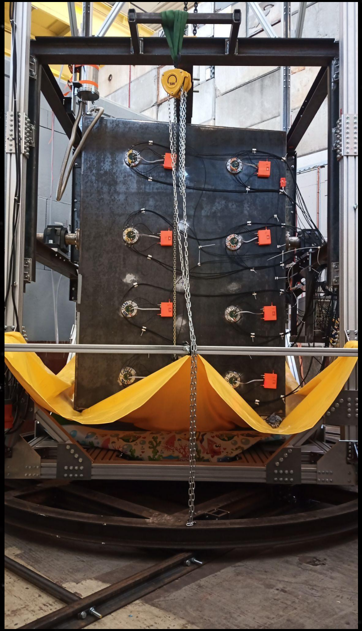
Reflective Coating

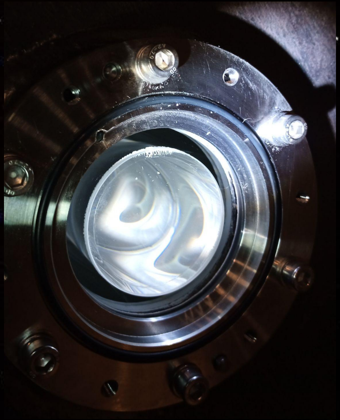
- increased reflectivity of inner detector walls with diffusely reflective paint
- photon transport simulation: increase of light yield by factor 4-5
- long term compatibility tests with scintillator and corten steel

Liquid Scintillator (LS)

- purification of LAB
- wavelength shifting (PPO) to transparent region of the LS
- LS quality conservation and monitoring
- liquid handling system

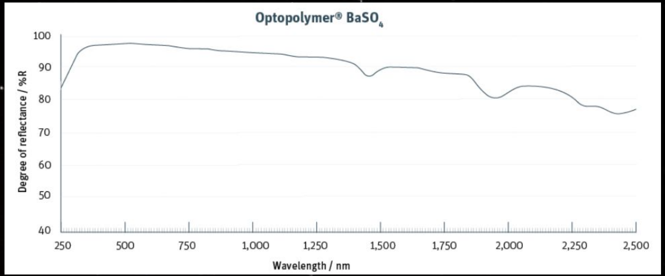






Preliminary Tests: Reflective Coating (WP 2.1)

- preliminary tests on stainless steel
  - promising candidate: “OPRC” BaSO4 paint from “Berghof Fluoroplastics”
  - simple application with spray gun
  - efficient diffuse reflector in UV region (380 nm)
- main challenge: yellowing due to rust from reactive corten steel
- water content of OPRC accelerates rust formation
- acrylic primer for increased physical stability of coating and protective layer between steel and coating → prevention of yellowing



Reflectivity of OPRC


Yellowed coating after direct application to corten steel

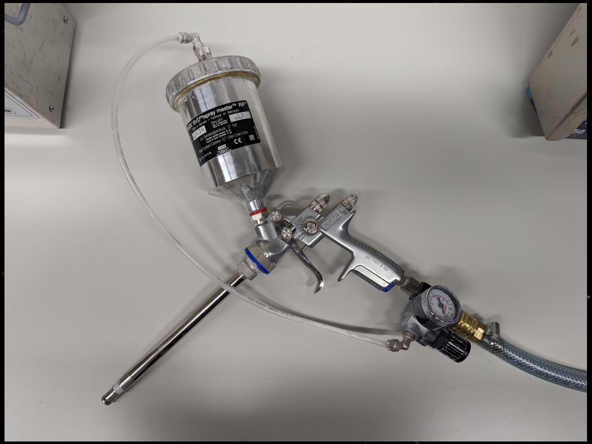

Primed samples without yellowing

Application of the Coating (WP 2.1)

- application after welding ensures:
  - stability of the coating
  - homogeneous reflectivity
- access through WOM entry points
- radial + 90° nozzle for SATAjet spray gun to (blindly) coat the inner walls
- double layer of primer + coating with several days of drying
- endoscopic camera to check for full coverage

Spray Gun Access

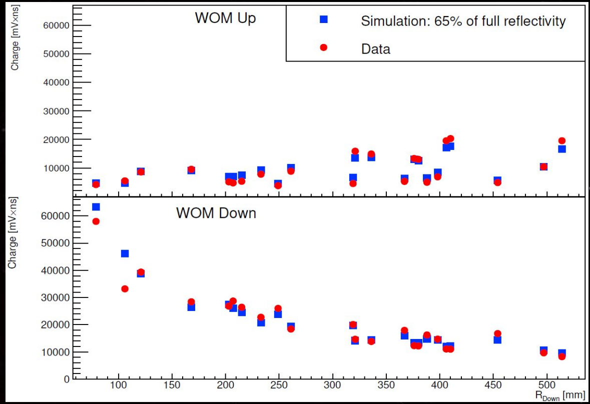
1-cell-prototype during coating (2022)



Assembled Spray Gun with radial nozzle and pressure cup

Coating Results 1-Cell-Prototype (TB DESY 2022) (WP 2.1)

- full coverage of inner walls was achieved
- longer drying time in detector prototype caused rust stains to spread into acrylic primer and reflective coating (not observed in primary tests)
- suboptimal result: 65% of diffuse reflectivity (vs. ~20% uncoated) was still achieved



Simulation / Data comparison to determine wall reflectivity

Inside view of the 1-Cell-Prototype after coating (l), after TB(r)

Coating Results 4-Cell-Prototype (TB CERN 2023) (WP 2.1)

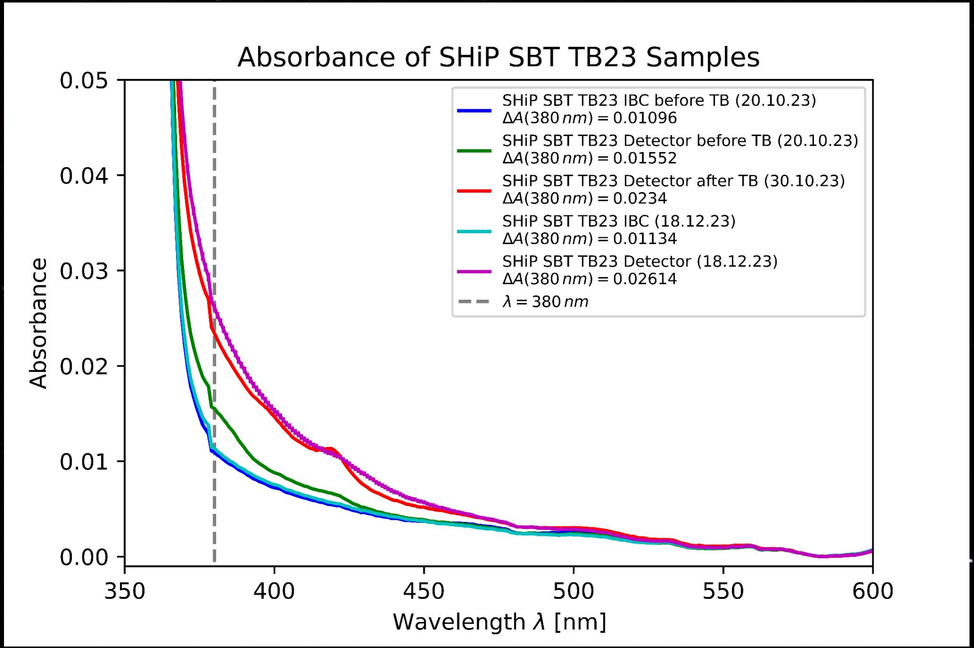
- use of anti-rust primer
- air ventilation with pressurized air inside the detector for shortened drying time
- final coating result shows no obvious yellowing (even after one month of being filled with LS)
- scintillator quality is monitored regularly

4-Cell-Prototype before coating

Inside view of the 4-Cell-Prototype after coating

LS Quality Monitoring TB 2023 (WP 2.1)

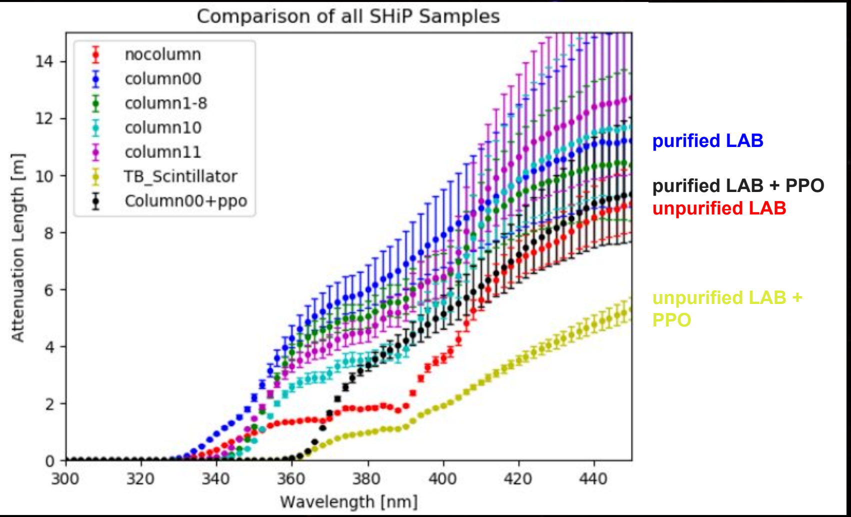
- no measurable absorbance increase through storage in IBC
- drop in LS quality after transfer from IBC to detector
- high aging rate in first 10 days of storage in detector
- lower aging rate for following 49 days in detector
- flushing the detector before filling with LS should lower the aging rates



Absorbance spectra of TB 2023 taken from IBC and detector at different times

Scintillator Purification TB 2022 (WP 2.1)

- purification of 300l of LAB in Mainz
- 1.6 kg Al2O3 column → purification of 25l of LAB
- small vacuum pump
- increase of attenuation length from 2m → 6m @ 380nm

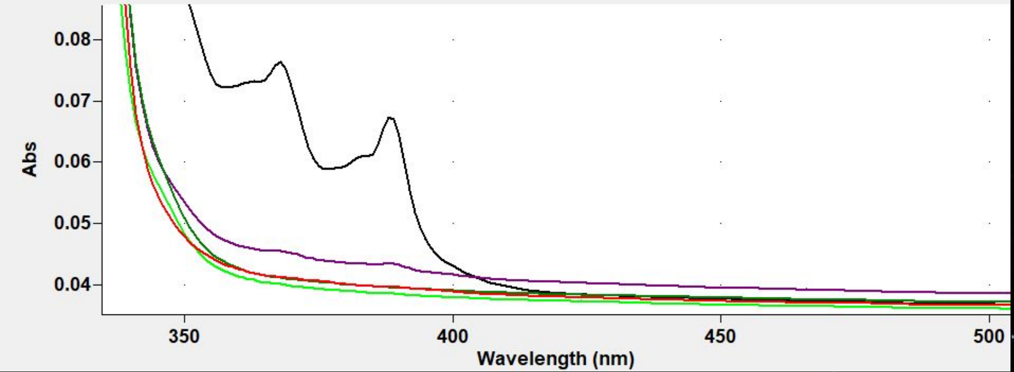


Purification Results with Al2O3 column in Mainz


Purification setup in Mainz

Scintillator Purification TB 2023 (WP 2.1)

- 1000l of LAB purified for TB 2023 in Heidelberg
- 2 x 10kg Al2O3 column → purification of ~350l of LAB
- direct transfer IBC → IBC
- no division into batches → more practical than Lab scale setup
- comparable increase in attenuation length to 2022

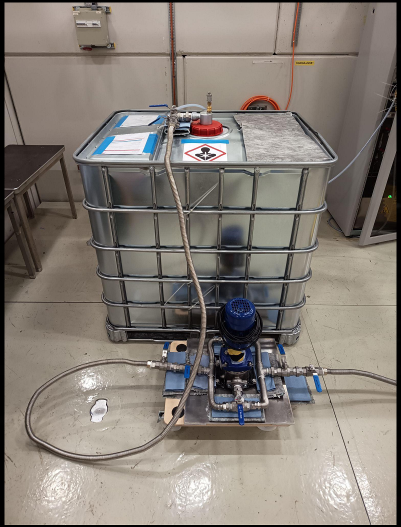


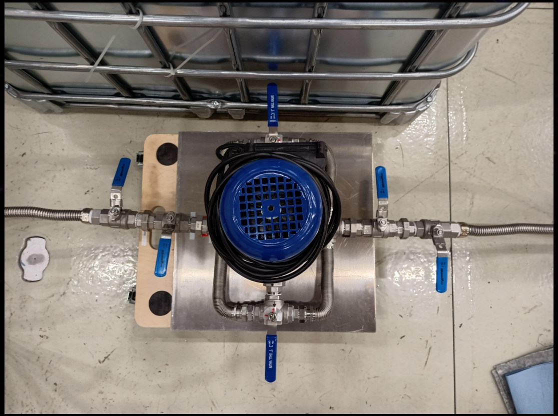
Purification results in Heidelberg

Purification setup in Heidelberg

Improved Liquid Handling System (WP 2.1)

- transfer of LS from IBC to detector prototype and back
- nitrogen atmosphere and flushing
- circulation for mixing of additives





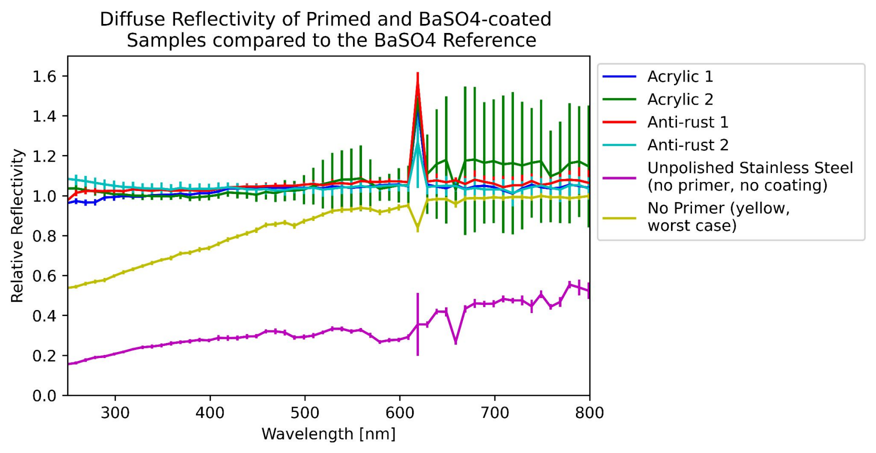
Summary

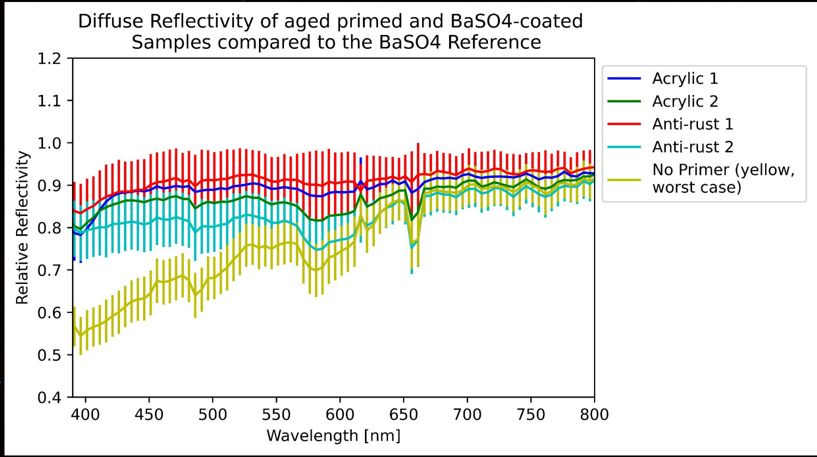
- application of a reflective coating in the 4-cell-prototype with improved results
- practical purification of LAB at a large scale (1000l)
- successful implementation of a LHS for large scale detector prototypes

Outlook:

- WP 2.2 / 2.3 in Mainz
  - small 1-cell-prototypes with different reflective coatings, WOM geometries and WLS coatings for cosmics and test beams
  - Oscar Winiker: “Readout of Wavelength-shifting optical modules using silicone photomultipliers” (Bachelor)
  - Johannes Molins i Bertram: continuation (Bachelor)
- ongoing measurements with 4-cell-prototype at CERN in 2024
- CERN decision on SHiP approval in March 2024
- large multi-cell-ring-prototype in 2025/26

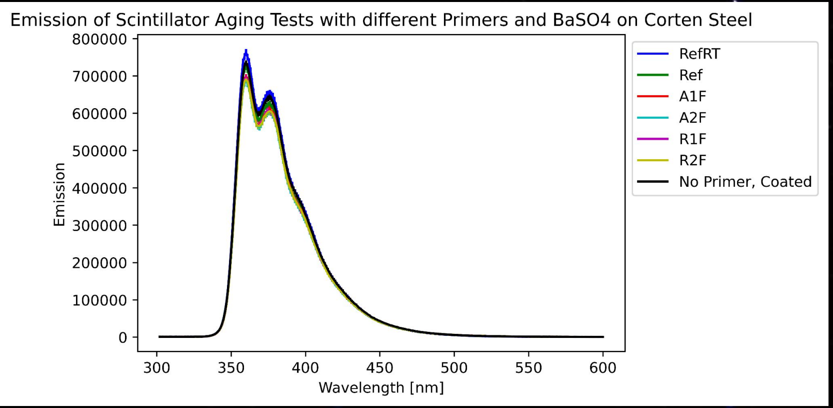
Diffuse Reflectivity Measurements before/after Aging

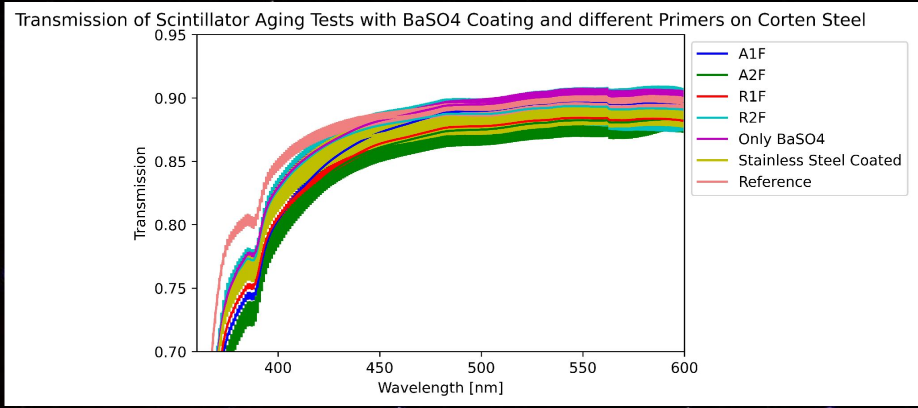




- reflectivity is independent of primer
- increase of diffuse reflectivity by factor 4 compared to stainless steel (400 nm)
- yellowed coating (worst case) still increases reflectivity significantly
- aging of 1.5 years led to a reflectivity reduction of 10-20% in all samples

Aged Scintillator Comparison

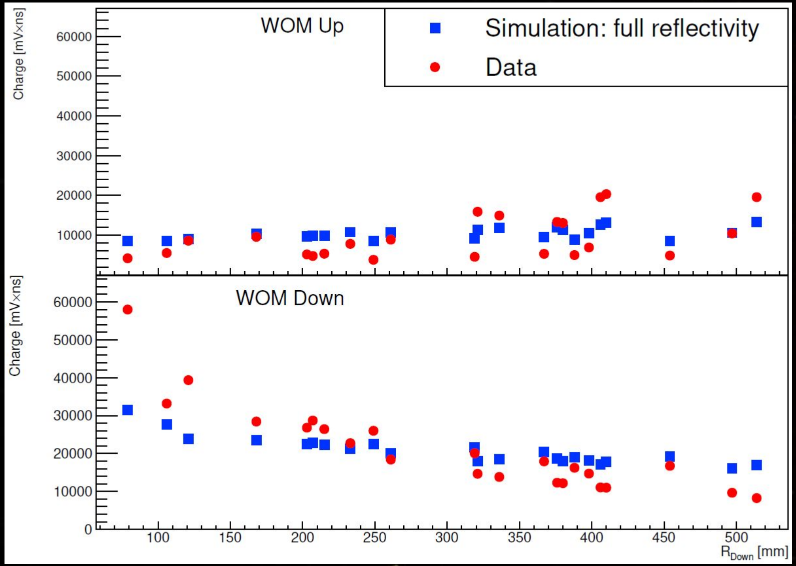


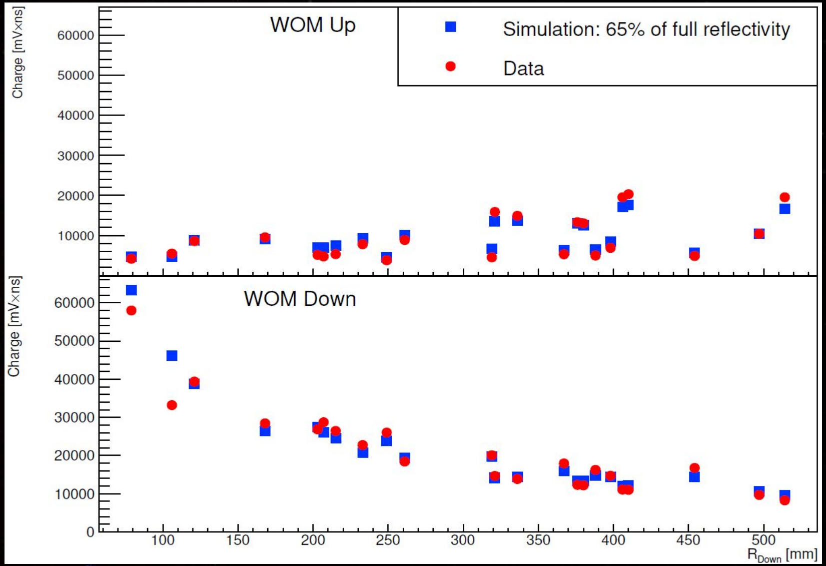


- no measurable change in scintillator emission properties
- transmission measurements show slight deviations ~5%
  - loss of transmission compared to the (unaged) reference is expected
  - not significant enough to identify negative impact from specific primers on the scintillator
- A1 was chosen for the DESY SBT Test Beam in 2022 (acrylic primers are easier to work with than anti-rust primers)

By Fairhurst Lyons

DESY Test Beam Results 2022

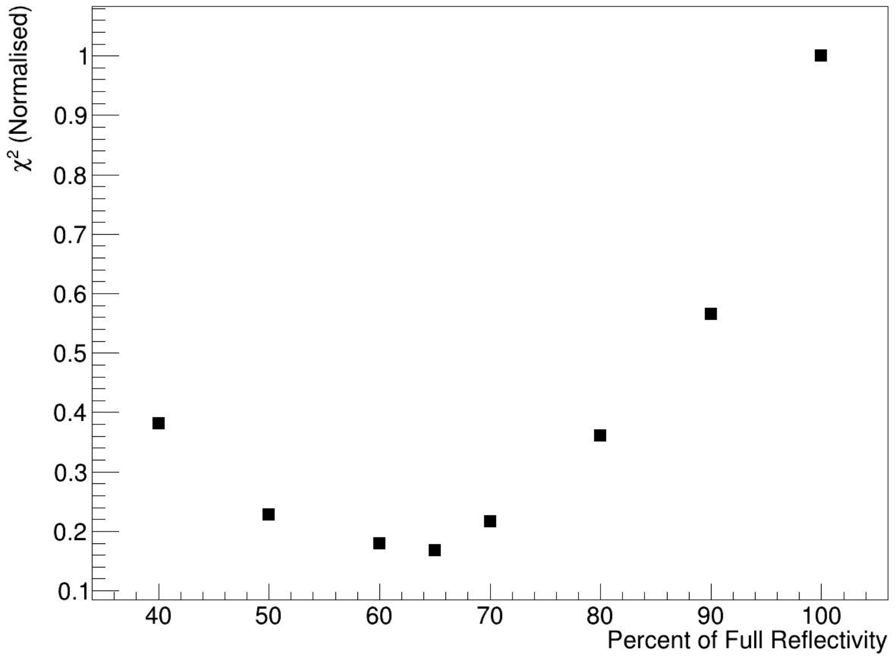




Coating before/after Test Beam 2022

By Fairhurst Lyons

DESY Test Beam Results 2022



Comparison of data with simulation at 65% reflectivity shows a close match

Conclusion

- 65% of diffuse reflectivity (vs. ~20% uncoated) was achieved
- without primer, corten steel rust stains spread into reflective coating
- acrylic and rust protection primers were compatible with the scintillator, reflective coating and corten steel in primary tests
- longer drying time in detector prototype caused rust stains to spread into acrylic primer too (not observed in primary tests)

Outlook

- new tests will focus on rust protection primers
- coating a 4-cell prototype for CERN Test Beam in Fall 2023 with the help of a professional painter