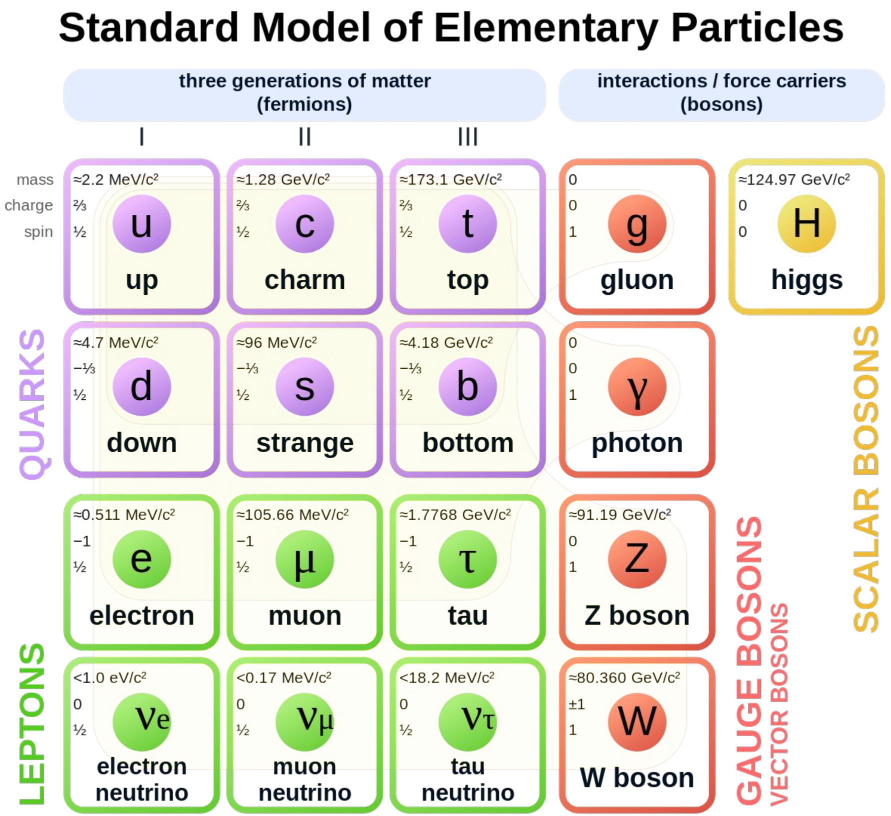
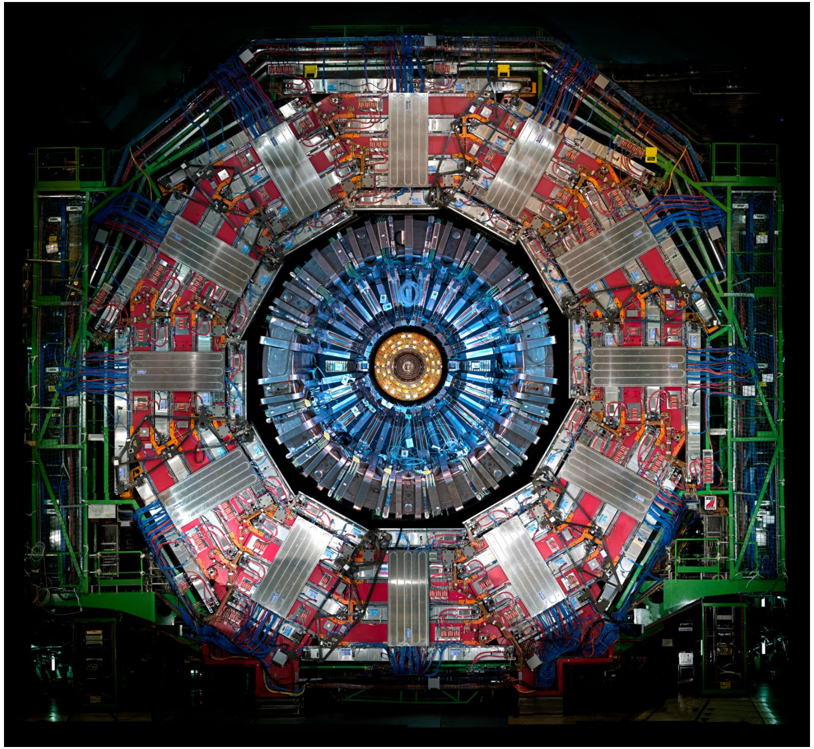
Latvian Students at CERN

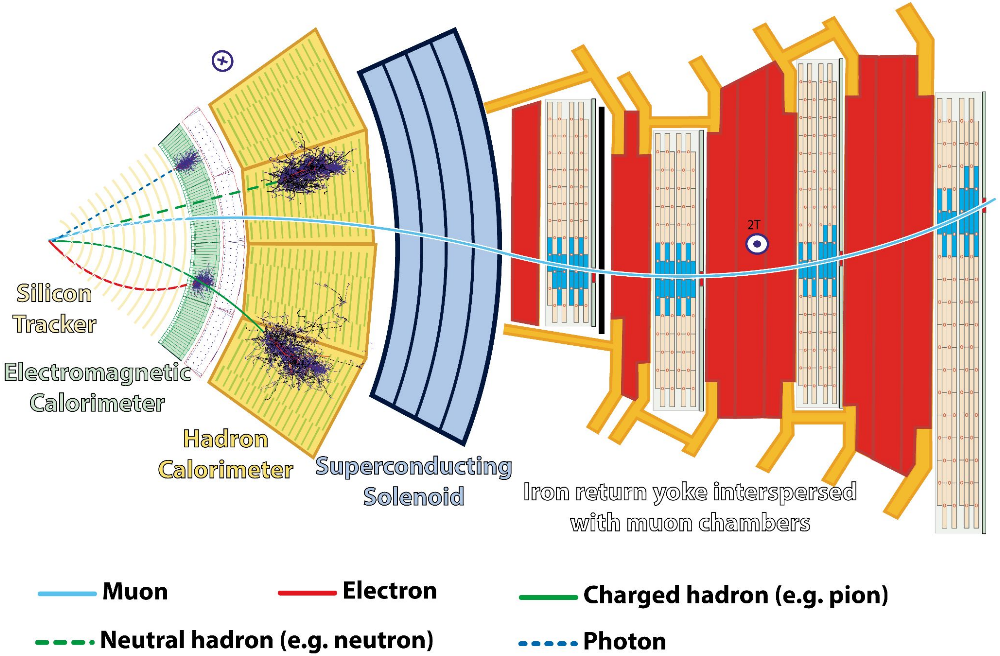
Standard Model

- Cornerstone of modern Particle Physics
- Describes 3 of the 4 fundamental forces of the universe
- Elementary particles → 6 quarks, 6 leptons, 4 gauge bosons, 1 scalar boson
- Still, many open question persist:
  - Inclusion of gravity,
  - Dark matter and energy,
  - Neutrino masses,
  - Matter/anti-matter asymmetry,
  - etc.



The CMS detector

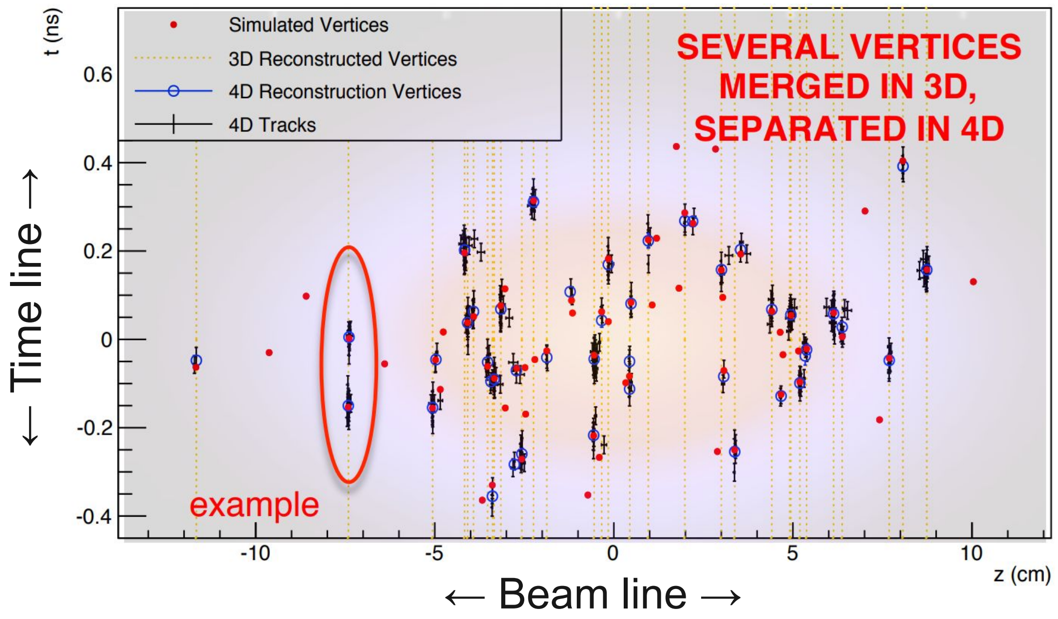




Minimum Ionizing Particle Timing Detector (MTD) will help untangle overlapping events

- High Luminosity LHC (HL - LHC) will deliver 150 - 200 simultaneous pp collisions (now 65) per bunch crossing.
- MTD is introduced to provide a better track-time resolution.

- MTD has two regions: Endcap and Barrel Timing Layer (ETL and BTL).
- BTL consists multiple trays forming a cylinder, ETL consists of several wedges forming discs.

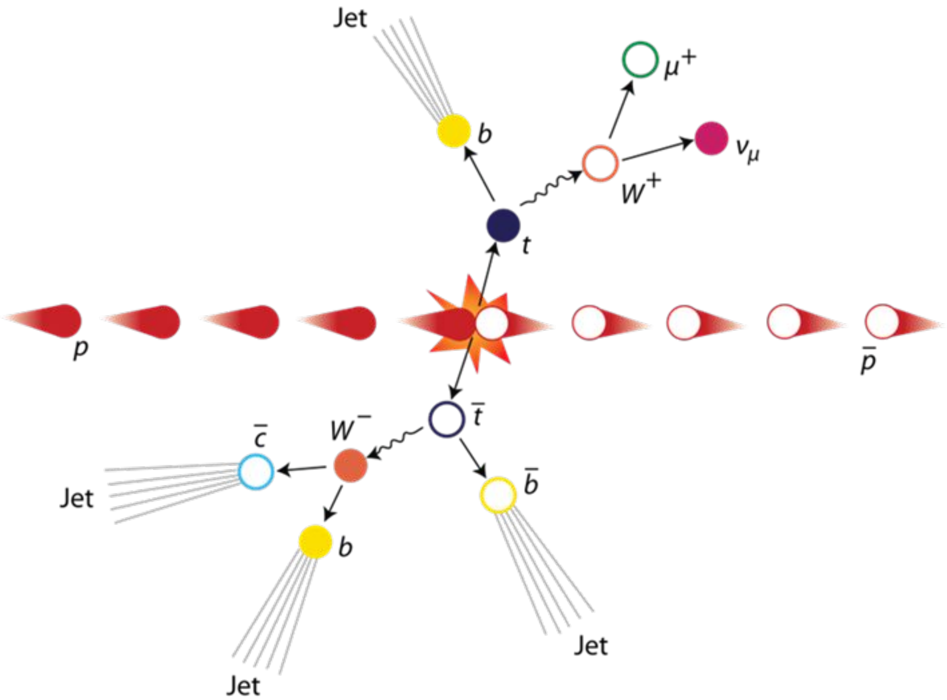


We are working with prototyping BTL mechanics and assembly

These tests and activities happened during last year to be prepared for this year, when the assembly is happening:

- BTL tray insertion tool assembly and testing.
- Tray assembly.
- Annealing test of the BTL prototype segment at 10° CO_2 cooling, and other regimes.

Studying top-quark decay channels



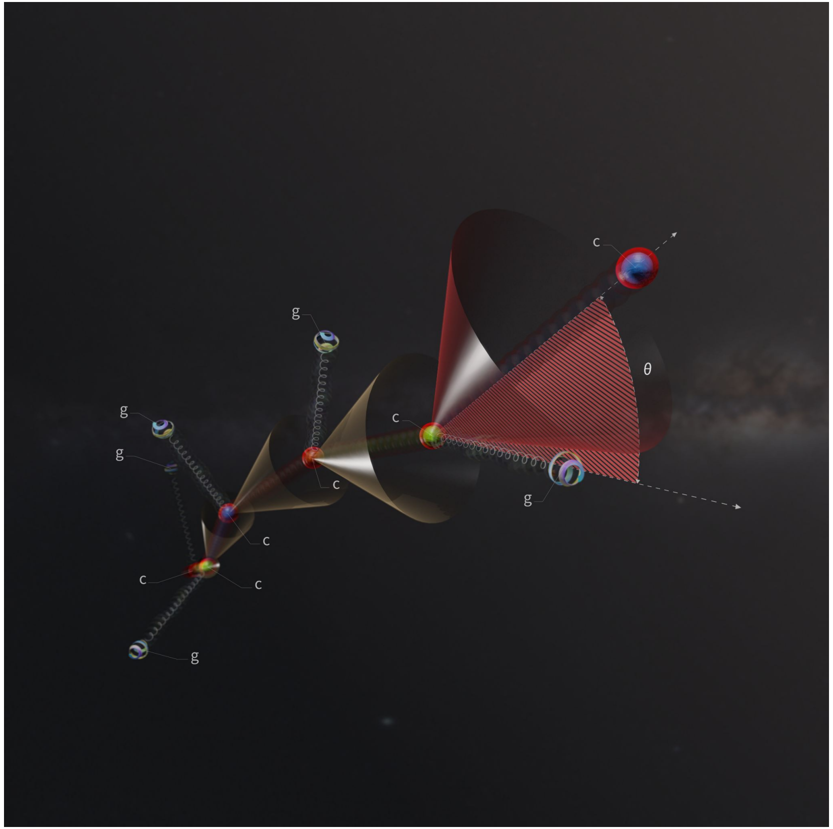
Proton collision → top-quark pair → bottom-quark jet

Dead-cone effect in b-jets in top-quark decays

- As the bottom quark decays, it looses its energy by radiating gluons
- This radiation is surpressed for a cone of angular size:

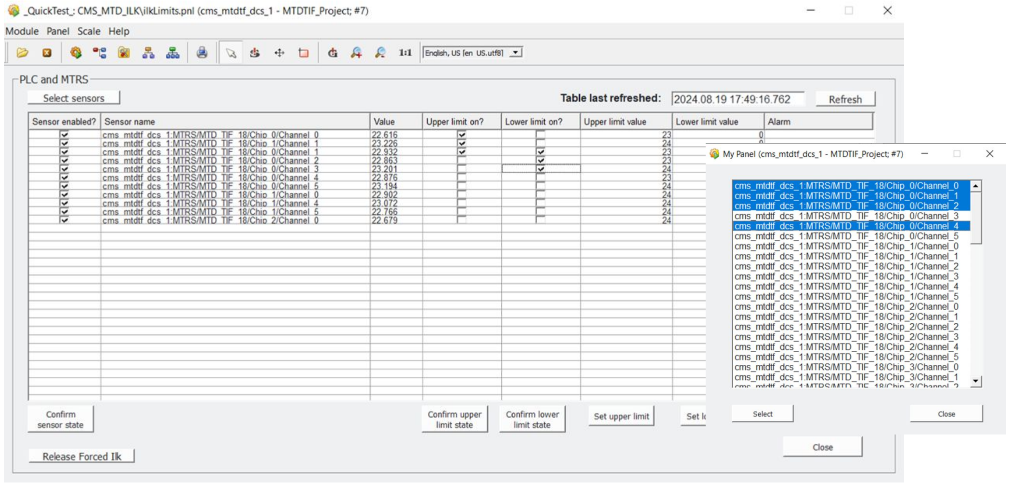
$$\Theta_Q = M_Q / E_Q$$

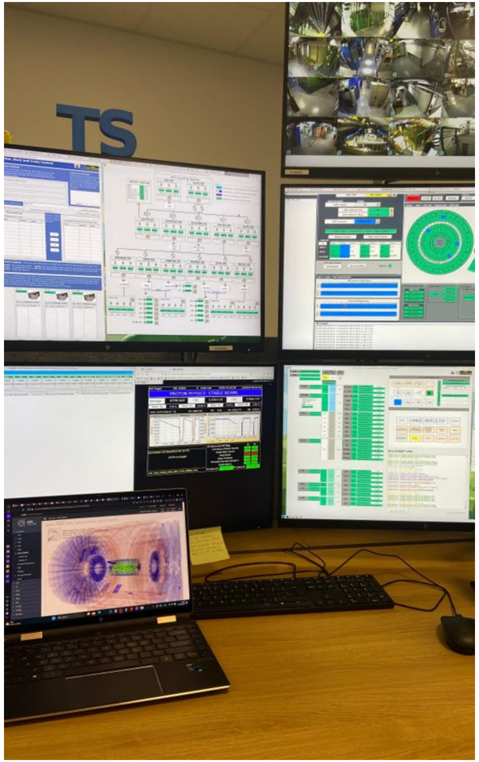
- This is called the **dead-cone** effect
- Measuring this effect is one of the ways of testing **QCD**
- This effect has already been measured for the charm quarks, but would be the first measurement for the bottom quarks



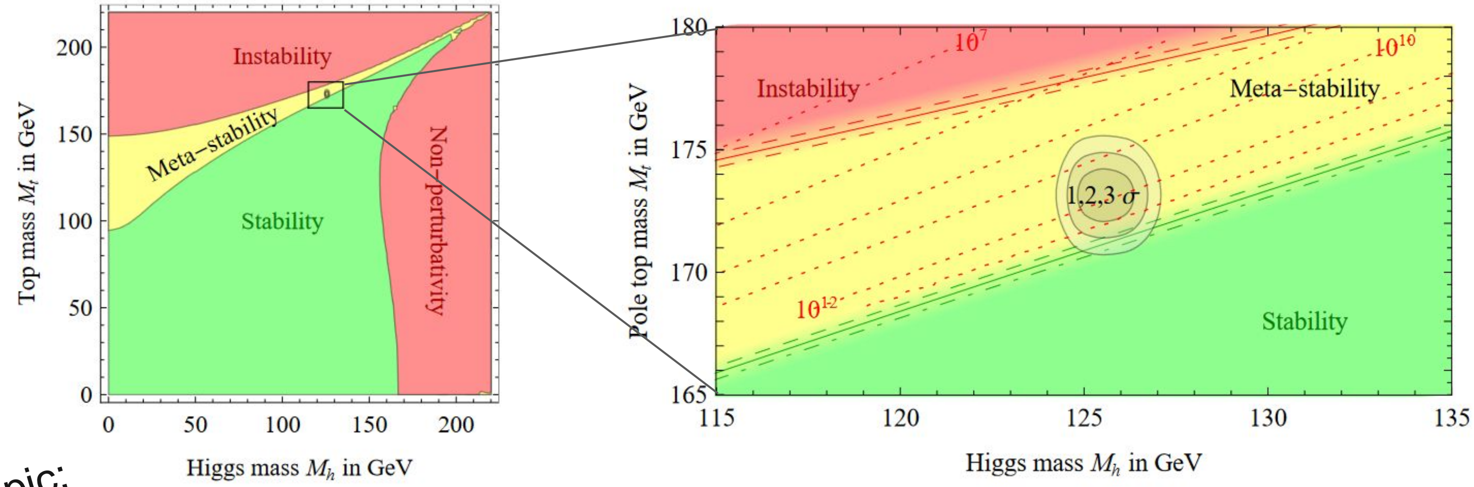
Other activities at CMS

- Working on MTD DCS (Detector Control System) and DSS (Detector Safety System)
- Doing DCS shifts at CMS Control room
- Previously worked on Particle Flow Hadron Calibration code



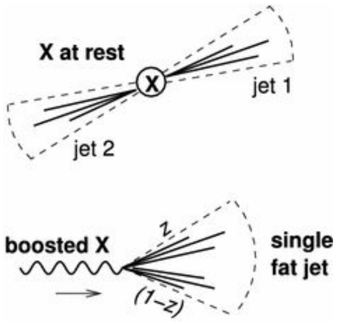


Importance of top quark mass



Thesis topic:

Measurement of boosted top quark mass at CMS experiment

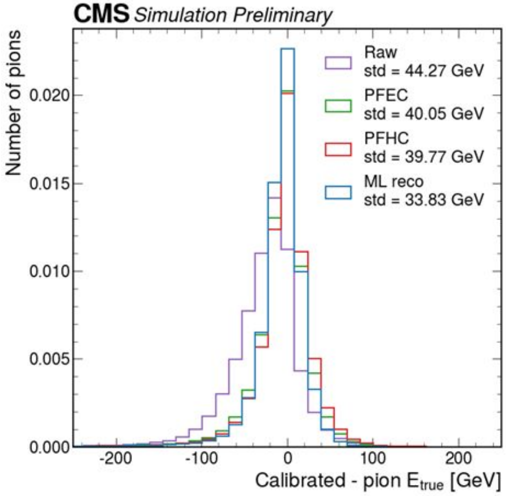


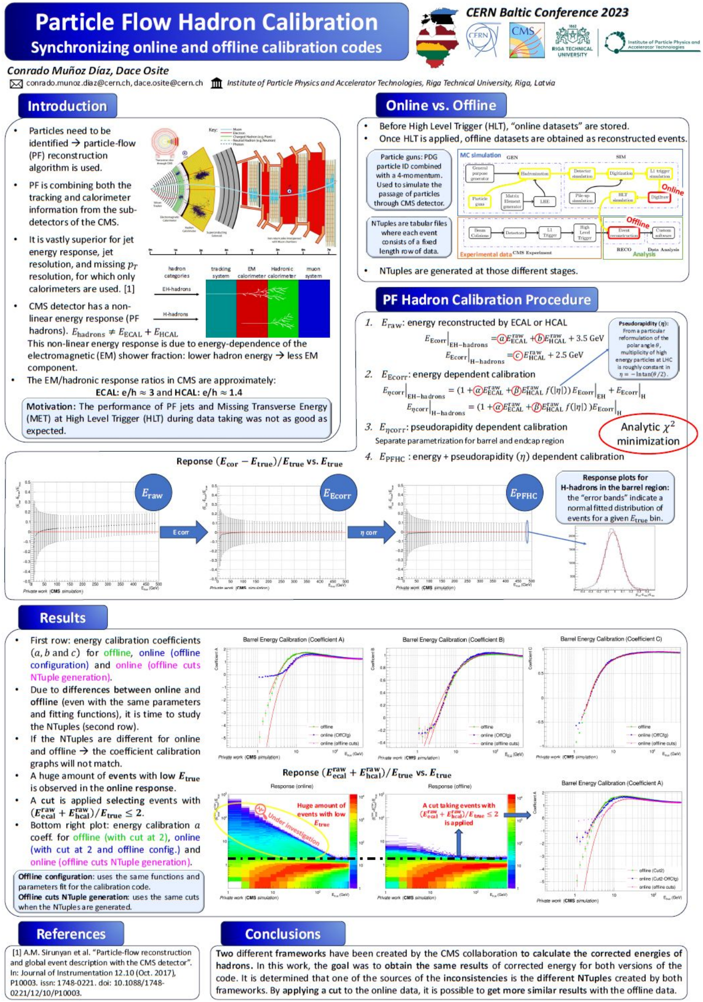
- Mass determination:
  - Probe of SM Higgs sector's structure
  - Physics beyond SM

1. Regions of absolute stability, meta-stability and instability of the SM vacuum.
2. Zoom in the region of the preferred experimental range (gray areas: allowed region at 1, 2 and 3σ)

Particle Flow Hadron Calibration

- CMS detector has non-linear energy response → hadrons needs to be calibrated.
- New code is being created in a different programming language (more comprehensive)
- Use of others methods to calibrate: power-law based or Machine Learning.





Work towards CMS autorship rights

- New collaborators must complete a set amount of non-analysis work to qualify for co-authorship rights for CMS publications
- Measured in EPR (Experimental Physics responsibilities) points (1 point = 1 month of work)
- To qualify, 6 EPRs are required (followed by 4 EPRs annually)

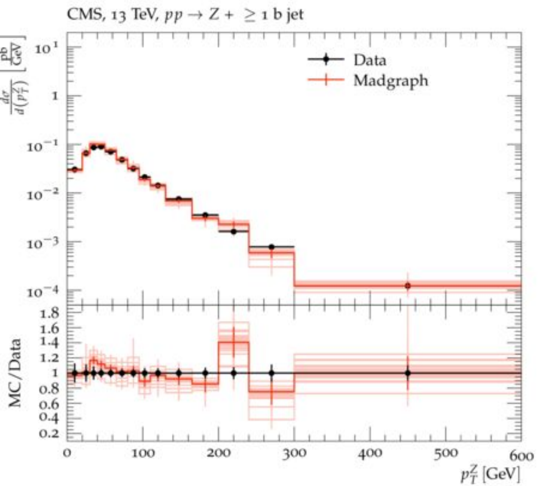
- 2 EPRs: Validation of ‘Special Remote DESY Summer-School 2023’ plugins with Rivet (14 in total between two PhD students)
- 2 EPRs: Development of read-only gridpack creation for MadGraph NLO event generation
- 2 EPRs: Work on the MIP timing detector for the HL-LHC upgrade (system development and assembly)

Experimental physics responsibilities

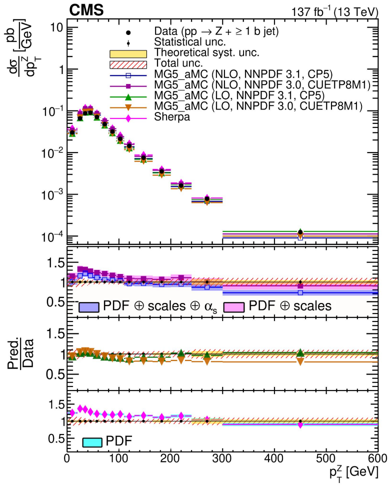
Validation of physics analysis summer school plugins with Rivet

- Rivet - toolkit used for validation of Monte Carlo event generators

Acquired



From article

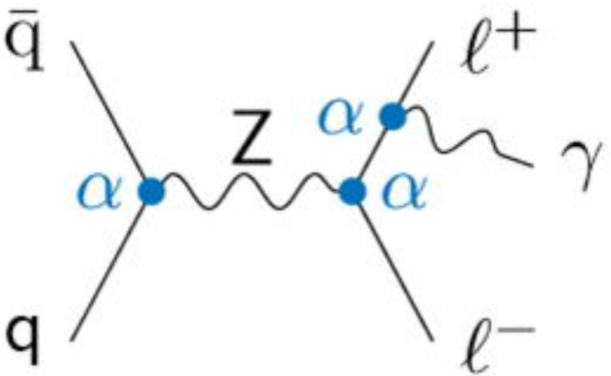


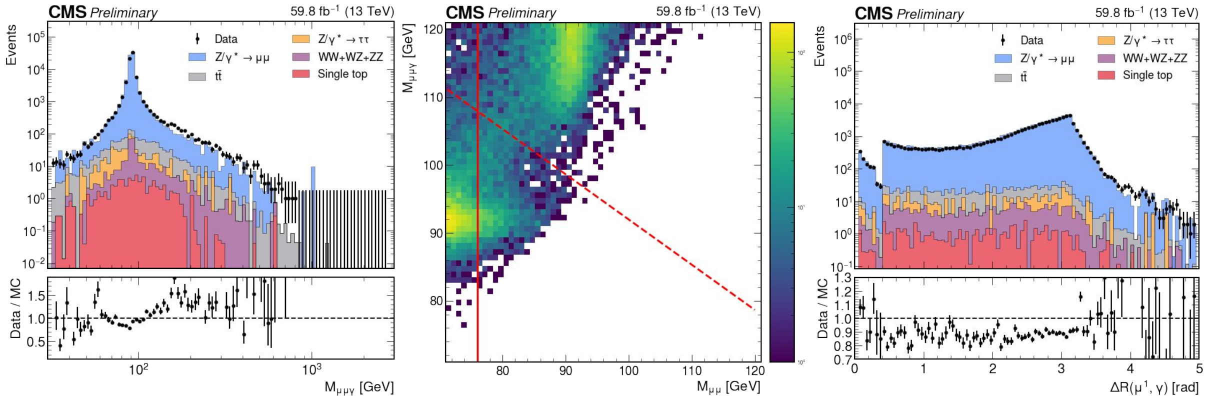
Read-only gridpack creation for MadGraph NLO event generation

- MadGraph - one of the Monte Carlo event generators used for collision simulations
- Monte Carlo generators allow to compare experimental data with theory
- Normally, preparation and untarring of gridpacks is a computationally heavy process
- This is why there is an effort to develop centralized read-only gridpacks that are pre-compiled and can be easily accessed for particle collision simulations

Work on thesis topic analysis

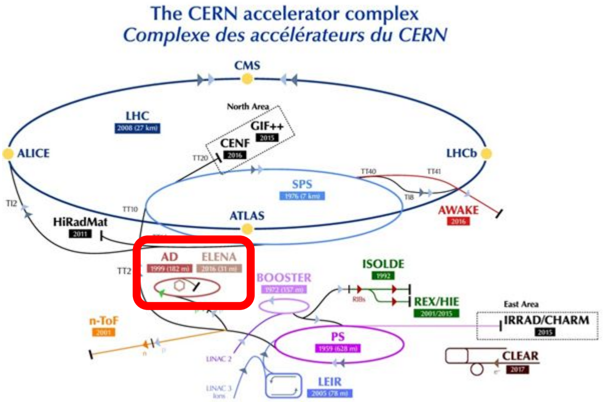
- Study of final-state radiation in Z boson decays produced at pp collisions at 13 TeV at the CMS
- Research of Z boson decay processes at 13 TeV will allow for more precise modelling of different particle production and decay parameters
- By conducting final state radiation measurements in Z boson decay events, the reconstruction of low transverse momenta photons in the CMS experiment can be improved
- In general, such a study would help improve various particle production and decay parameters, like the radiative contribution to the Z and W boson decays

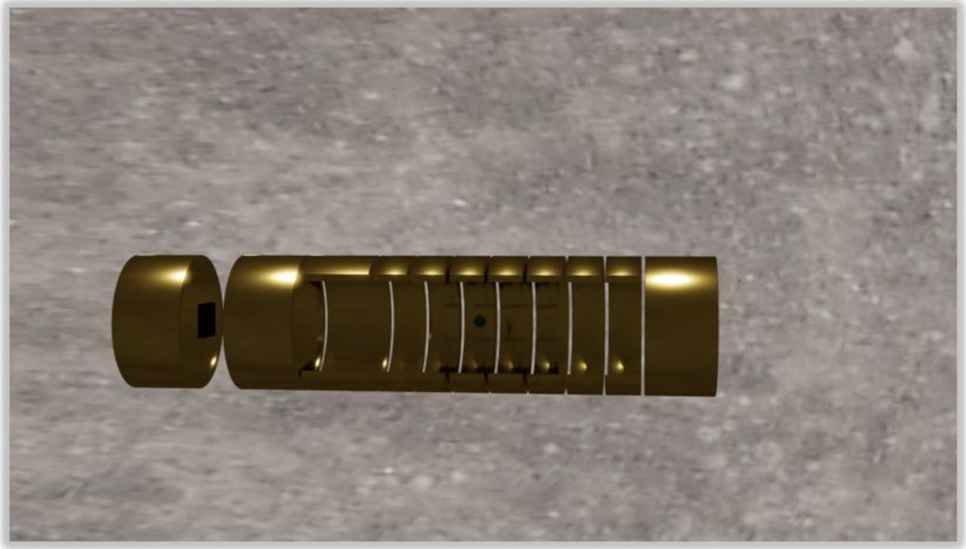


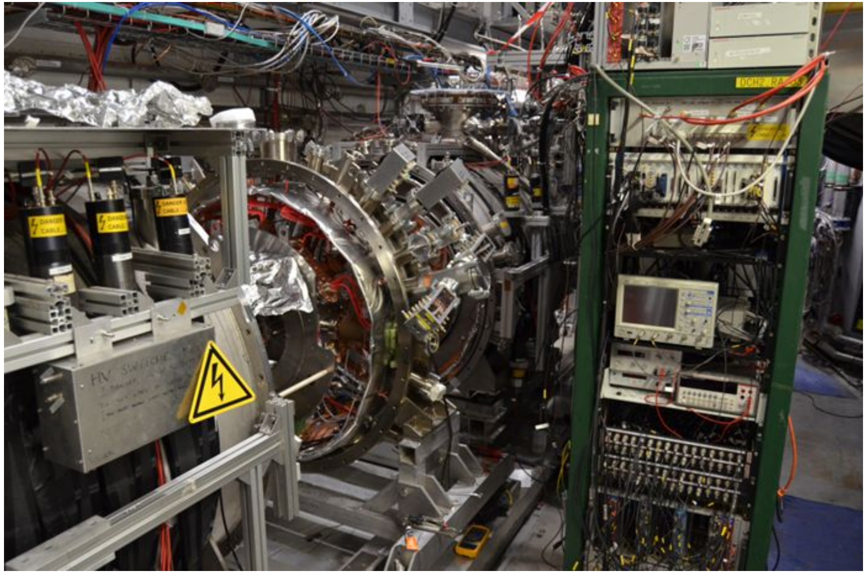


AEgIS

Antimatter Experiment: gravity, Interferometry, Spectroscopy





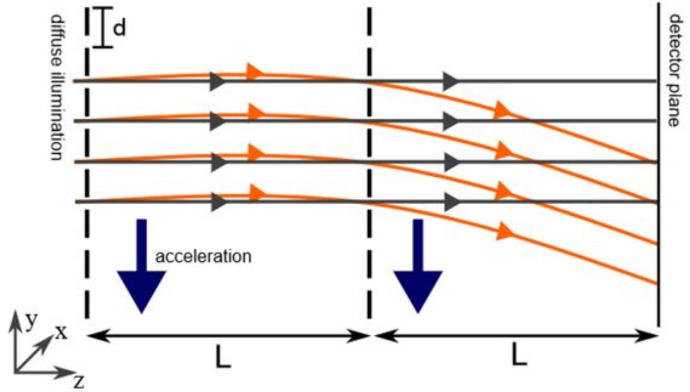


Feasibility study for OTIMA interferometer

Moiré deflectometer

Grating periodicity: >40μm

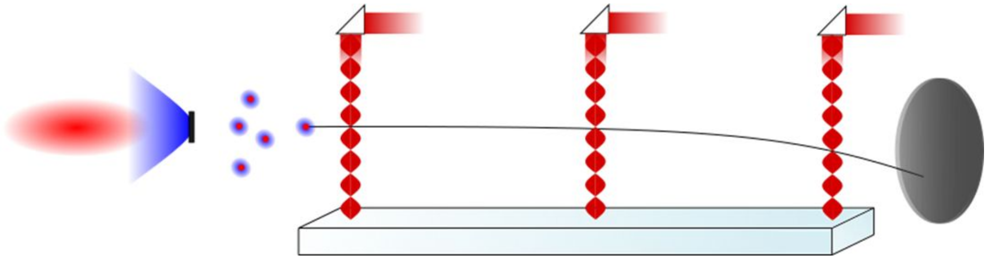
Flux only depends on solid angle



OTIMA interferometer

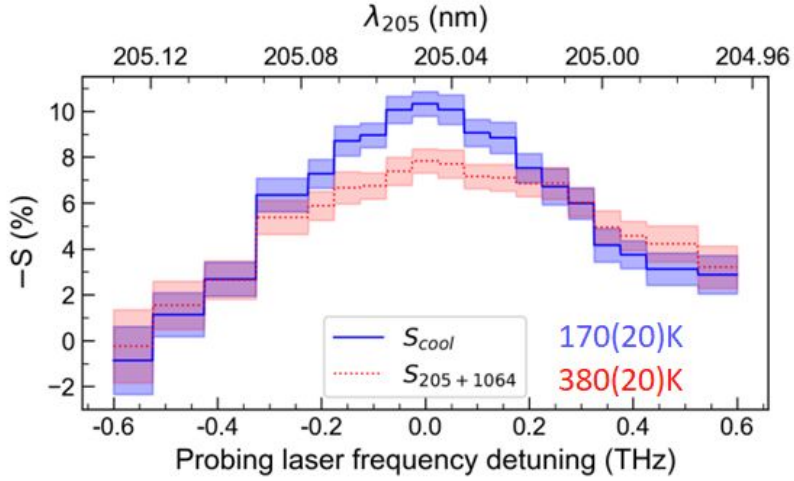
Grating periodicity: 532nm (if 1064nm laser is used)

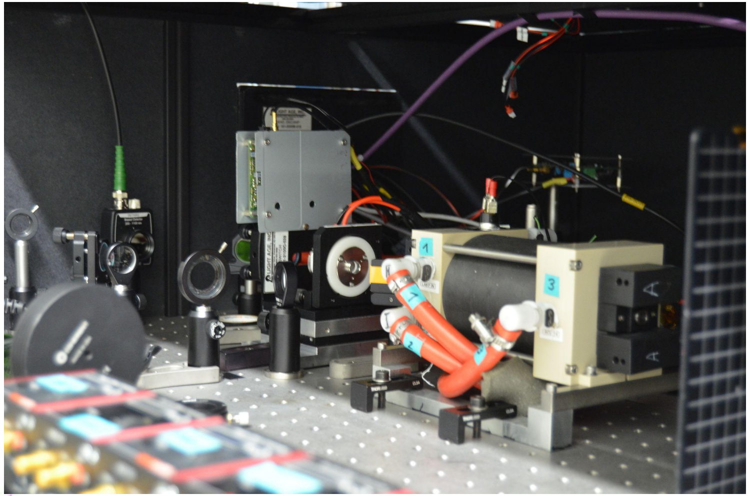
Flux depends both on solid angle and limits imposed by time



Positronium studies

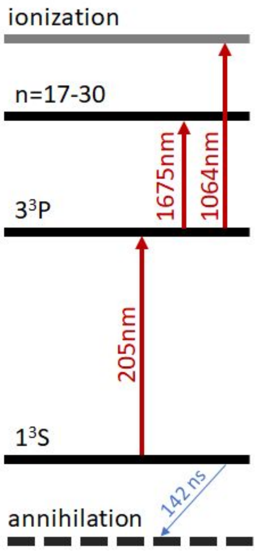
Positronium laser cooling

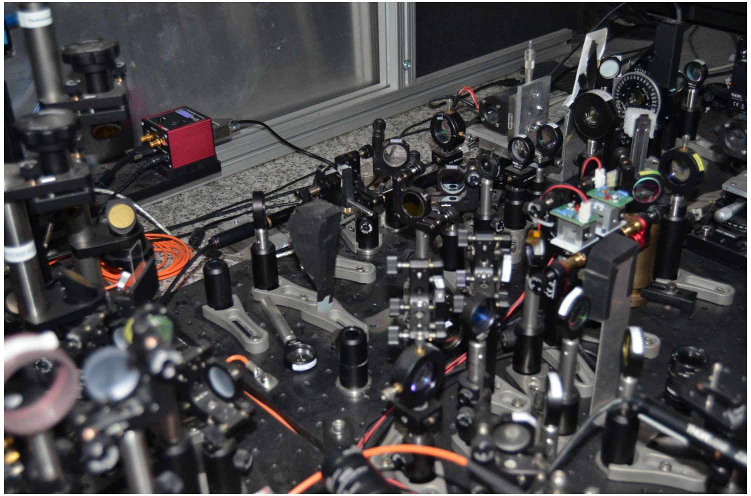


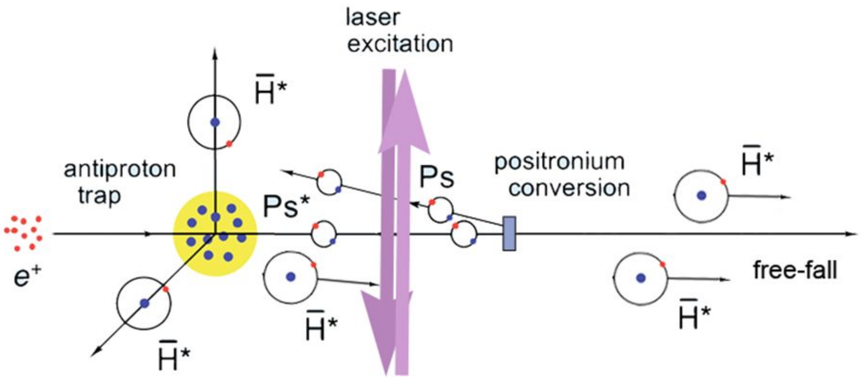


Positronium studies

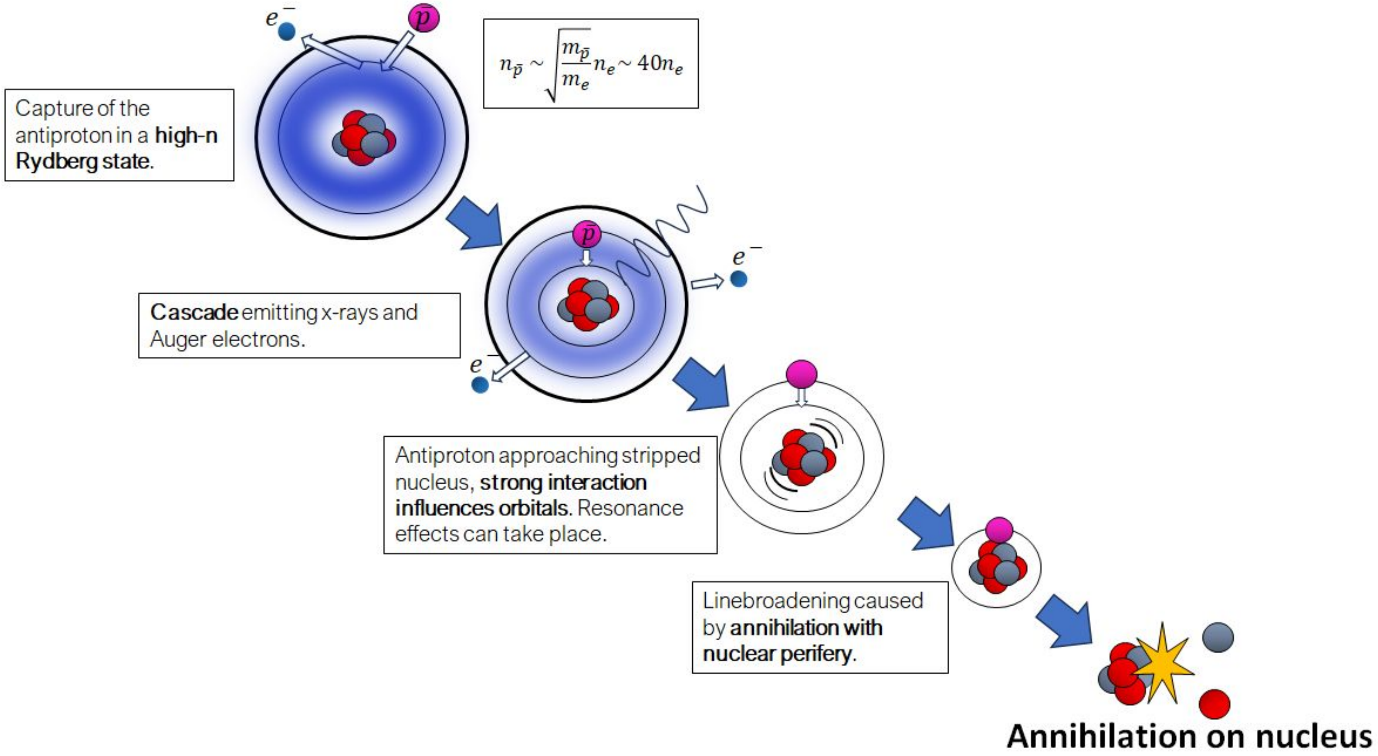
Upgrade of the Rydberg excitation laser





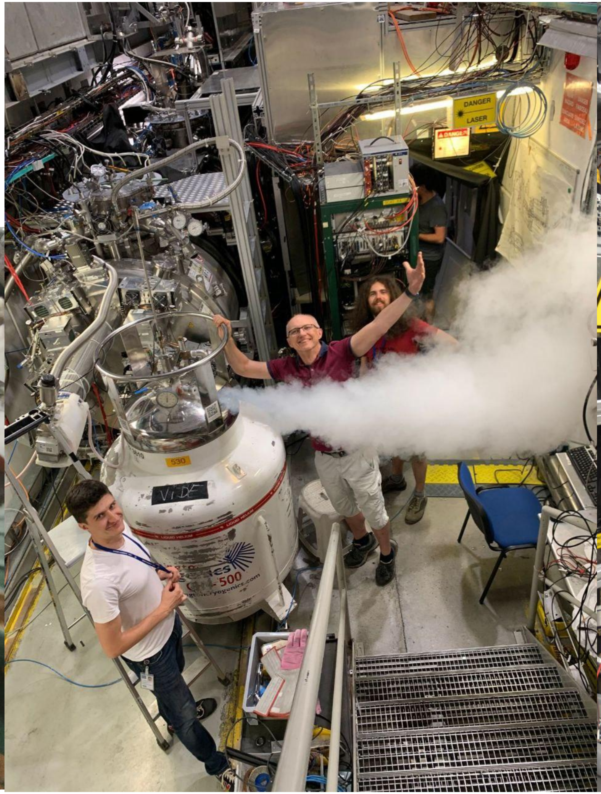


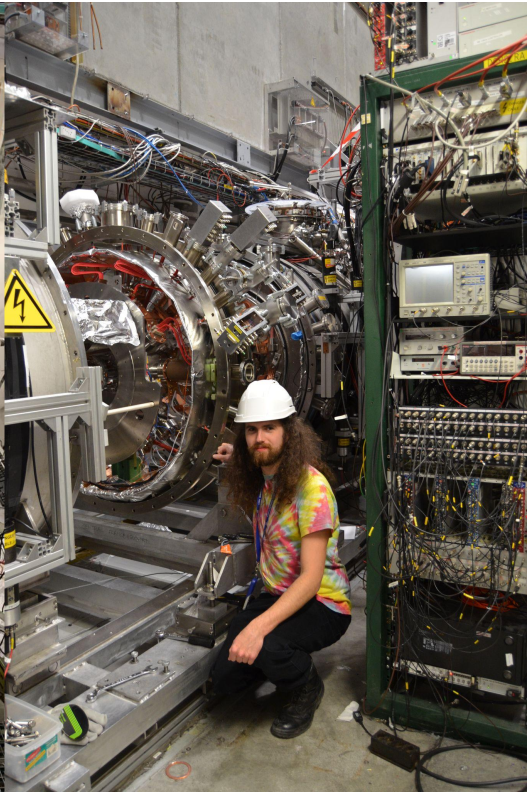
Antiprotonic atoms



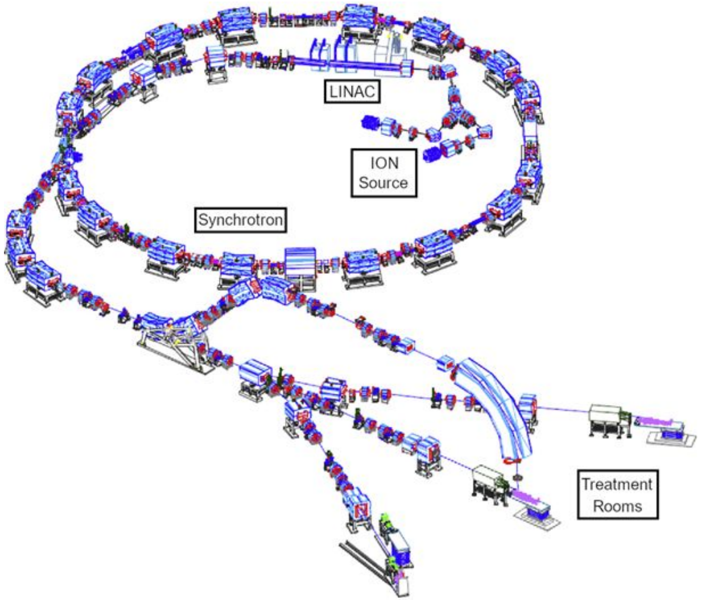
Other participation in AEgIS

Technical support



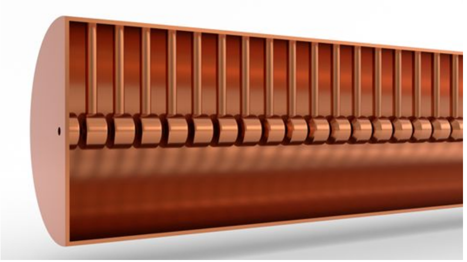


LINAC Overview

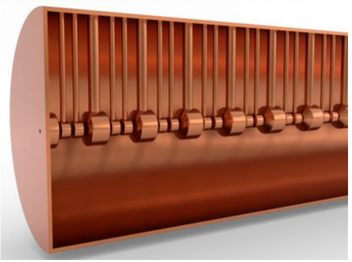


LINAC Structures

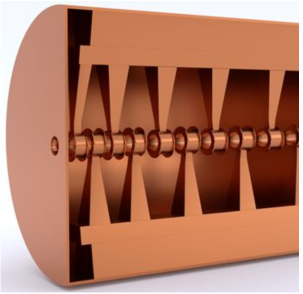
Alvarez Drift Tube LINAC (DTL)



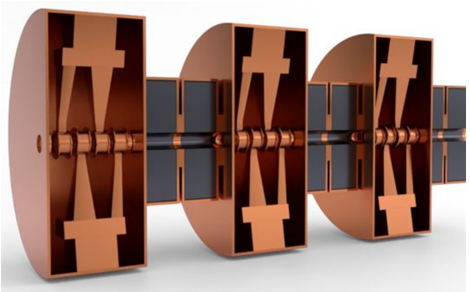
Quasi-Alvarez Drift Tube LINAC (QA-DTL)



Interdigital H-mode DTL (IH-DTL)

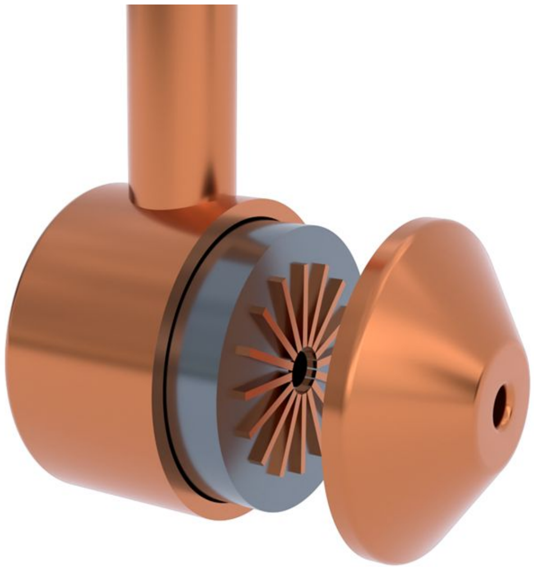


Separated Interdigital H-mode DTL (S-IH-DTL)



LINAC Drift Tube Design

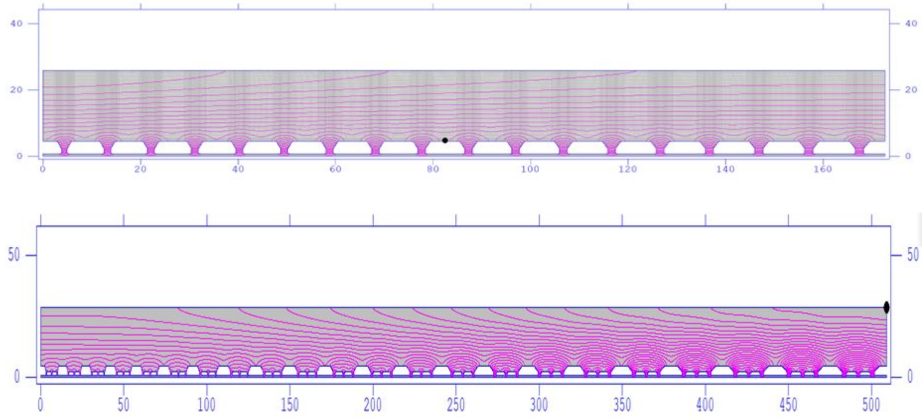
Drift Tube within E-mode DTLs



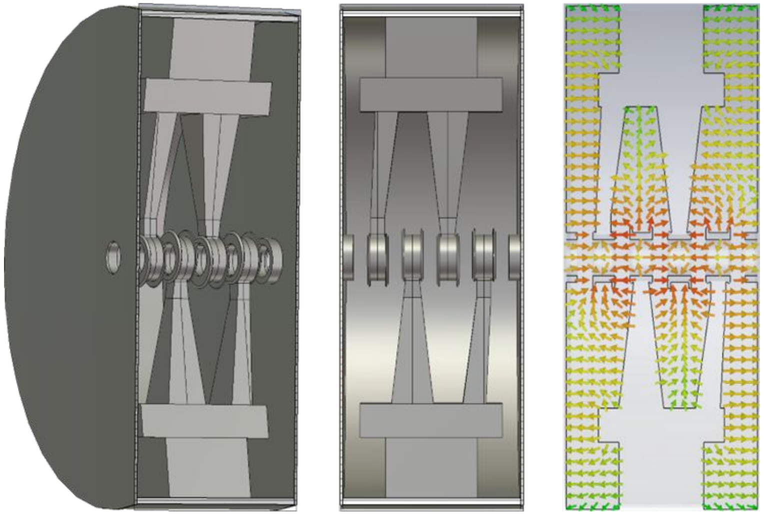
Drift Tube within H-mode DTLs

Radio Frequency (RF) Design

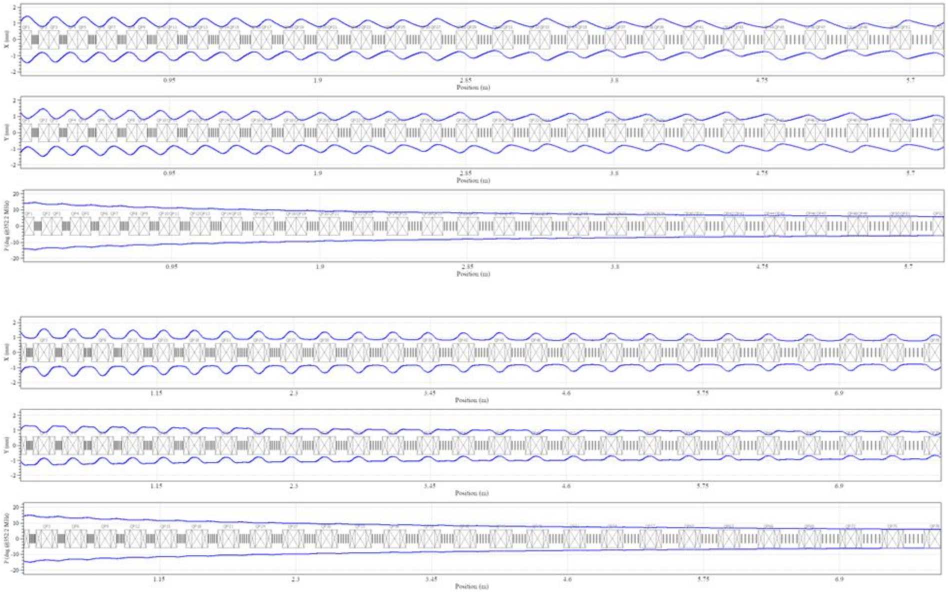
Poisson Superfish Codes

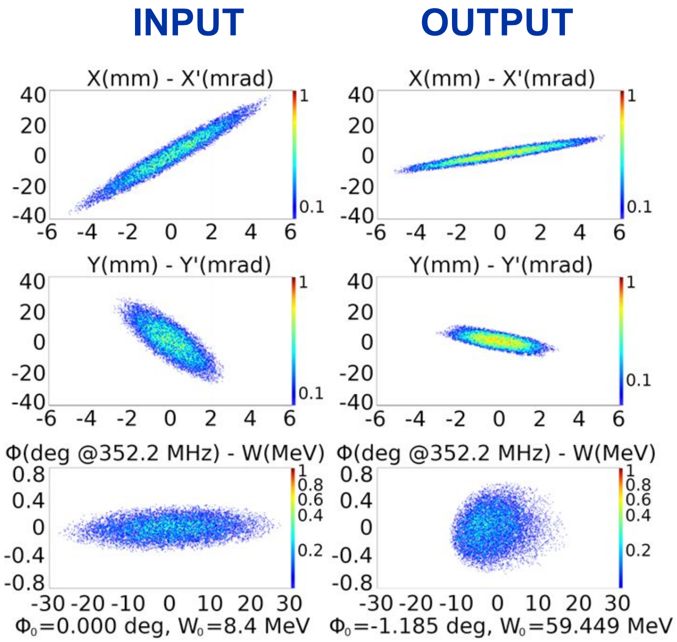


CST Studio Suite

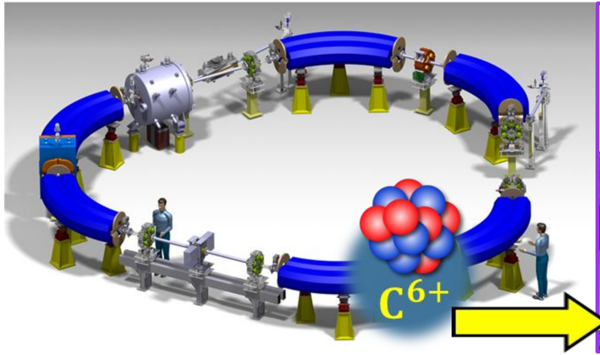


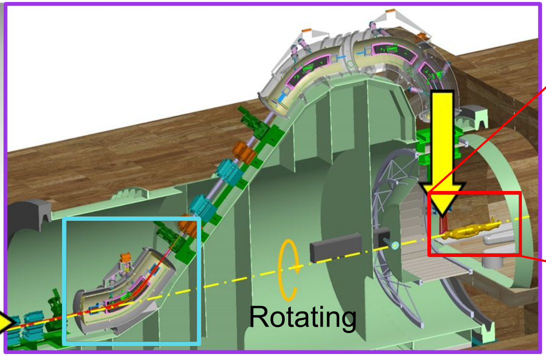
Beam Optics - $^{12}C^{4+}$ Ions

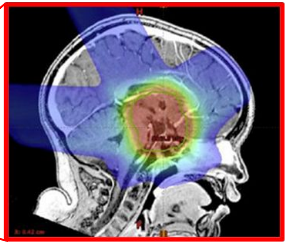


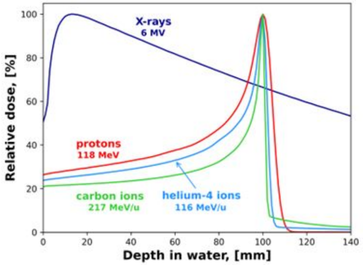


Design and Optimization of Suspension System for Hadron Therapy Gantry Superconducting Magnets

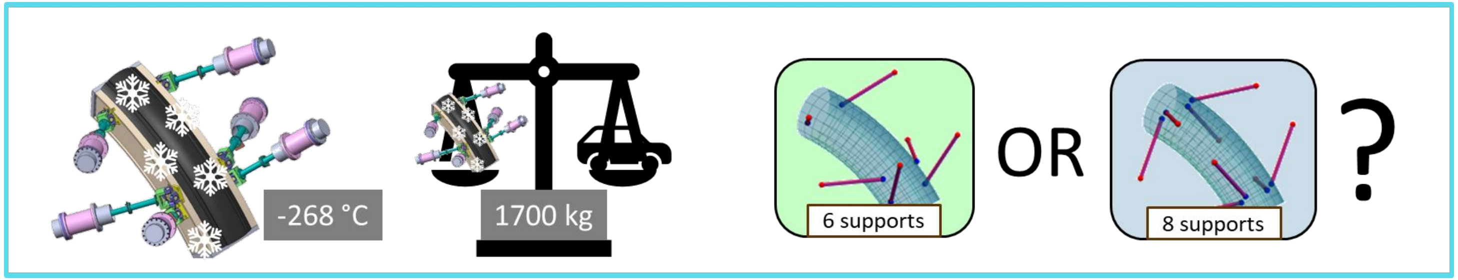




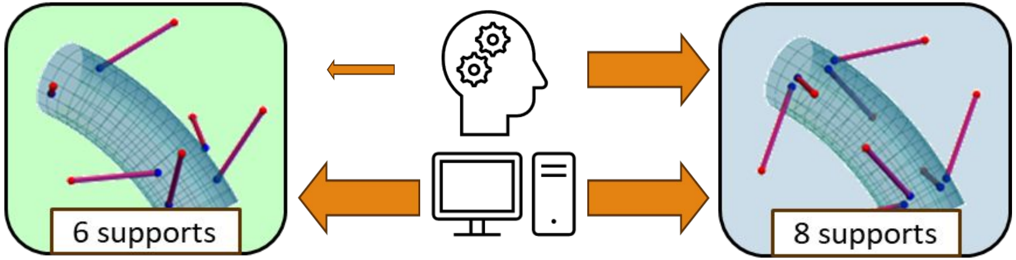




PhD Thesis study HITRIplus contribution to Mechanical Integration



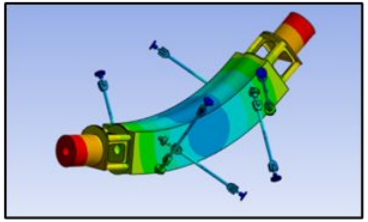
How to make the comparison unbiased and fair?



- **20 variables**

- 6 variables (symmetry)
- Existing examples

Finite Element Analysis
(Standard Engineering)



5 - 10 configurations/h

Lumped Parameter Model (PhD)

$$\int_0^L \mathbf{N}_j \cdot \left(\frac{\mathbf{N}_0 + X\mathbf{N}_X + Y\mathbf{N}_Y}{EA} \right) ds = \mathcal{W}_{\text{ext},j}$$

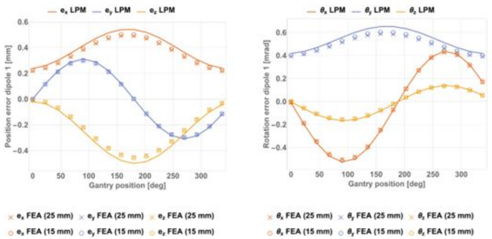
50000 configurations/h

1) **LPM modelling**

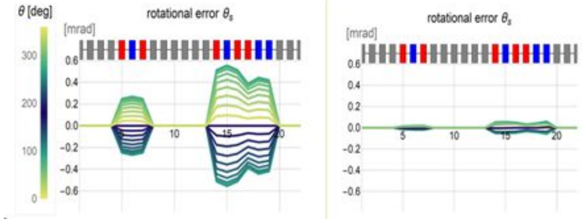
$$\int_0^L \mathbf{N}_j \cdot \left(\frac{\mathbf{N}_0 + X\mathbf{N}_X + Y\mathbf{N}_Y}{EA} \right) ds = \mathcal{W}_{\text{ext},j}$$

Can be extended to n > 8 tie rods

2) **LPM Validation**

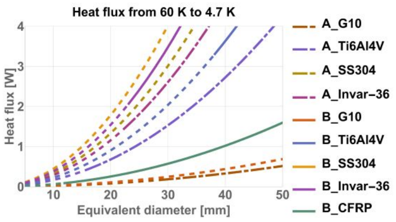


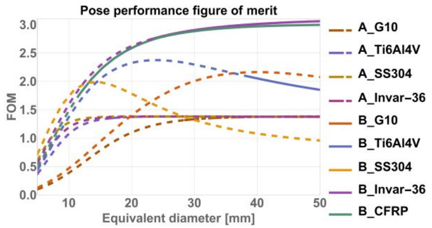
3) **Optimization…**



How to make the comparison unbiased and fair?

4) …Design (Material and dimensions)





5) Comparison

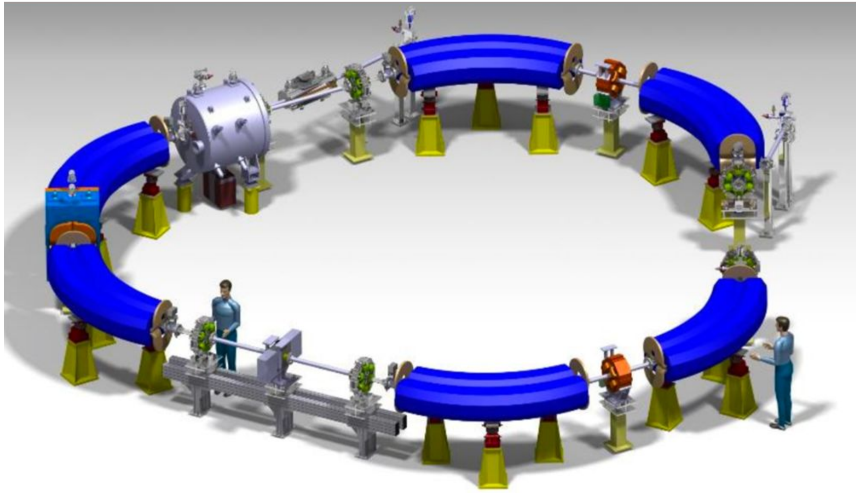
Table 2. Comparison of the main parameters and figure of merits of the two architectures.

		A	B	% improv.
Material		Ti6Al4V	CFRP	
Geometry		tube	double band	
Equivalent diameter	mm	18.0	13.2	
e_x	mm	0.36	0.37	-4%
e_y	mm	0.32	0.24	23%
e_s	mm	0.45	0.36	20%
θ_x	mrad	0.16	0.04	73%
θ_y	mrad	0.36	0.12	65%
θ_s	mrad	0.56	0.22	60%
FOM dipole 1		1.3	1.8	38%
FOM dipole 2		2.3	1.3	-43%
FOM dipole 3		2	1.4	-30%
FOM dipole 4		1.7	1.3	-24%
FOM average		1.79	1.44	-20%
Max load	kN	19.9	22.3	
Safety factor		12.2	12.2	
Heat flux @ 4.5 K	W	0.55	0.11	80%
Compressor input power	kW	2.6	0.5	80%

- Mathematical models for the 6 supports and 8 supports have been developed and validated
- Mathematical model for 8 supports can be extended to “n” supports
- Both designs have been optimized (Genetic algorithms) thanks to the models developed
- The designs can be compared in a fair manner thanks to the methodology used
- The 6 supports system is easier to align and more reliable during the alignment
- The 8 supports system is less subject to deformations during operation and cheaper to maintain at cold

Next Ion Medical Machine Study and FLASH therapy

HeLICS *Helium Light-Ion Compact Synchrotron*



Development of next-generation compact accelerator technologies for medical applications in ion therapy: developments on new lattice designs, superconducting magnets, extraction methods and ***FLASH* delivery**

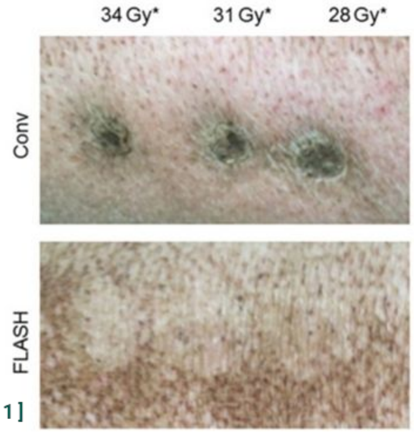
FLASH therapy

- Biologically observed differential effect – when irradiation with ionizing irradiation is performed at ultra-high dose rates - **adverse effects in healthy tissue are greatly reduced while DNA damage in cancerous tissue remains the same**
- Timescale of dose delivery: **milliseconds**

- To achieve it dosimetrically:
  - **high dose: > 8-10 Gy**
  - **high dose rate: > 40 Gy/s**

- Open questions regarding pulse structure, radiation quality, fractionation etc.

COULD WE COUPLE FLASH AND HEAVY ION THERAPY?

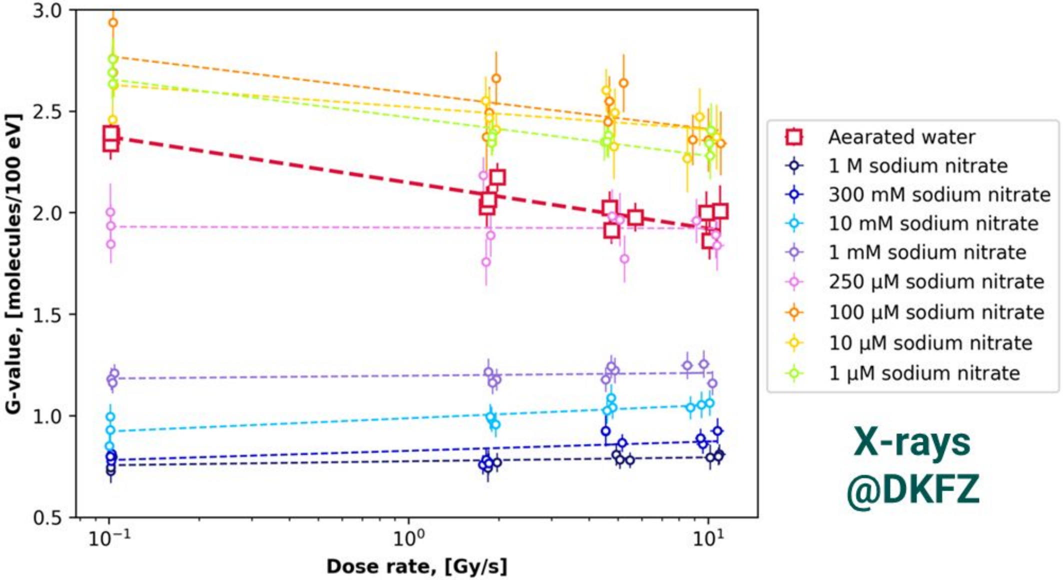


[1]

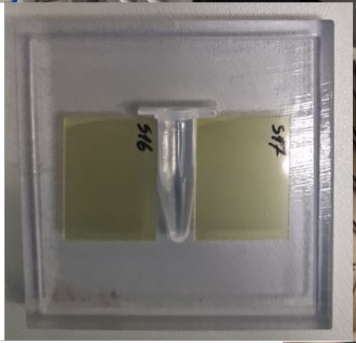
[1] Vozenin M-C, De Fornel P, Petersson K, et al. The Advantage of FLASH Radiotherapy Confirmed in Mini-pig and Cat-cancer Patients. Clinical Cancer Research 2019

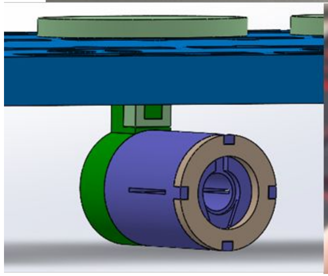
Experimental radiochemistry studies under UHDR

- Measurement of long-lived, stable radiolysis end-products - **hydrogen peroxide** - for verification of radioactive oxygen species (ROS) importance for *FLASH* therapy
- Solvated electron scavangers (*nitrous oxide and sodium nitrate*) were used to gain mechanistical insight in radiochemical processes



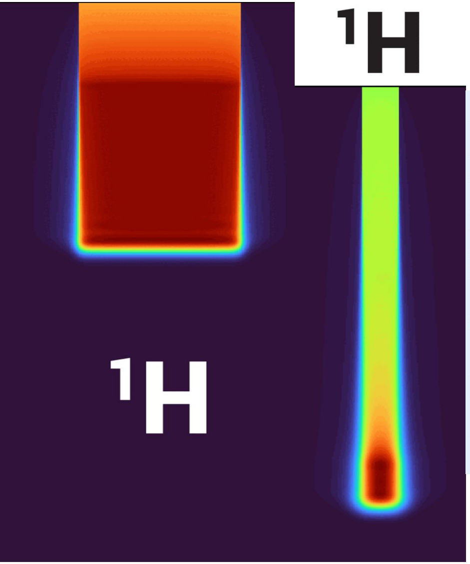
X-rays @DKFZ

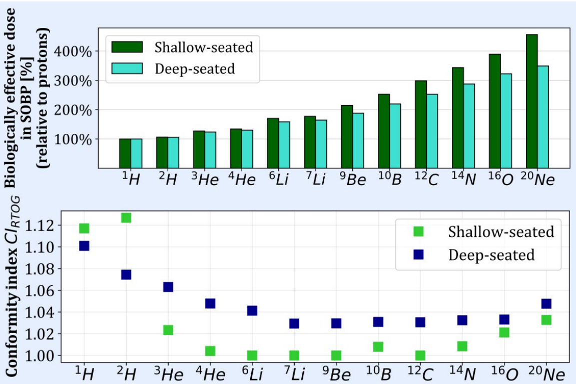




Modelling studies on *FLASH* effect and delivery

Dose threshold

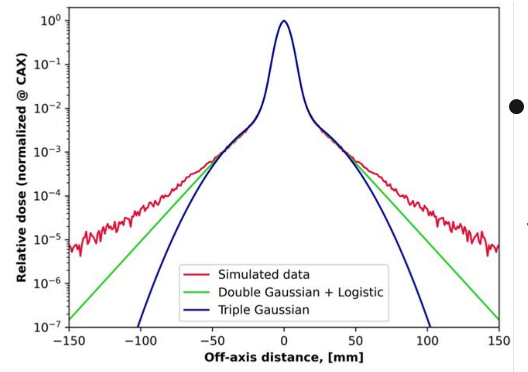


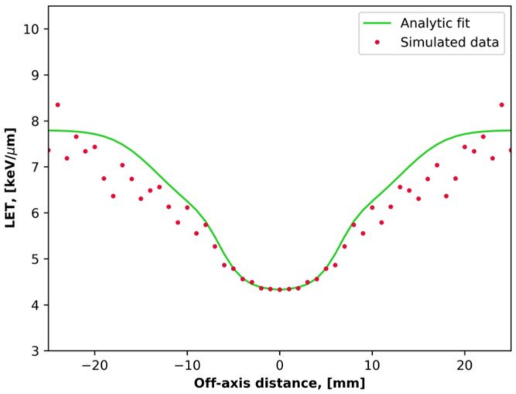


Through chemistry: Dose rate

- Exploration of radiochemical changes under UHDR irradiation - **dose rate threshold scaling for different ion types**

Pencil beam model for delivery



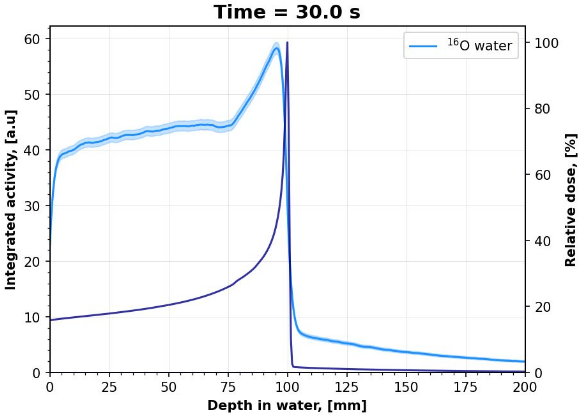


- Accounting for dose, LET and parametrs for biological effect modelling

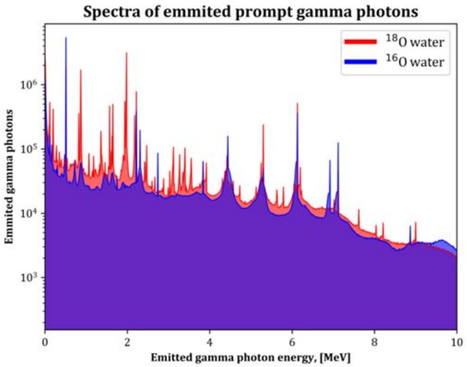
For comparison of different UHDR delivery approaches for ions: *transmission beams, 3D range modulators, focused beams etc.*

Work with bachelor students: Imaging methods

PET verification

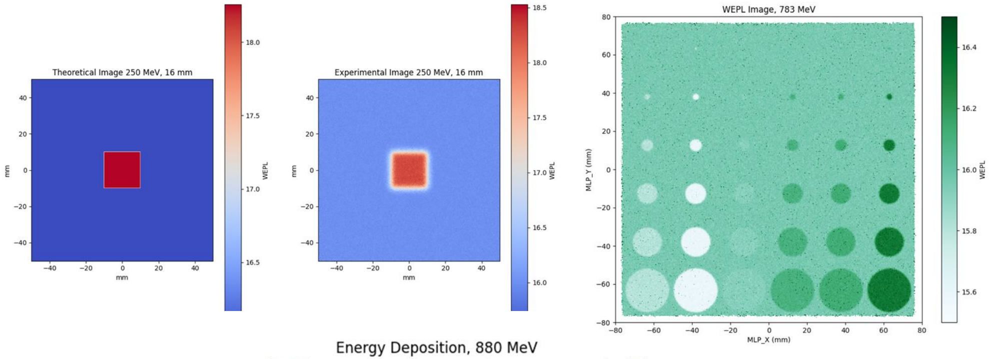


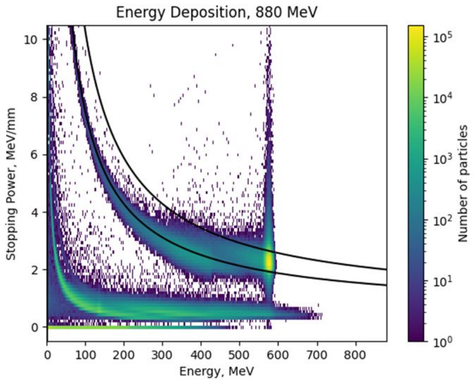
Contrast agent and prompt gammas



Particle radiography

- Work of CERN summer students:
  - High energy proton radiography by **Aurelija Vinke**
  - Helium-3 radiography by **Ilze Baumgarte**



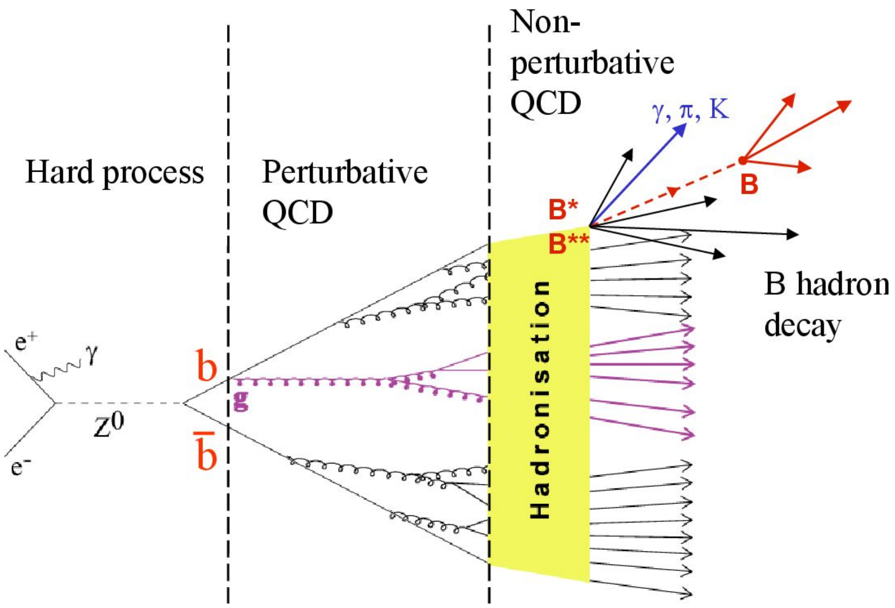


Paldies!

Backup

Study of the b-fragmentation function at the CMS experiment

- Process through which b quarks produced in high energy collisions transform into a bottom hadron through combination with other quarks and gluons.
- **Fragmentation function:** probability distribution that describes how a b quark eventually fragments into a bottom hadron - determined experimentally and parametrized in theoretical models.
- Essential for precision measurements (*CP violation, Higgs boson and top quark properties, new physics searches*).
- **Plays significant role in reconstruction and identification of b jets.**



EPR tasks & other activities

- Involvement into the assembly and testing of the **Barrel Timing Layer (BTL)**, a thin cylindrical detector for the MIP Timing Detector (MTD). Tasks performed include:
  - Tray insertion tests and rail installations at the BTST (BTL Tracker Support Tube).
  - Thermal and annealing tests on SiPMs (Silicion Photomultiplier Modules).
  - Cooling Tray assembly shifts.
- Assigned the role of **Top Data Quality Management (DQM) contact** for the TOP PAG as part of my EPR tasks. Tasks performed include:
  - Assessing the quality of new data and Monte Carlo campaigns to ensure accuracy and reliability.
  - Identifying issues and investigate causes.
  - Generate reports.
  - Developing and maintaining tools.
- Performed shifts at CMS control room as a **Detector Control System (DCS) Technical Shifter**.
- Implementing performance analytics scripts for the new **Tier-2 grid site in Latvia** which was inaugurated on *5/06/2024*. Liaison point between the IT engineers in Latvia and the CMS O&C group while on the Long Term Attachment (LTA).

Experimental physics responsibilities

Validation of Rivet plugins

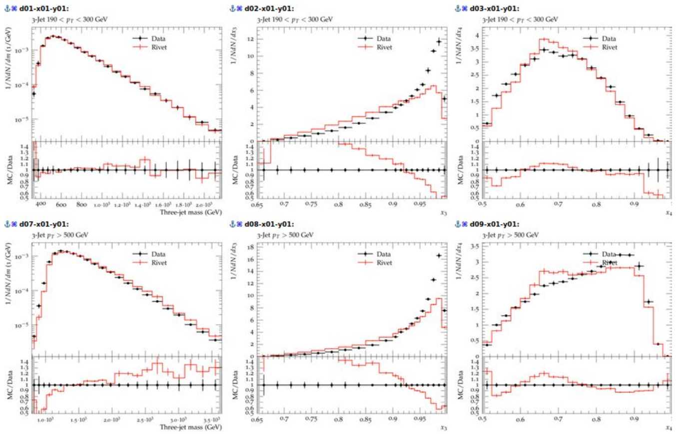
Monte Carlo (MC) contact for BTV group

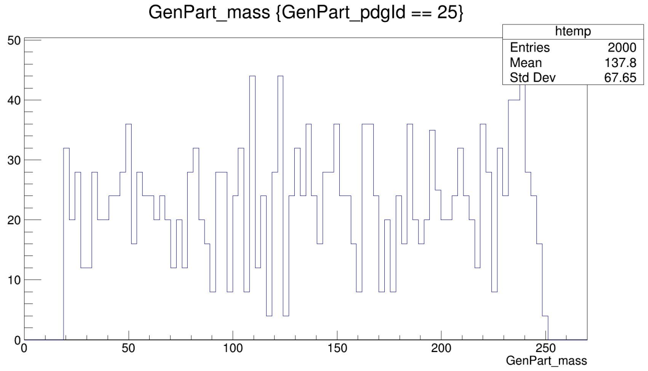
- preparing fragments of MC datasets and requesting them on behalf of the analyzers

Setup of training in b-hive with UParT

- b-hive is a framework for machine learning (ML) on ROOT files
- UParT is ML model for b-jet tagging

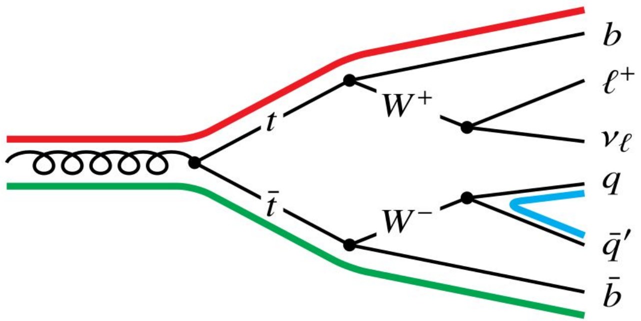
Work on the assembly of MIP timing detector



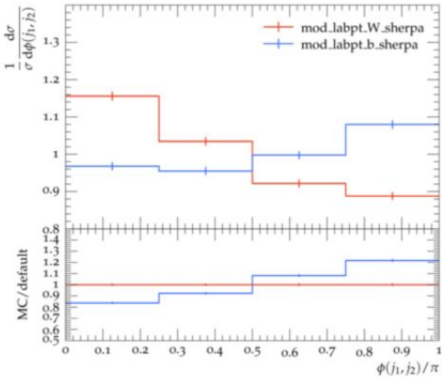


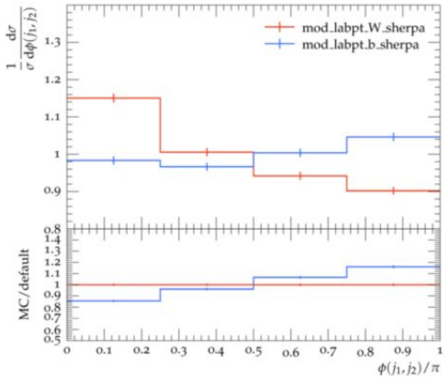
Colour flow and jet pull

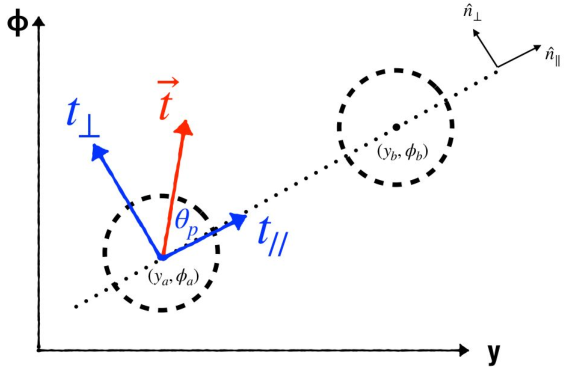
- quarks and gluons carry QCD charge, known as colour (three different colour states r, g, b)
- by "tracking" the colour flow, it is possible to distinguish whether quarks come from colourfull particles (gluons) or colourless particles (e.g. bosons)
- an observable that can be used in distinguishing between the two is called jet pull



arXiv:1805.02935







arXiv:1911.05090