





MRADSIM – MATTER RADIATION INTERACTION SIMULATOR

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BEAMDE CINFN MRADSIM: <u>M</u>ATTER-<u>RAD</u>IATION <u>SIM</u>ULATOR

The main project at the foundation of innovative start up of INFN (National Institue for Nuclear Physics), BEAMIDE srl, is the MRADSIM software (<u>www.mradsim.com</u>). The goal is to create a unique tool for studying the effects of radiation and possible mitigation

It is divided in three main components:

- Conversion tool: from STEP files (output of CAD software) to GDML (input of the simulation backend)
- Simulation tool: based on Geant4, an open-source particle physics software developed at CERN
- Graphical user interface: Modern and intuitive, it allows the user to visualize the geometry of the project, easily set the simulation parameters and view the results obtained





MRADSIM: COMPOSITION

- Source code developed in C++
- Compilation tool **CMake**
- GUI developed using Qt5
- 3D engine developed using **OpenCascade**
- Monte Carlo based physics simulator developed using **Geant4**
- Graphical results representation developed using **Qt5**

Bilateral agreements with Qt and OpenCascade for licensing & commercialization







CONV-FREE: developed as free demo to collect initial feedback on the project. It does not contain the physics simulation tool. It has received very positive feedback from many famous institutes (NASA, Stanford University, ESA, CERN, M.I.T. di Boston, etc.). Actually it is used in >150 copies in 26 Countries around the

World. . <u>(MRADSIM-Converter: A new software for STEP to GDML conversion)</u> Computer Physics Communications, Volume 286, May 2023, 108688.

- **CONV-PRO**: advanced version of the converter, with additional and innovative features compared to the free version. For advanced users who only need the link between the CAD project and their own simulation software.
- **BASIC:** version containing the converter pro with simple simulation and analysis tools.
- SPACE: version with more simulation and analysis options, optimized for space applications.
- **EARTH**: version with simulations optimized for terrestrial applications.
- Modularity: other than the two optimized versions, we want to provide our clients the possibility to customize his product by starting from the basic version to which additional modules can be added.
- WEB: As long-term plan, all the versions will be made available as online service accessible via subscription.



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	We are now proceeding to trying some	e more realistic and detailed (CAD files. I will keep you updated.		
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PROBLEMS VS SOLUTIONS

Problems	Solutions			
The exponential increase radiation-induced risks on electronics and on living organisms	Simulate effects in advance to take measures of protection, mitigation effects			
Lack simulation tools modularly adoptable for Space and Earth apps	MRADSIM is modular for types of applications			
Increase performance and reduce simulation time	Multithread & Develop and apply AI/ML algorithms			
Large error because of low statistics in big geometries	Use of AI/ML and GPU power			
Long STEP conversion times into GDML	MRADSIM converts 260 mb STEP in 2.5 min versus 45 min conversion commercial competitors			







Figure 2: Summary of different machine learning methods used for generative models.

«MRADSIM-Converter: A new software for STEP to GDML conversion»

Computer Physics Communications, Volume 286, May 2023, 108688.



t6a - MRADSIM Converter Pro - 1.0.6

MRADSIM-ConverterPro : FEATURES & EXAMPLES



16-October-2024



Table 1. Feature list of ConverterFree and ConverterPro.

ConverterFree Features Interactive geometry view STEP-to-GDML conversion Adding new material definitions to the database Added Features for ConverterPro \geq x20 faster STEP-to-GDML conversion Large STEP files (\geq 30 Mb) STL, IGES, VRML file type support Improved compatibility with latest STEP file standards Dedicated GDML viewer Overlap check feature Large material database Material assignment on multiple volumes Create and combine simple shapes with preview Add simple shapes to converted STEP file Single piece, multiple pieces and total mass calculation Size measurement tool Search tool for components Screenshot tool Multithread support Multilanguage support (ENG, TR, IT, CN) Technical Support in 48 hours Multiple user/seat licensing option

Table 2. The file formats and versions that MRADSIM supports.

File Format	Extension	Version
STEP	.step, .stp	AP203, AP209,
		AP214, AP214e3,
		AP214, AP214e1
STL	.stl	ASCII/Binary
IGES	.iges, .igs	IGES 5.3
VRML	.wrl 1	VRML 2.0





MRADSIM-ConverterPro FEATURES & PERFORMANCE

- Table 1: Unique Features of MRADSIM-ConverterPro
- Table 2: CAD file formats and versions that MRADSIM-ConverterPro supports
- Upper right: STEP file reading time, GDML file writing time and overlap check performance of MRADSIM for STEP files with various file sizes.
- Lower right: Overlap check performance of MRADSIM with and without multithreading for STEP files with various file sizes.



MRADSIM-Space INPUT/OUTPUT

MRADSIM needs five key inputs to perform the analysis:

GEOMETRY
 SOURCE PARTICLE
 ANALYSIS PARAMETERS
 PHYSICS DEFINITION
 OTHER

MRADSIM offers various analysis methods for space study purpose:

- Energy Deposition
- 3D SCORE Dose Depth
- Total Ionization Dose
- Fluence on DUT surface
- Path Length Analysis
- Linear Energy Transfer
- Non Ionising Energy Loss (NIEL)
- Charging



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MRADSIM-SPACE SIMULATION TECHNIQUES

- Forward and Reverse montecarlo methods
- Artificial Intelligence (AI) algorithms (RandomForest) to perform
 - 3-D Dose maps,
 - Dose-Depth Curves
 - Total lonizing Dose (TID) estimations



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MRADSIM AI – SUPER RESOLUTION FOR 3D DOSE MAPS





Use ML to artificially increase resolution on 3D dose map distributions

Created model architecture and tested two different models

- 3D-VAE
- Random Forest Regressor

First tests with limited dataset

Results are not yet optimized

Future plans:

- Increase volume and complexity of training dataset
- Test with different optimizers, loss functions, and other models
- Increase the number of events to predict (up to 10¹2)

DEAMIDE (INFN TECHTRAN

MRADSIM-SPACE BENCHMARKING

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MRADSIM-Space Benchmarking with **GRAS5** (Forward MC)

$0 (m g_{\tau}) = 0$	# of sigma =	$(V_m -$	$V_{g4})/$	σ_m^2 +	σ_{g4}^2
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TRAPPED PROTONS							
	MRADSIM GRAS 5						
Units		Value	Error	Value	Error	Delta [sigma]	
	# events	4E+08	-	40000000	-		
S	Total time	56343,5	-	87694,2	-		
us	Time per event	140,859	Ξ.	219,2355	2	182	
e	Quartz - Charging	5,53E+09	9,22E+08	5,68E+09	9,34E+08	-0,117041	
MeV	Quartz - Edep	1,03E+09	1,86E+08	1,05E+09	1,90E+08	-0 <mark>,085438</mark>	
mSv	Quartz - EqDoseQF	147,723	27,243	148,522	26 <mark>,48</mark> 51	-0,021029	
mSv	Quartz - EqDoseRWF	111,869	20,2141	114,338	20,6702	-0,085399	
particles/cm2	Quartz - Fluence - total	7,22E+08	1,20E+08	7,42E+08	1,22E+08	-0,117043	
particles/cm2	Quartz - Fluence - electron	0	0	0	0	-	
particles/cm2	Quartz - Fluence gamma	0	0	0	0	-	
particles/cm2	Quartz - Fluence - proton	7,22E+08	1,20E+08	7,42E+08	1,22E+08	-0,117043	
MeV/cm	Quartz - LET	8,07E+19	1,79E+18	8,10E+19	1,76E+18	-0,119525	
95MeVmb	Quartz - NIEL	8,73E+11	1,51E+11	8,70E+11	1,48E+11	0,016247	
mm	Quartz - Path	1,03E+07	1,86E+06	1,08E+07	2,07E+06	-0,173949	
rad	Quartz - TID	0,55934	0,101071	0,571691	0,103351	-0,085419	
e	Silicon - Charging	3,53E+09	7,37E+08	3,38E+09	7,20E+08	0,149072	
MeV	Silicon - Edep	6,88E+08	1,59E+08	5,79E+08	1,49E+08	0,499295	
mSv	Silicon - EqDoseQF	380,207	86,8132	296,294	74,4485	0,733737	
mSv	Silicon - EqDoseRWF	277,662	64,0829	233,751	60,2313	0,499297	
particles/cm2	Silicon - Fluence - total	3,29E+08	6,87E+07	3,15E+08	6,72E+07	0,149071	
particles/cm2	Silicon - Fluence - electron	0	0	0	0	1.	
particles/cm2	Silicon - Fluence gamma	0	0	0	0	1 12	
particles/cm2	Silicon - Fluence - proton	3,29E+08	6,87E+07	3,15E+08	6,72E+07	0,149071	
MeV/cm	Silicon - LET	5,87E+19	2,21E+18	6,34E+19	3,67E+18	-1,110623	
95MeVmb	Silicon - NIEL	4,08E+12	1,30E+12	1,28E+12	4,63E+11	2,030266	
mm	Silicon - Path	7,62E+06	1,79E+06	7,18E+06	1,89E+06	0,171075	
rad	Silicon - TID	1,38831	0,320415	1,168750	0,301157	0,499308	

Co60 – Cs137 γ s to various target materials **MRADSIM-Space vs pure Geant4**





MRADSIM NEWS

MRADSIM is now officially available to INFN members

- Already installed: TRIESTE, MILANO-BICOCCA, PADOVA
- In progress: LNGS

CNTT proposed MRADSIM for VQR 2024

A webinar for all interested INFN members will be organized soon



MRADSIM

Ultima modifica: 27 Maggio 2024

Descrizione Generale

MRADSIM (Matter Radiation Interactions Simulator) è un software di simulazione sviluppato da BEAMIDE srl, uno spinoff ufficale dell'INFN.

MRADSIM è un pacchetto di software finalizzato alla simulazione degli effetti dannosi delle radiazioni su apparati elettronici, tessuti biologici e materiali utilizzati in progetti spaziali o terrestri. Informazioni dettagliate si possono trovare in https://www.mradsim.com/about-mradsim/.

Dettagli licenza MRADSIM

MRADSIM è un prodotto per il cui utilizzo è necessario disporre di una licenza.

L'INFN e BEAMIDE, grazie alla attività del CNTT, hanno sottoscritto un License Agreement che consente all'INFN di rendere disponibile MRADSIM al personale dipendente ed associato INFN a titolo gratuito.

L'EULA dà diritto all'INFN ad utilizzare fino ad un massimo di 25 installazioni di MRADSIM, una per struttura. Una installazione consiste in un server fisico o virtuale connesso alla rete locale della struttura INFN, con il software installato, su cui gli utenti della struttura possono connettersi interattivamente, anche concomitantemente, ed utilizzare il software. Il software acquisisce una licenza via rete tramite un license server nazionale installato sulla infrastruttura dei SSNN della CCR.

https://web.infn.it/CCR/index.php/it/sito-utenti-del-calcolo/licenze/mradsim/mradsim-descrizione

Recent presentations at:

- SERESSA2023 "19th International School on the Effects of Radiation on Embedded Systems for Space Applications", 4-7 December 2023, Turin
- ASI Workshop "Tecnologie spaziali per le future missioni di ASI", 16-19 April 2024, Rome
- ESA/ESTEC RADSHIELD Workshop, 12-13 June 2024, Noordwijk
- IAC/IAF 2024, 14-18 October 2024, Milan

BEAMDE CINFN OUR TEAM MEMBERS



BEHCET ALPAT SCIENTIFIC CONSULTANT & FOUNDER

High energy nuclear physics; Particle detector; Scientific simulation; Team manager



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Al application integration and advanced algorithm implementation.



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- A free demo of MRADSIM-Converter largely used by early adopters since 2021
 - Early adopters include NASA, Stanford University, ESA, CERN, NCSS-CAST, M.I.T. of Boston, Brookhaven National Lab-BNL, etc.
- Now released MRADSIM-CONVERTER-PRO and first version of MRADSIM-SPACE
 - In 2024 also the release of MRADSIM-BASIC
- MRADSIM now published on CCR website and available to all interested INFN sections
- MRADSIM is already winner of many projects
 - SMARTUP 2021-POR FESR Umbria 2014-2020 (ended 30 Sept 2023)
 - INVITALIA-SMART&START ITALIA Decreto 30 Agosto 2019 (ends May 2025)
 - EOSC (European Open Science Cloud) pilot project (ended 30 June 2023)
 - PRIN- PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE Bando 2022, Prot. 2022YEEB9Y. REASE project
 - MINISTRY OF DEFENSE, ITALY: Project submitted with THALES-ALENIA-ITALY and BEAMIDE for «<u>simulation of nuclear explosions in space</u>», Approved

Recently, BEAMIDE SrI was selected for Premio America Innovazione, the awards ceremony took place on March 14th, 2024 at Italian Parliament

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MRADSIM DEMO

MRADSIM Demo Video.mp4

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THANKS FOR ATTENTION

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