UNIVERSITÄT BONN

UNI BONN – PARTICLE PHYSICS SEMINAR

THE LOHENGRIN EXPERIMENT

P. Bechtle, K. Desch, H. Dreiner, O. Freyermuth, M. Gruber, H. Hajjar, M. Hamer,
J. Heinrichs, J. Kaminski, M. Lupberger, T. Schiffer, P. Schwäbig, M. Schürmann, S. Vashishta

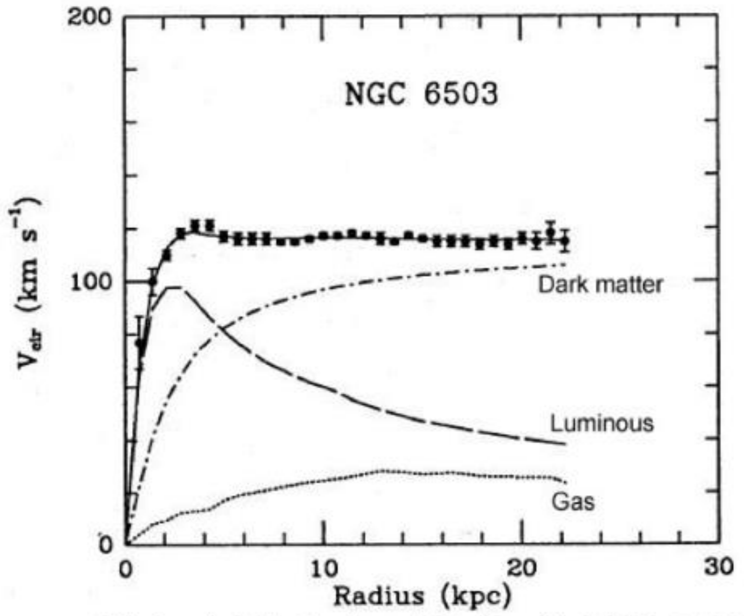
OUTLINE

- motivation for Lohengrin: light dark matter
- general principle of Lohengrin
- studies done so far
  - detector layout
  - tracker development
  - ECAL development
- latest ideas and changes to the experiment layout

DARK MATTER

$$\langle T\rangle = -\frac{1}{2}\sum_{k=1}^{N}\langle \mathbf{F}_k \cdot \mathbf{r}_k\rangle$$

$$v(r) = \sqrt{G\frac{m(r)}{r}}$$

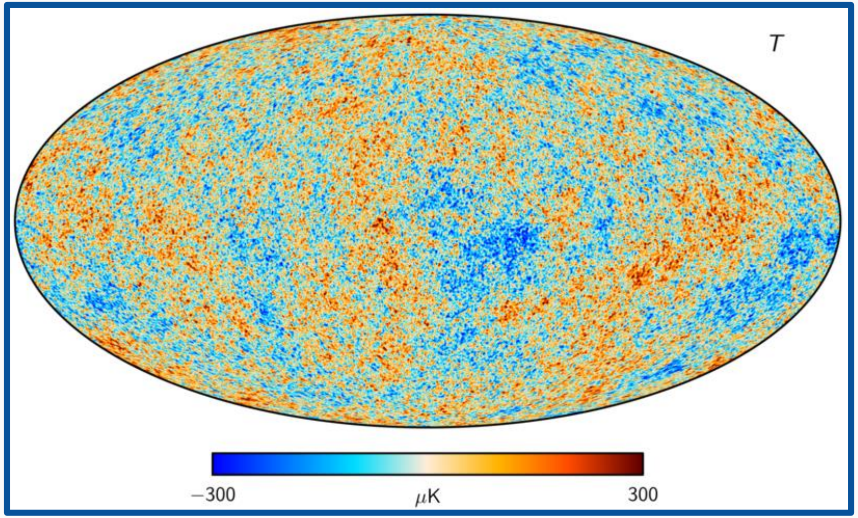


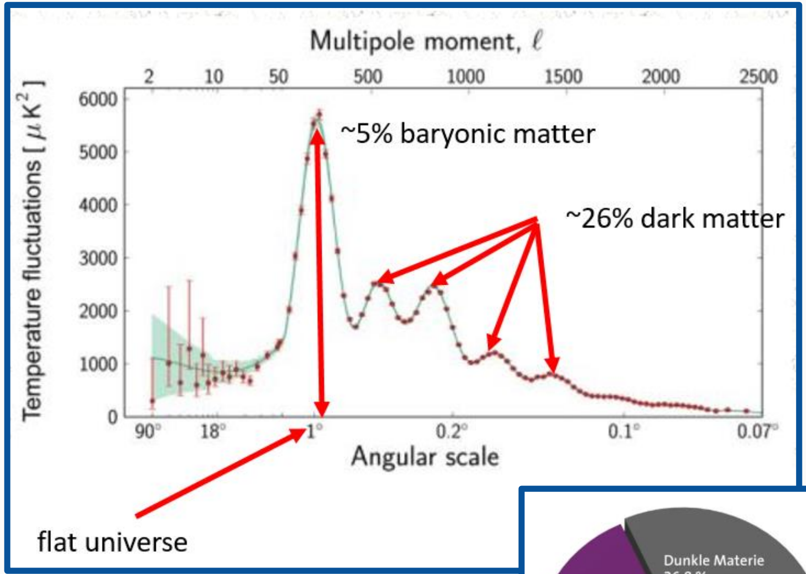
K.G. Begeman, A.H. Broels, R.H. Sanders. 1991. Mon.Not.RAS 249, 523.

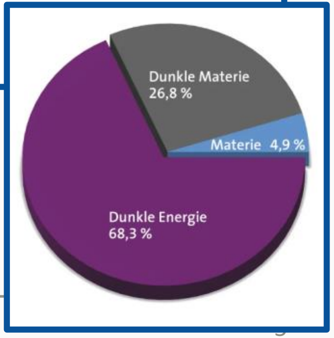
DARK MATTER


"visible matter" (X-ray)
matter distribution (gravitational lensing)

DARK MATTER

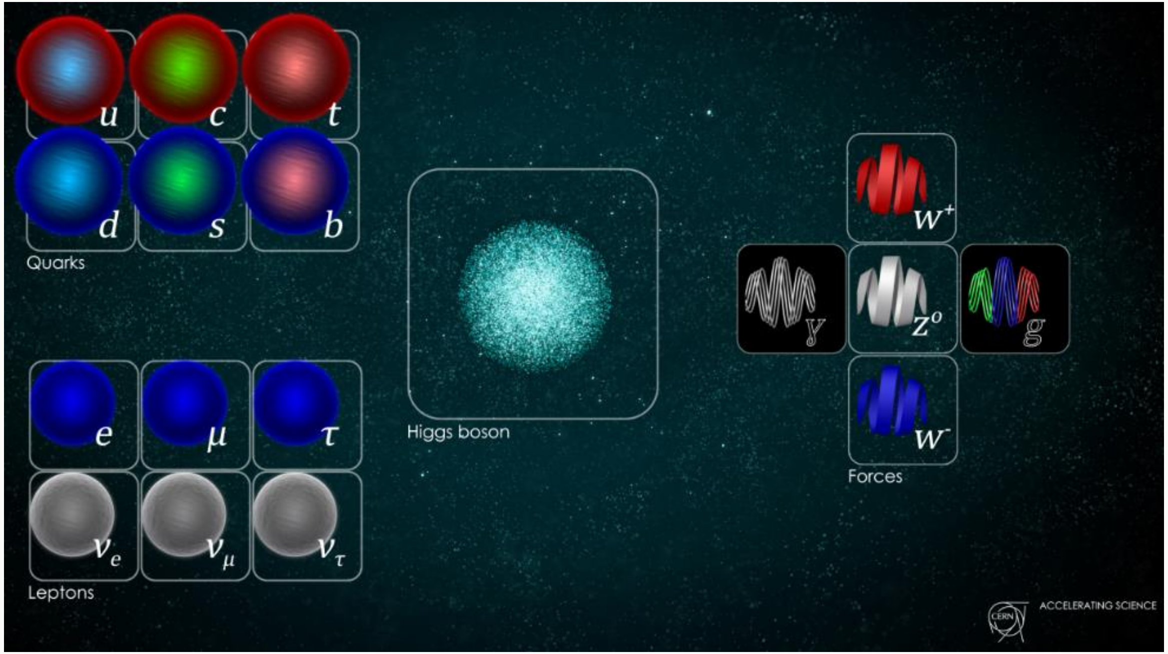






$$T(\theta,\phi) = \sum_{lm} a_{lm} Y_{lm}(\theta,\phi) \longrightarrow C_l \equiv \langle a_{lm} a^*_{lm} \rangle$$

DARK MATTER - CANDIDATES?



- the SM cannot explain dark matter
  - we require one or multiple extensions to the SM in order to do that!

DARK MATTER – THE LANDSCAPE

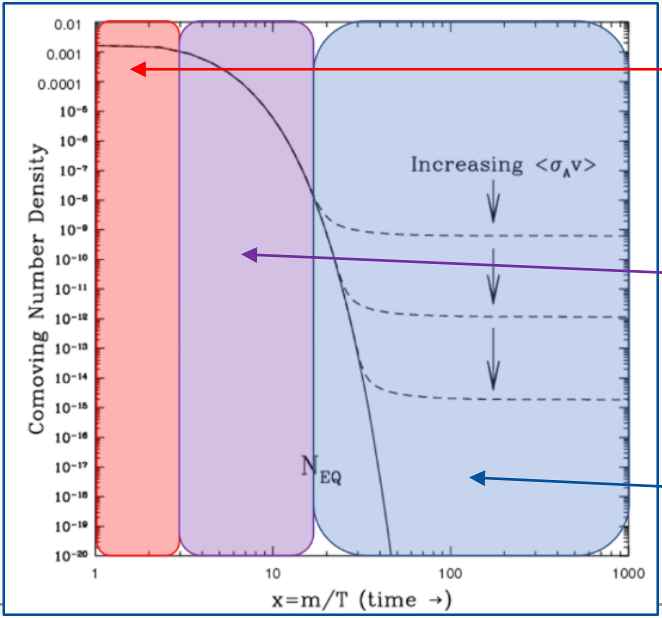
- what do we know about dark matter?
  - no so much, but we can infer some of its properties if we make certain assumptions

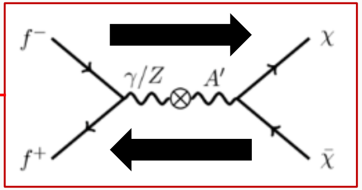
- relic density depends on annihilation cross-section, but not directly on the mass of the dark matter particle

$n_X / s \propto 1/M_X$

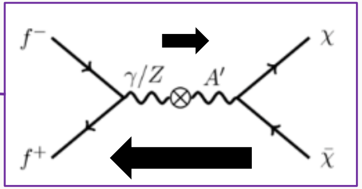
$\Omega \propto M_X * n_X$

- coupling of sole DM candidate → mass of DM candidate

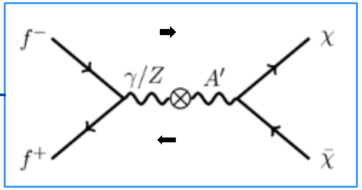




- thermal equilibrium
  - annihilation and production balance



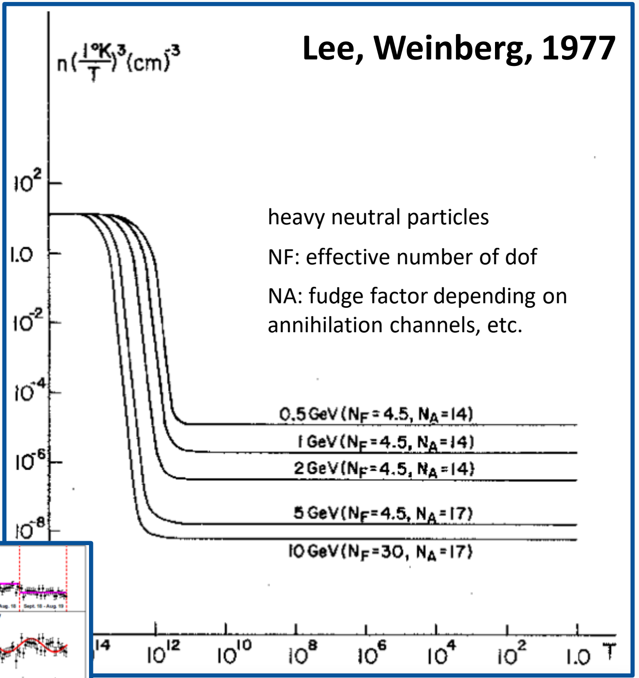
- T dominated region
  - production is suppressed due to available energy

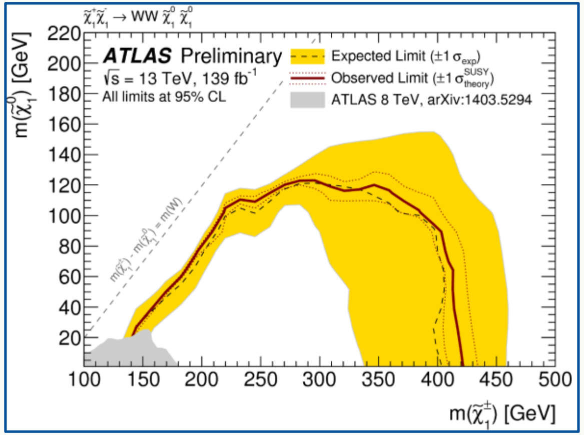


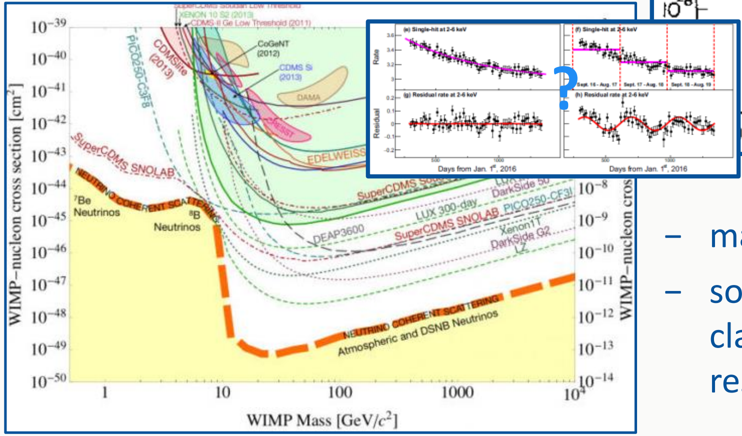
- H dominated region
  - annihilation is suppressed due to number density

DARK MATTER – WIMPS?

- assuming weak coupling between SM and DM:
  - smaller dark matter mass → smaller annihilation cross-section
  - DM mass is limited in the range of GeV – TeV
  - looking for weak-scale DM seems natural







- many negative results from searches
- some direct detection experiments claim to have found signal, but results are not reproducible

DARK MATTER – WISPS AND LDM

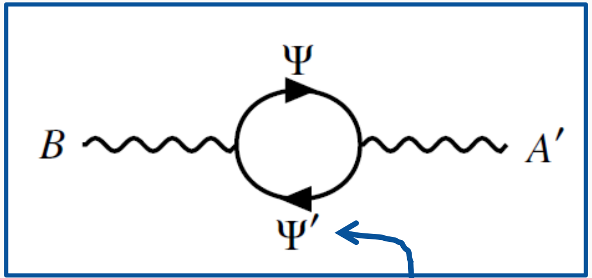
- dark matter from light particles?
  - need a fitting interaction between dark matter and SM sector
  - models with vector or scalar portals → can tune interaction strength to get right relic density
- one of the more simple models: massive boson from spontaneously broken $U(1)_D$ as portal → "dark photon"
- minimal model: SM + DM + $U(1)_D$ → introduce coupling between DS and SM through **kinetic mixing**

$$\mathscr{L} = \mathscr{L}_{SM} + \mathscr{L}_{D} + \mathscr{L}_{SM\otimes D}$$

$$\mathscr{L}_{D} \supset -\frac{1}{4}F'_{\mu\nu}F'^{\mu\nu} + \frac{1}{2}m^2_{A'}A'_\mu A'^\mu - g_D A'_\mu J^\mu_D$$

$$\mathscr{L}_{SM\otimes D} = -\frac{\sin\varepsilon_Y}{2}F'_{\mu\nu}B^{\mu\nu}$$

$$\mathscr{L} \supset -\frac{1}{4}F'^{\mu\nu}F'_{\mu\nu} + \frac{m^2_{A'}}{2}A'_\mu A'^\mu - A'_\mu(\epsilon e J^\mu_{EM} + g_D J^\mu_D)$$



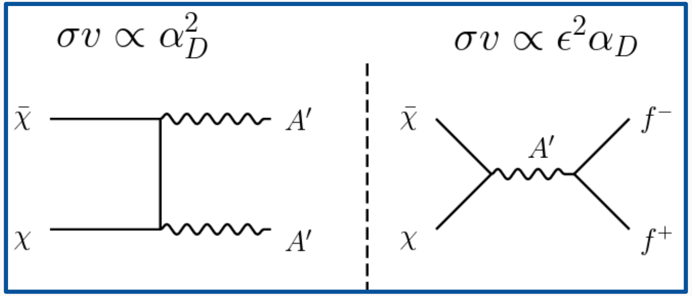
some heavy particles charged under both $U(1)_D$ and $U(1)_Y$

$$m^2_A = 0$$

$$m^2_{\tilde{Z}} = m^2_Z\left(1 + \varepsilon^2_Y \frac{m^2_Z s^2_W}{m^2_Z - m^2_{A'}}\right)$$

$$m^2_{A_D} = m^2_{A'}\left(1 + \varepsilon^2_Y \frac{m^2_Z c^2_W - m^2_{A'}}{m^2_Z - m^2_{A'}}\right)$$

DARK MATTER – DARK PHOTONS



- dark photon phenomenology
  - fundamental distinction: “visible” and “invisible” dark photons
  - “visible” dark photons: $m_{AD} < m_\chi$:
    - dark matter annihilation through pair production of A’
    - A’ decays into SM particles, decays into DM kinematically forbidden

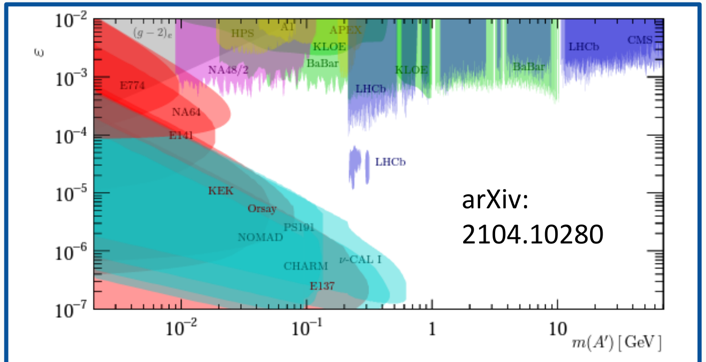


Figure 3

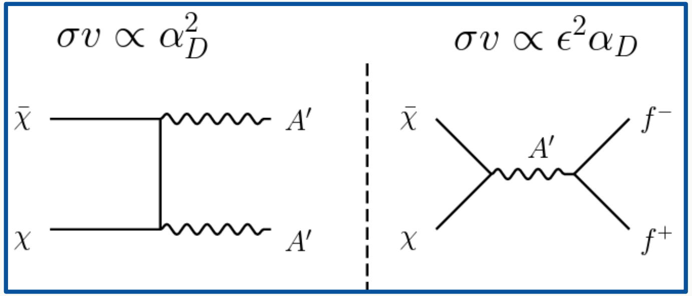
From Ref. (14) made using Ref. (19): Constraints on visible A' decays from electron beam dumps, proton beam dumps, e^+e^- colliders, pp collisions, meson decays, and electron on fixed target experiments. The constraint derived from $(g-2)_e$ is shown in grey (20, 21). The gaps in the prompt limits correspond to regions near the masses of the QCD vector mesons.

- prompt A’ decays:
  - irreducible $\gamma \rightarrow ff$ background

$$n(A' \to \ell^+\ell^-) = \varepsilon^2 n(\gamma^* \to \ell^+\ell^-)\mathcal{F}(m_{A'})/2\Delta m$$

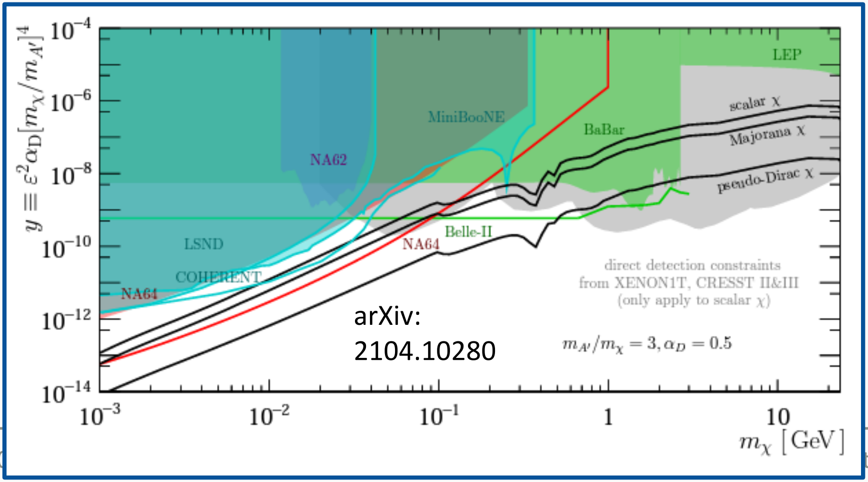
- displaced A’ decays
  - $\tau_{A'} \propto [\varepsilon^2 m_{A'}]^{-1}$
  - beam dump experiments with baselines up to O(100m)
  - collider searches with displaced vertices

DARK MATTER – DARK PHOTONS



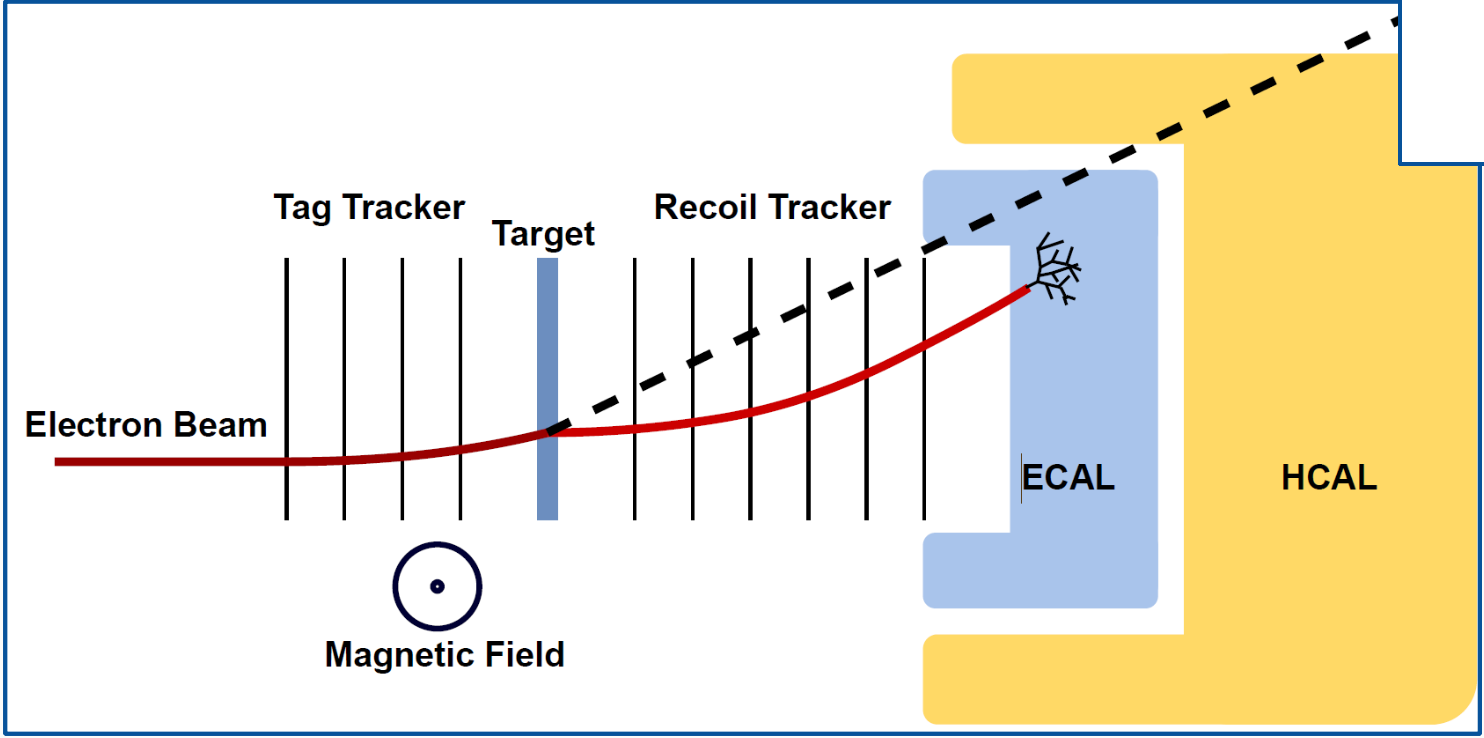
- dark photon phenomenology
  - fundamental distinction: “visible” and “invisible” dark photons
  - “invisible” dark photons: $m_{AD} > m_\chi$:
    - dark matter annihilation through s-channel A’ into fermions
    - once produced, dark photon and its decay products do not necessarily produce any detectable signal

$n_{vis} / n_{invis} \propto \varepsilon^2$

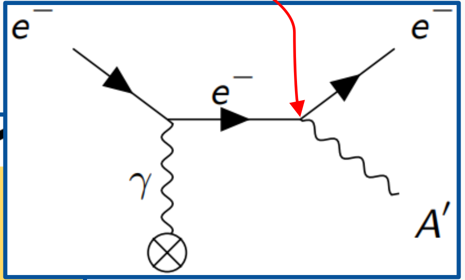


- collider searches, beam dump experiments (with and without direct detection) and direct detection experiments
- in particles for DM masses < 1 GeV, i.e. mA’ < 3 GeV, sizeable gap to relic target

FIXED TARGET DARK PHOTON SEARCH



$\mathcal{M} \propto \varepsilon$



- electron beam on fixed target (~10% X0)
- dominant reaction: SM bremsstrahlung, sometimes subsequent electro-nuclear or photo-nuclear reaction
- depending on $m_{A'}$ and ε: occasional radiation of dark photon

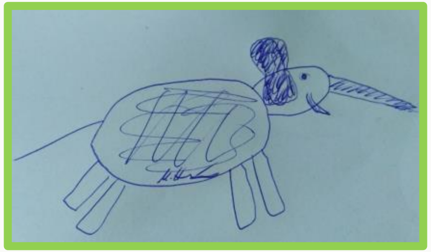
LOHENGRIN - IDEA

- inspired by the proposal for the LDMX experiment
  - electron beam-dump experiment with 4-16 GeV electrons and up to ~tens of electrons on target per spill (see arXiv:1808.05219)
    - Phase I: μ_e = 1 @ 50 MHz
    - Phase II+: μ_e = 2-10 @ 50 MHz -200 MHz

- can do the same thing in Bonn at lower energies, possibly lower number of electrons on target per extraction
  - started to study the feasibility of a DM experiment at ELSA in 2019
  - general parameters:
    - benefit from electron energy resolution of ELSA
    - “cheap” experiment built from as many existing parts as possible
    - study orthogonal approach to LDMX calorimeter triggered approach

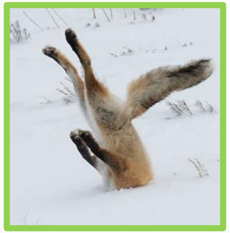
DARK PHOTON SEARCH AT ELSA: LOHENGRIN

model used in this presentation



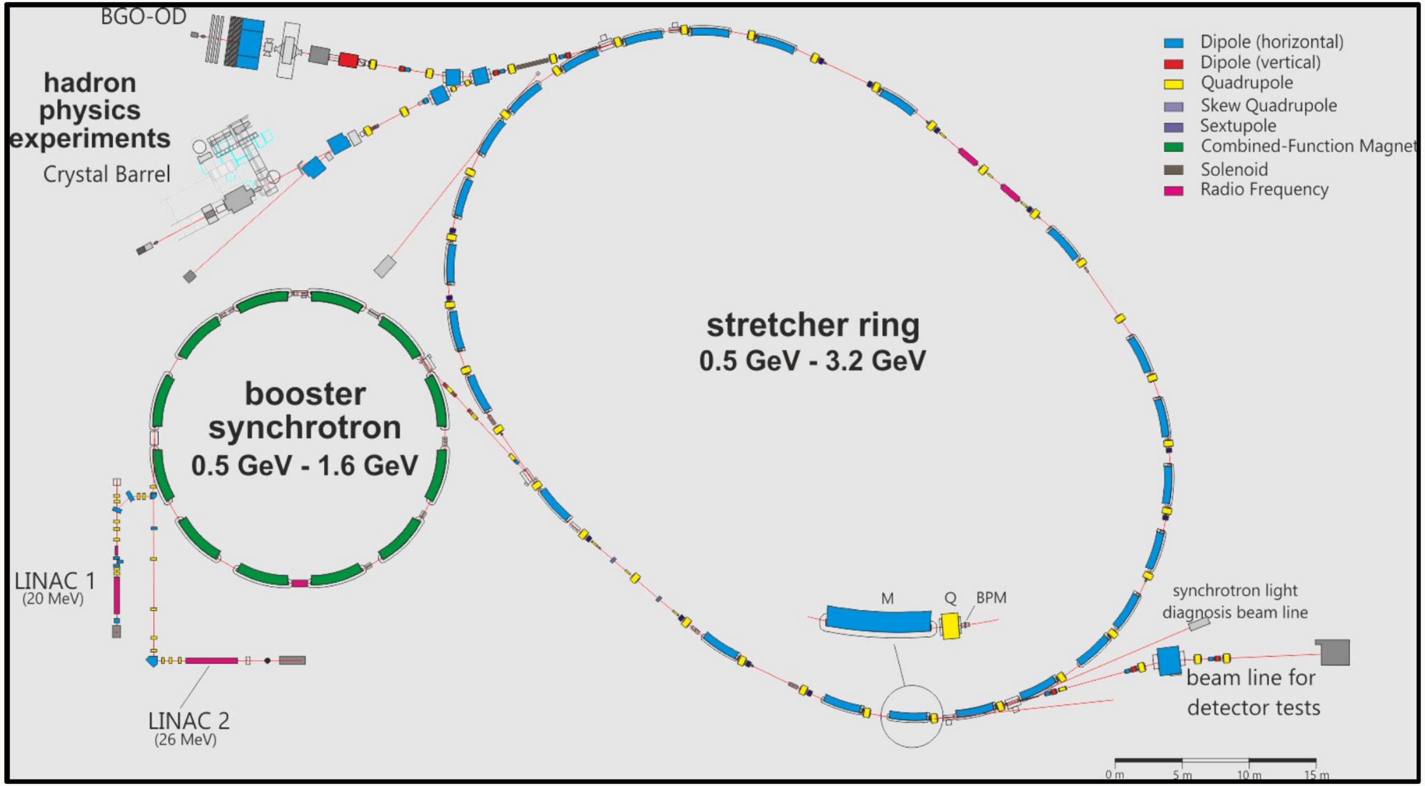
two equally likely options for the final thing

hopefully not the final thing



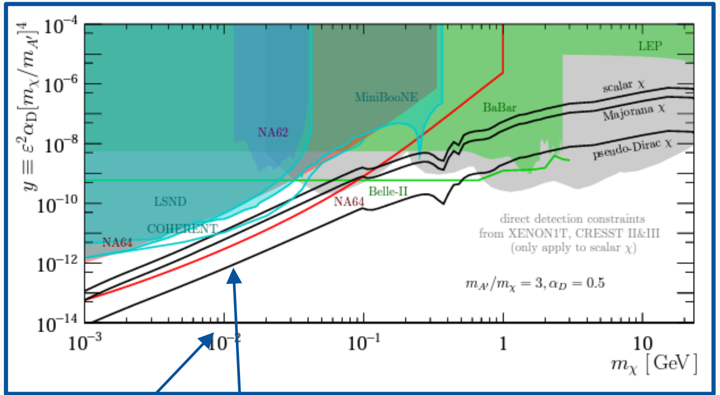
(almost) certainly not the final thing

ELSA – ELEKTRONEN STRETCHER ANLAGE



- ability to extract μ = 1 electrons per 2 ns bunch
- electron energy up to 3.2 GeV
- this should be enough to do produce some lightweight dark photons in Bonn!

DARK PHOTON PRODUCTION AT ELSA

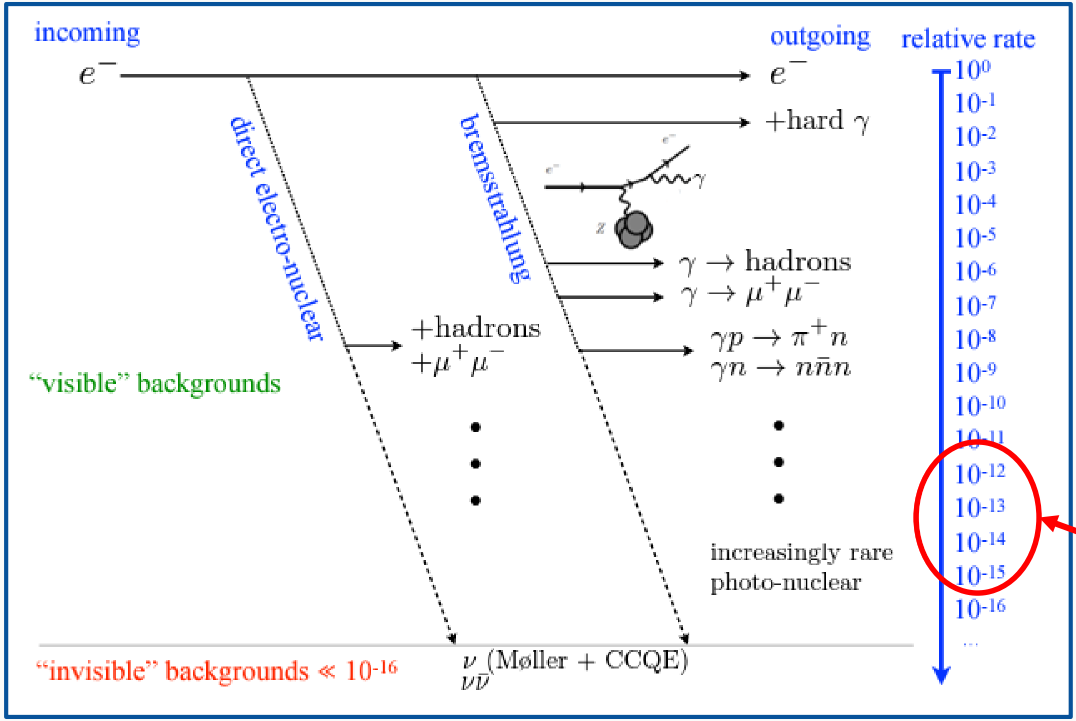


- how many electrons on target do we need (10% X0 tungsten target) to produce 1 dark photon with right "relic target properties"?
- how many full days of beam time would we need to produce 100 dark photons at 100 MHz EoT rate?

	Scalar			Majorana			Pseudo-Dirac		
mA [Mev]	ε^2	EoT_1	$t_{100}2$ [days]	ε^2	EoT_1	$t_{100}2$ [days]	ε^2	EoT_1	$t_{100}2$ [days]
4.5	4.3E-11	**4.9E+12**	112	2.2E-11	**9.6E+12**	221	2.9E-12	**7.4E+13**	1709
10	2.0E-10	**4.7E+12**	110	9.8E-11	**9.7E+12**	225	1.3E-11	**7.5E+13**	1729
100	2.6E-08	**1.0E+13**	238	1.2E-08	**2.1E+13**	495	1.2E-09	**2.2E+14**	5205
1000	5.4E-07	**1.0E+19**	238388060	2.7E-07	**2.0E+19**	472519191	2.5E-08	**2.2E+20**	5188446020

there is hope to find dark photons at ELSA with the right properties if we can control our backgrounds!

BACKGROUNDS



- taken from arXiv:1808.05219
- dominant process: SM bremsstrahlung
- relatively rare:
  - photo-nuclear and electro-nuclear reactions producing neutral hadrons
  - neutrino backgrounds generally expected well below signal levels

this is where the music plays!

LOHENGRIN – WHAT HAS BEEN DONE SO FAR?

- goal posts are set
  - strategy to get there in Bonn, considering the constraints?
  - initial approach:
    - shoot single electrons on target → use "tag tracker" to establish the presence of one or more incoming electrons in the event
    - use ultrafast, ultrathin untriggered tracker to identify events with strongly scattered outgoing electrons
    - veto events with hadronic activity (HCAL)
    - search for events with a significant amount of missing energy in the final state

→ critical input: layout of the experiment

- divide and conquer:
  - start with certain assumptions, possibly unrealistic
  - determine parameters for critical elements (magnet, tracker, calorimeter)
  - iterate!

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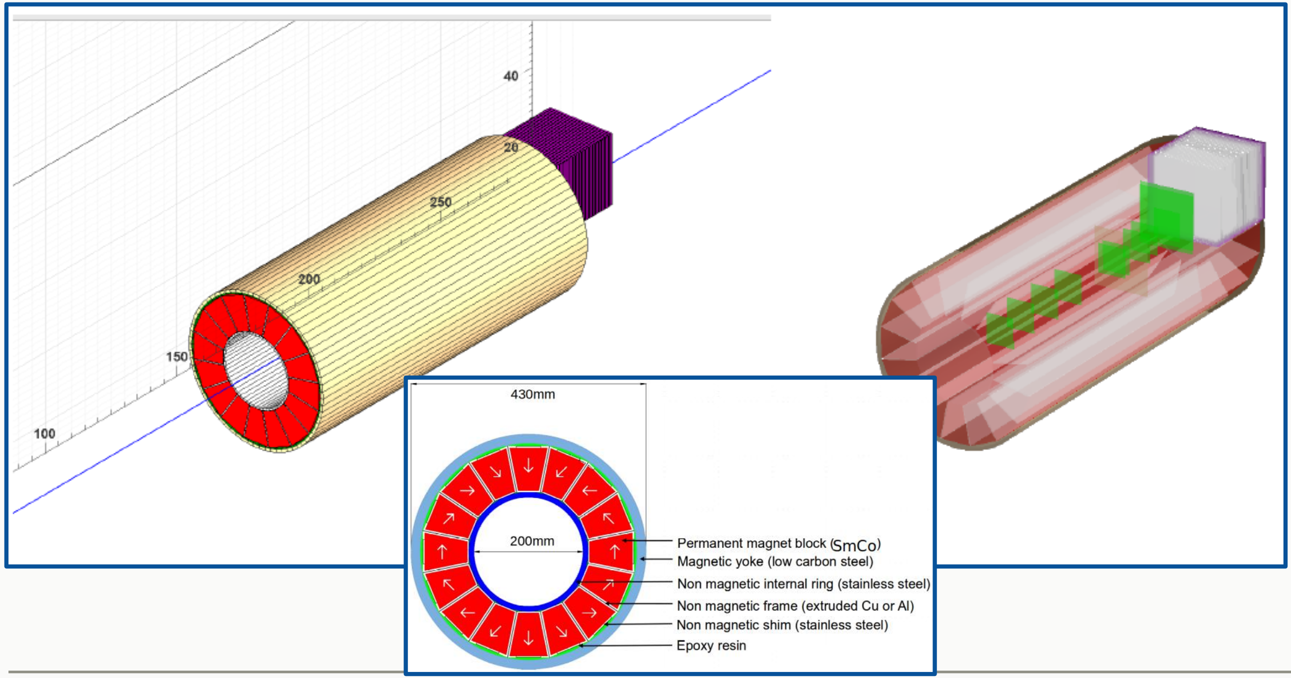
STUDIES ON DETECTOR LAYOUT - MAGNET

- started with implementation of simple magnet and a few thin silicon tracking planes in ExPlORA framework

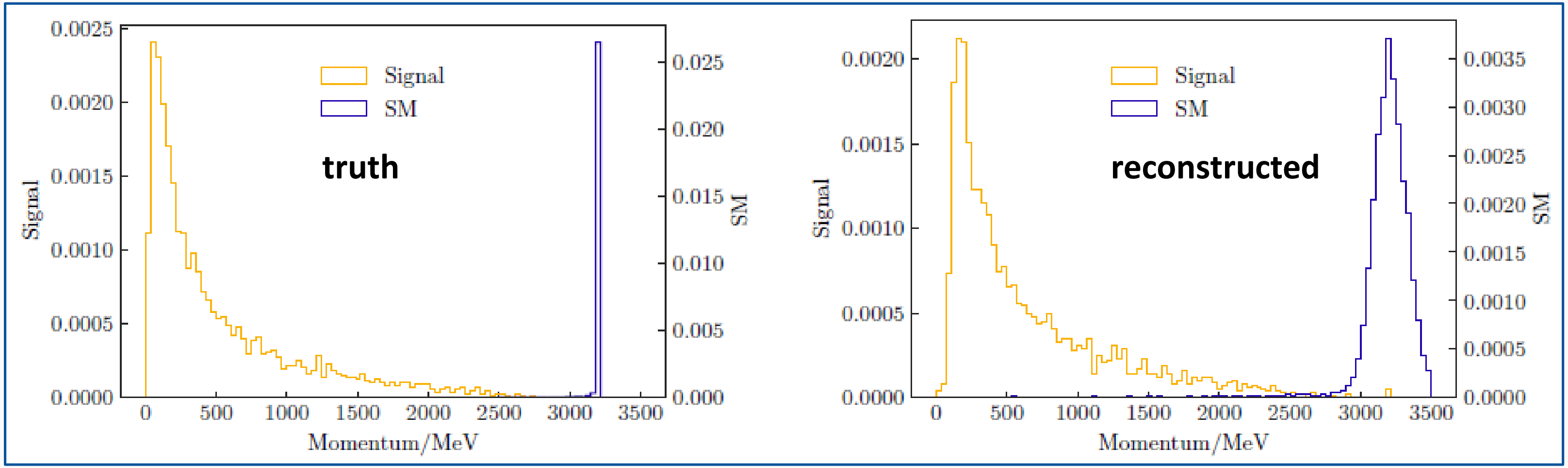


- 1 m long permanent dipol magnet (Halbach array), 0.5 T orthogonal to beam axis (thanks to our colleagues from the FASER collaboration)
- 6 layers of pixel tracking detectors in front of target
- 6 layers of pixel tracking detectors behind target
- thin tungsten target
- particle gun producing ELSA quality electrons with a momentum of 3.2 GeV

Jan Heinrichs

STUDIES ON DETECTOR LAYOUT – TRACKER AND TRACKING

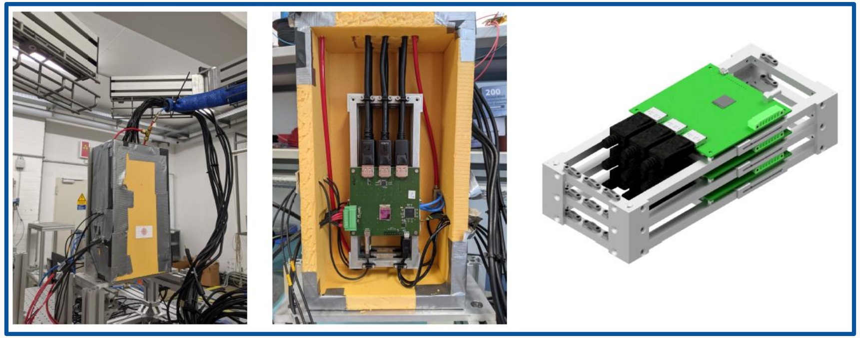
- started with implementation of simple magnet and a few thin silicon tracking planes in ExPlORA framework
  - electron tracking: Kalman filter with smoothing steps for tag- and recoil-tracker
  - started to look into Gaussian sum filter and higher order effects to improve tracking
  - performance so far is an excellent starting point for improvements



LOHENGRIN – RATE TESTS WITH TIMEPIX3 MINITRACKER

Leonie Richarz
Markus Gruber
Tobias Schiffer

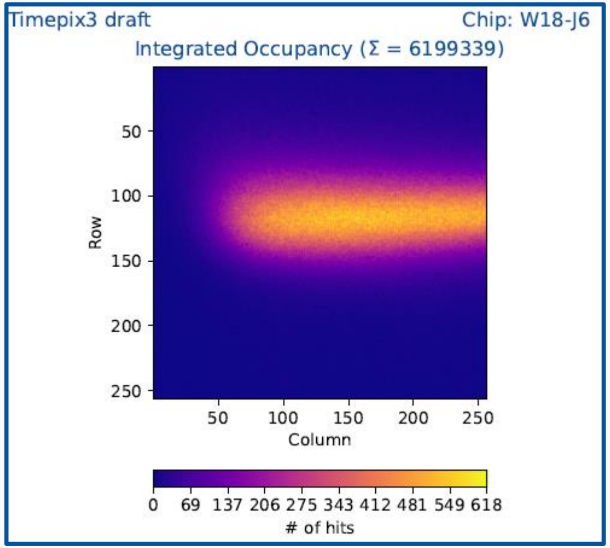
- started focusing on the tracker
  - implementation of a Kalman filter in simulation
  - production of a mini-tracker using untriggered TimePix3 silicon modules with beam telescope
    - rate capabilities of TimePix3 tested
    - first analysis of multiple scattering done



Leonie Richarz
Markus Gruber
Tobias Schiffer

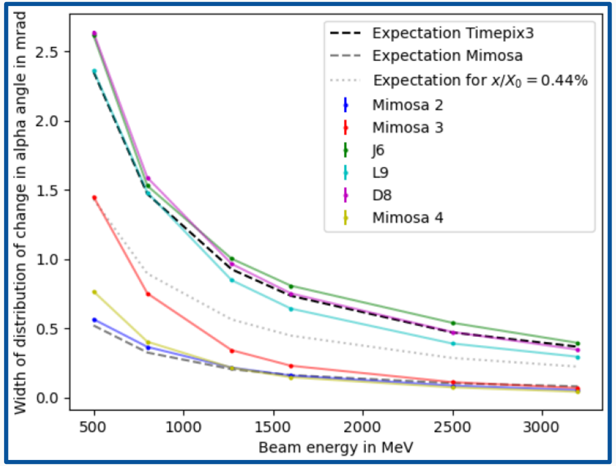
LOHENGRIN – RATE TESTS WITH TIMEPIX3 MINITRACKER

- detector development: tracker
  - first testbeam in 2020 with 3 Timepix3 silicon assemblies



2.5 GeV electron beam, 100 kHz

rate in kHz	energy in GeV	length	settings	remarks
2.00	2.50	10 min	nominal	ok
10.00	2.50	7 min	nominal	ok
50.01	2.50	2,5 min	nominal	ok
100.60	2.50	30 s	nominal	ok
500.00	2.50	30 s	nominal	ok
1000.00	2.50	30 s	thr: 4 150	ok
1000.00	2.50	30 s	thr: 4 200	some errors
750.00	2.50	30 s	nominal	ok
875.00	2.50	30 s	nominal	some errors
825.00	2.50	30 s	nominal	ok
850.00	2.50	30 s	nominal	some errors



- tests with Timepix3 minitracker with and without ANEMONE telescope
  - lower than expected maximum rate (bottleneck in software)
  - tracking resolution not perfectly understood yet (MS? track reco?)

Jan Heinrichs
Christoph Schmidt

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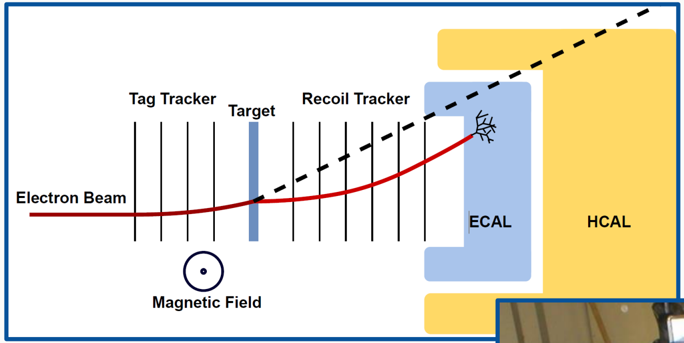
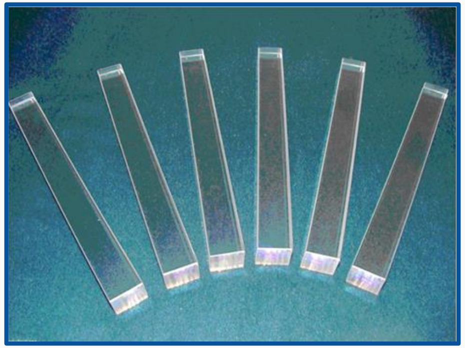
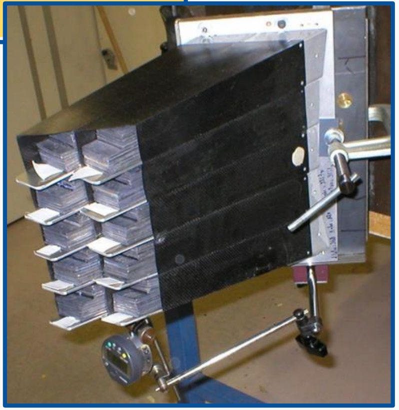
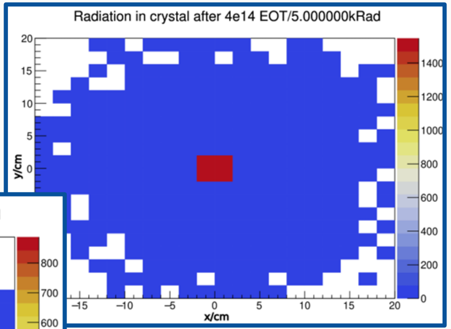
LOHENGRIN – ECAL

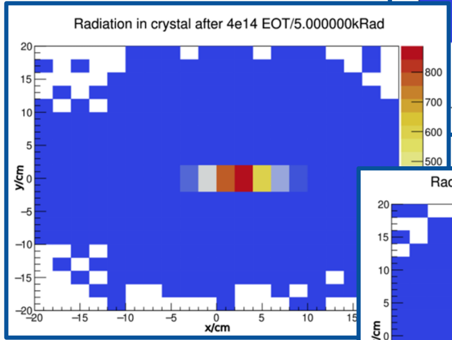


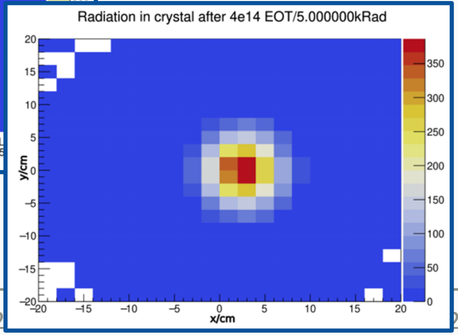
- second detector of interest: electromagnetic calorimeter
  - ECAL from $PbWO_4$ crystals?
    - 500 kHz readout rate achievable
    - radiation hardness ~50 Gy











assuming a B-field of 0.5 T

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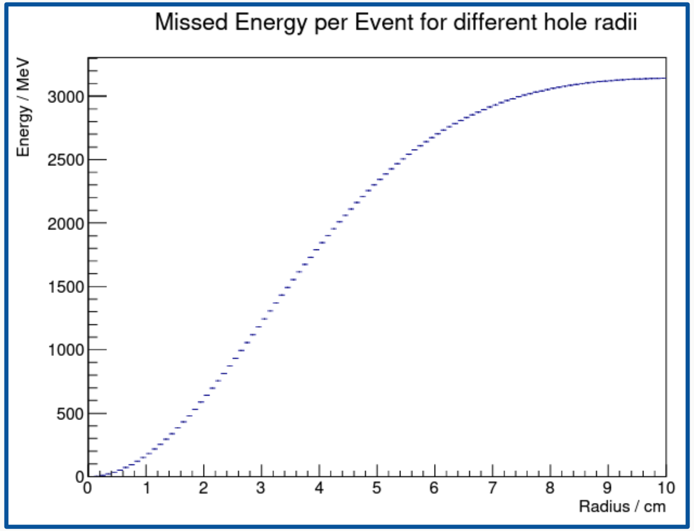
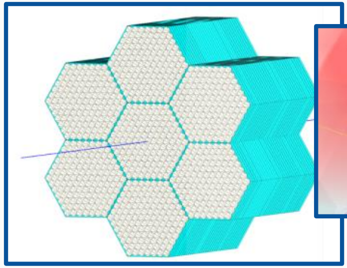
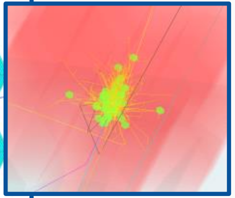
LOHENGRIN – ECAL

- with enough information from tracking, do we have to measure the electrons in the center of the beam profile in the ECAL?



  - missing a significant amount of energy from electrons and photons if we cut a hole in the ECAL
  - we have to reconstruct the photons from SM bremsstrahlung to be sensitive to dark bremsstrahlung!
  - considering the beam divergence, a central hole in the ECAL probably not the best idea



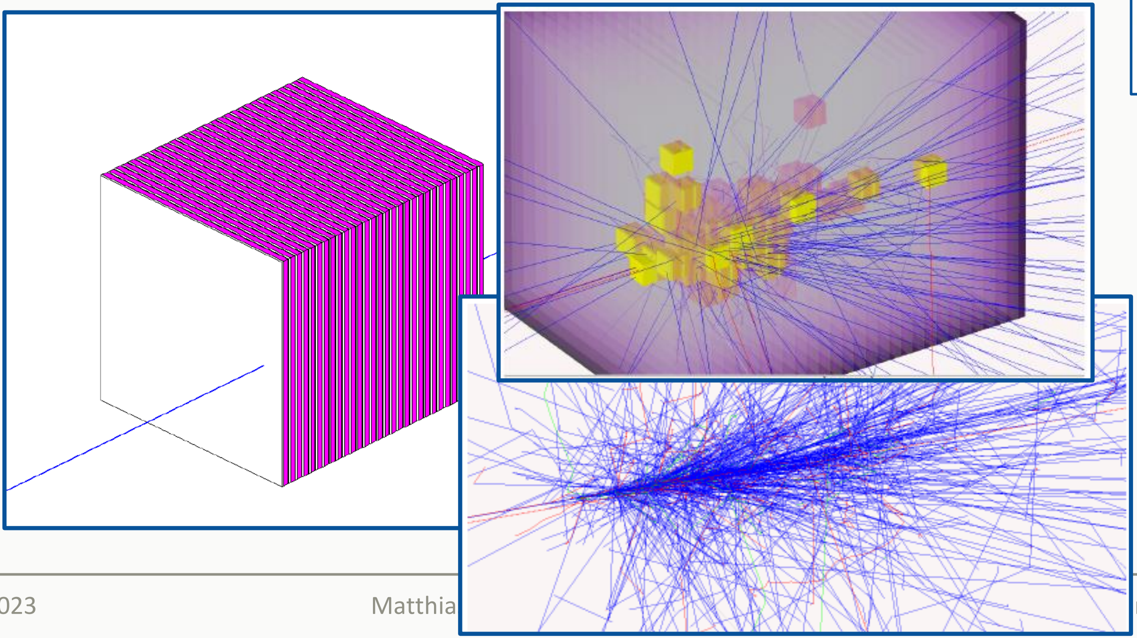


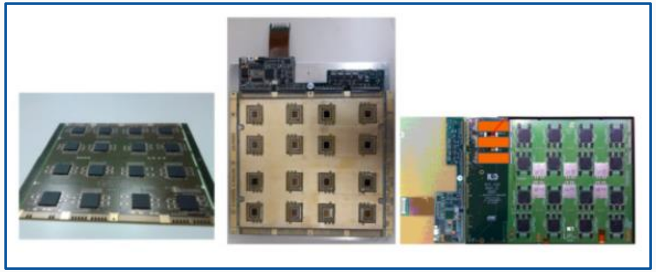
  - Si-W sampling calorimeter could remedy radiation hardness issues
  - readout speed and rate remains an issue

LOHENGRIN – ECAL

Jan Heinrichs
Dirk Zerwas
Roman Pöschl
Jihane Maalmi
Dominique Breton

- implementation of ECAL in simulation: CALICE
  - CALICE ECAL looks like a promising candidate for the Lohengrin ECAL
  - inclusion of a simple 15 layer ECAL in the Lohengrin simulation





- 5.5 x 5.5 mm2 silicon pixels
- modular design, 16 readout chips per ~16x16 cm2 plane
- chips can buffer integrated readout data for some time
- implementation of a “clear command” for use of Lohengrin DAQ strategy under study

Patrick Schwäbig

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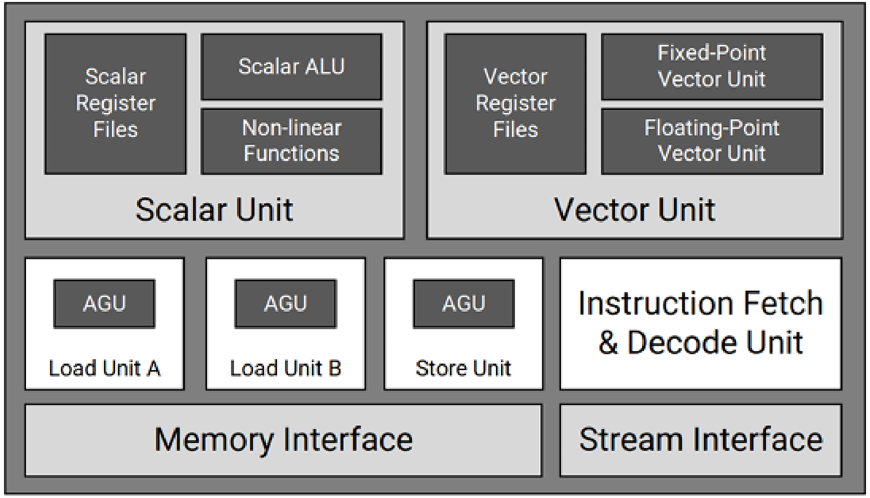
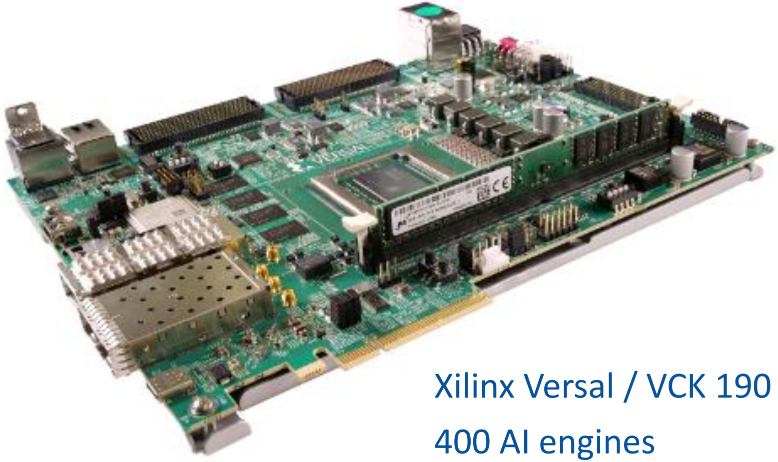
LOHENGRIN – TRIGGER

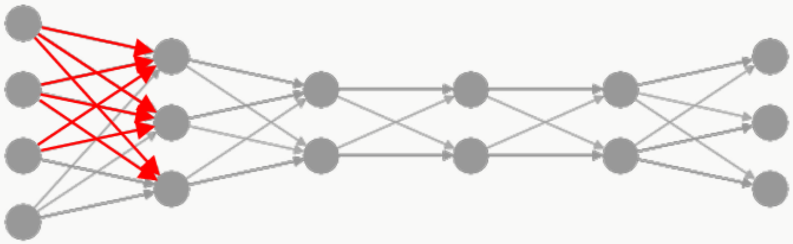
- use of AI engine driven track trigger for Lohengrin?
  - pattern recognition for multi-track events
  - implementation of track building and track fitting, e.g. Kalman filter





Xilinx Versal / VCK 190

400 AI engines



THINKING THINGS OVER

- ECAL that “catches” the full electron beam challenging
  - rates and radiation hardness
- tracker with fast readout in combination with an online track trigger of some sorts seems possible
  - AI engines as L1 trigger after a fast “LUT”-like Level 0 trigger

- shape, size and strength of magnet critical to achieve good sensitivity
  - started to study a scenario in which the electron beam is bent around the ECAL

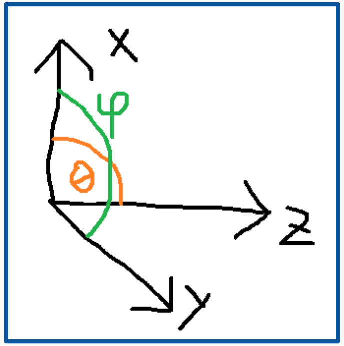
  - will explain a somewhat more recent study in a bit detail now

    - inputs for this study:
      - 3.2 GeV electron beam on 10% X0 tungsten target
      - 4e14 electrons on target (@100 MHz: 50 days of beam time)

LOHENGRIN – EVENT VARIABLES AND COORDINATE SYSTEM

- event variables:
  - y: fraction of scattered electron energy $y = E_e$ / Ebeam
  - θ_e: polar angle of scattered electron with respect to the beam axis
  - x: fraction of photon energy $x = E_\gamma$/Ebeam
  - θ_γ: polar angle of radiated photon with respect to the beam axis

- z-axis is the incident electron beam axis
- magnetic field in tracker points in positive y direction



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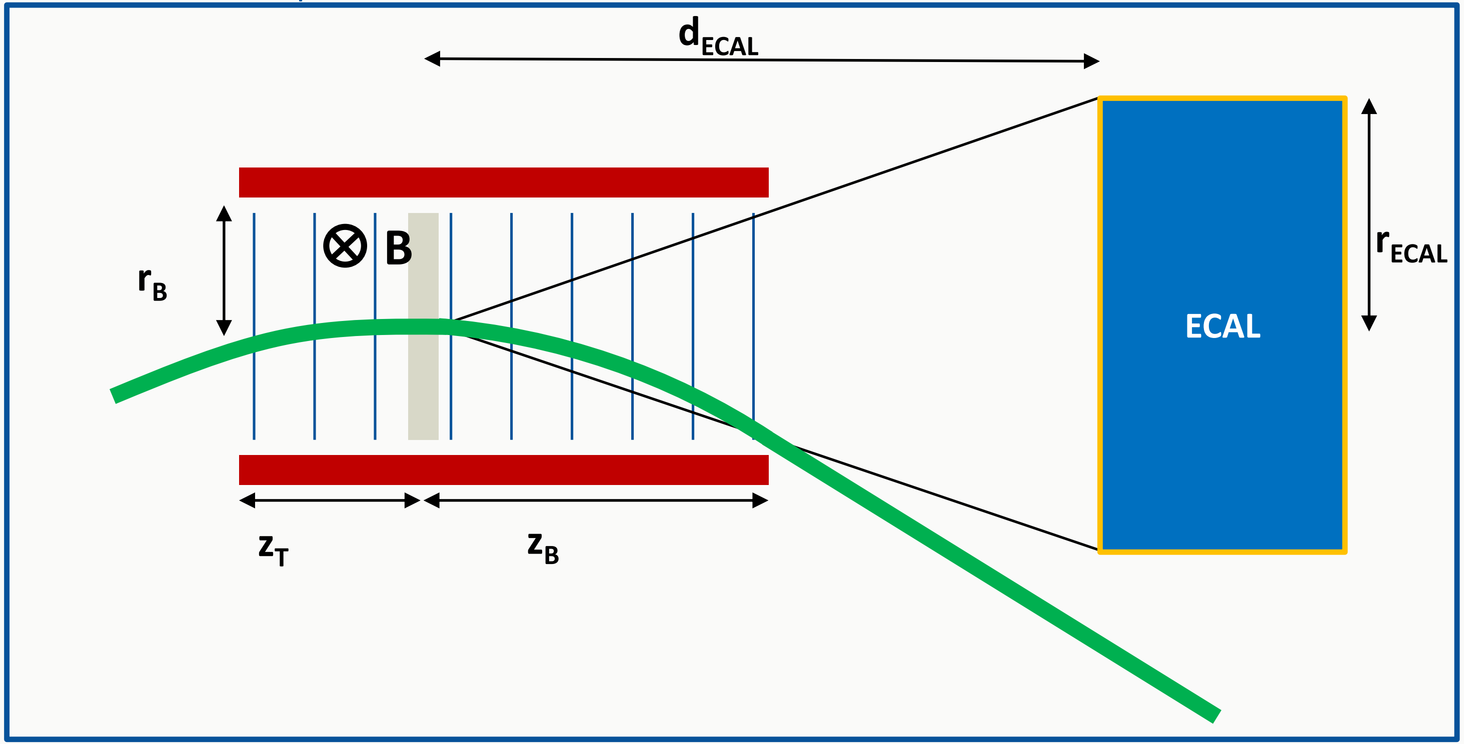
LOHENGRIN – LAYOUT AND SENSITIVITY STUDY

$$\theta_e(\mathrm{zBmax}) = \arcsin\left(\frac{\mathrm{zBmax}}{R_{\mathrm{bend}}}\right)$$

$$r_e(\mathrm{zBmax}) = R_{\mathrm{bend}} \cdot (1 - \cos(\theta_e(\mathrm{zBmax})))$$

$$d_e(d_{\mathrm{ECAL}}) = r_e(\mathrm{zBmax}) + \tan\theta_e(\mathrm{zBmax}) \cdot (d_{\mathrm{ECAL}} - \mathrm{zBmax})$$

– assumed setup:



$$\tan\theta_\gamma^{\max} = \frac{\mathrm{rBmax}}{\mathrm{zBmax}}$$

$$\tan\theta_\gamma^{\mathrm{ECAL}} = \frac{r_{\mathrm{ECAL}}}{d_{\mathrm{ECAL}}}$$

key parameters:

- **rBmax**
- **zBmax**
- **dECAL**
- **rECAL**
- **B**

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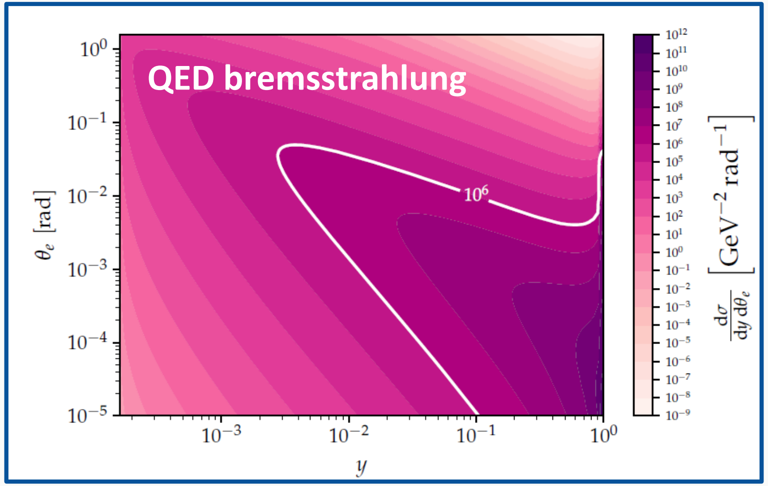
Martin Schürmann

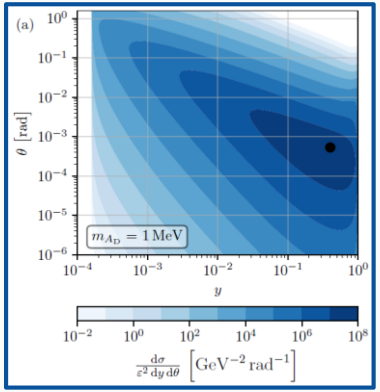
LOHENGRIN – LAYOUT AND SENSITIVITY STUDY

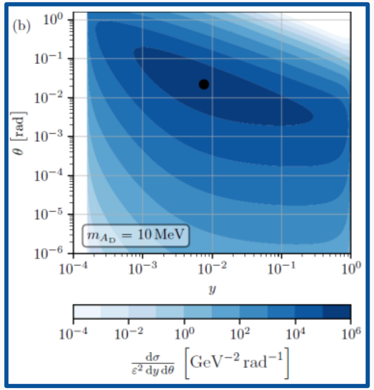
- "coarse-tuning" the experiment
  - using "masterfunction" to calculate the expected number of SM bremsstrahlung events where
    - $y \in [y_{min}; y_{max}]$
    - $\theta_e \in [\theta_{e\,min}; \theta_{e\,max}]$
    - $x \in [x_{min}; x_{max}]$
    - $\theta_\gamma \in [\theta_{\gamma\,min}; \theta_{\gamma\,max}]$

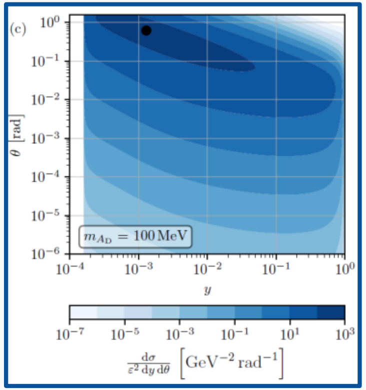
can already guess potential signal regions:

- (very) low y
- high scattering angle → more signal events, but for fixed, low y, also more potential background events





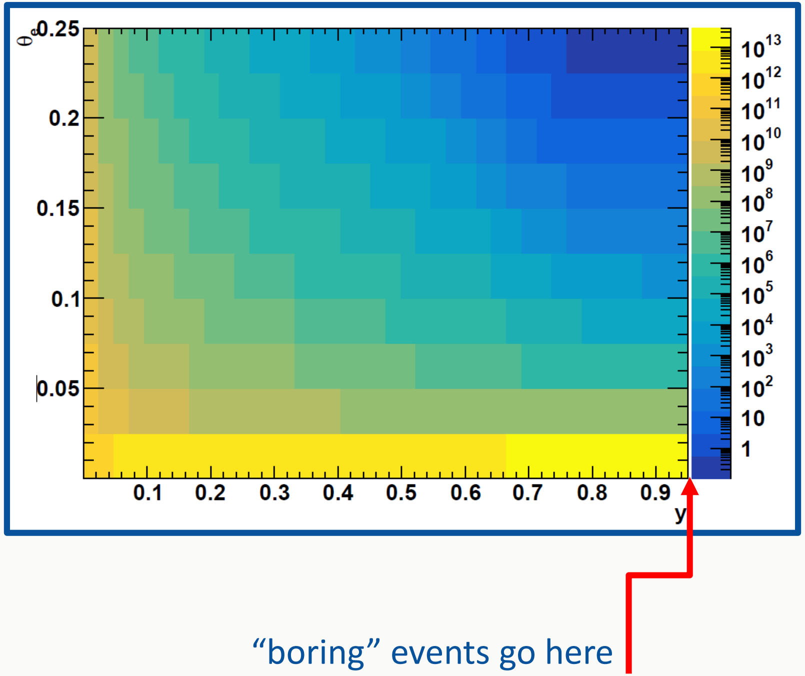




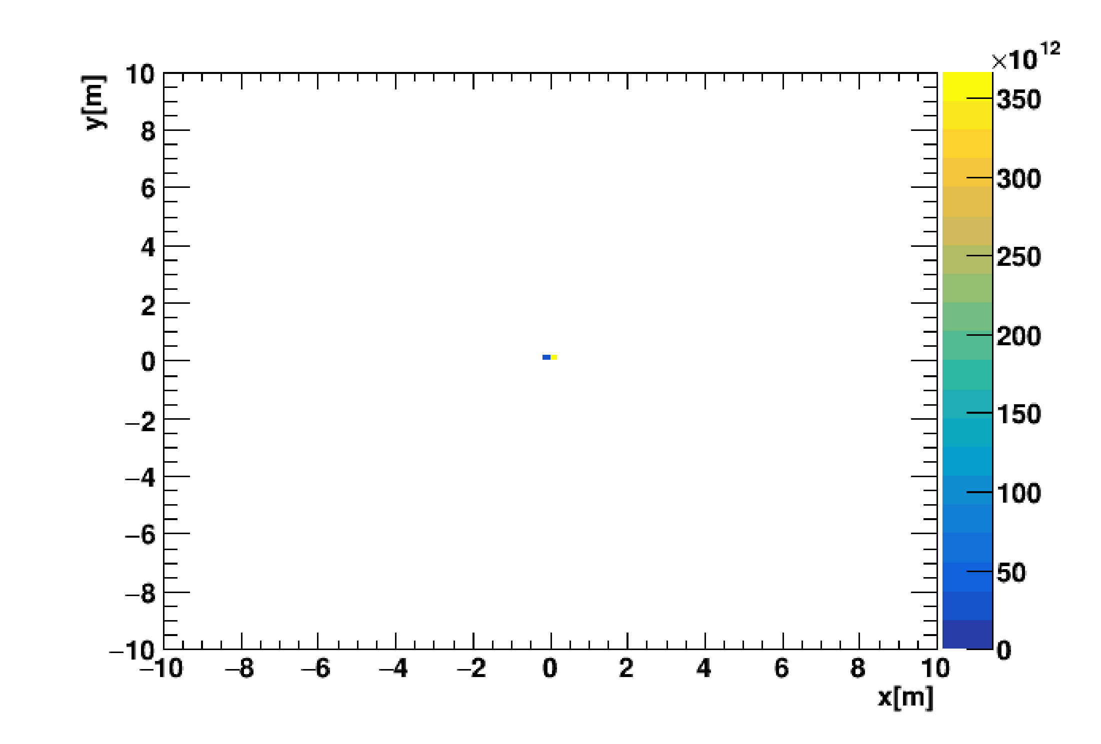
Martin Schürmann

LOHENGRIN – LAYOUT AND SENSITIVITY STUDY

- "coarse-tuning" the experiment
  - used 4000 bins to define three baseline benchmarks for our experiment:
    - y = [1.6e-4; 0.95] in 40 bins
    - x = [0;1] in 1 bin (x = 1-y is, very roughly, a good approximation for non-pathological (i.e. boring) events)
    - θ_e = [1.e-5;0.25] in 10 bins
    - θ_γ = [1.e-5;0.25] in 10 bins
  - "masterfunction" predicts 3.08 x 10^{14} events in the above region
  - added 9.02 x 10^{13} "boring" events with y = 1, x = 0, θ_e = 0 to cover the phase space gap the masterfunction had problems calculating
  - for all events, electrons and photons are equally distributed in 100 ϕ-bins
  - looking at electron beam propagation and photon distribution to estimate rate in ECAL



BEAM PROPAGATION



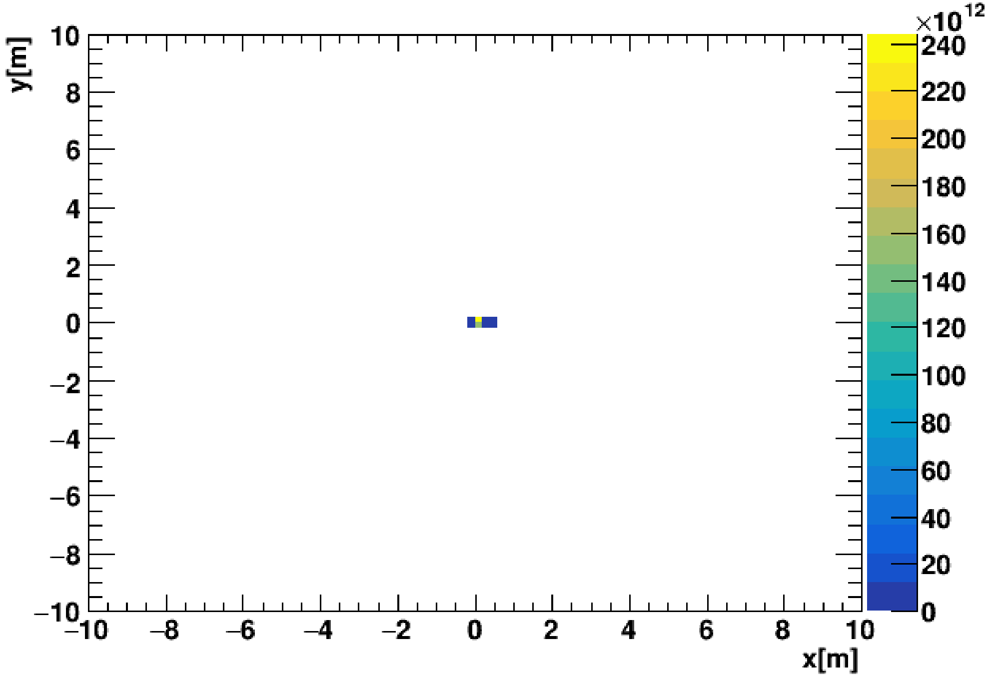
B = 0.9 T

z = 0.0 m

BEAM PROPAGATION

B = 0.9 T

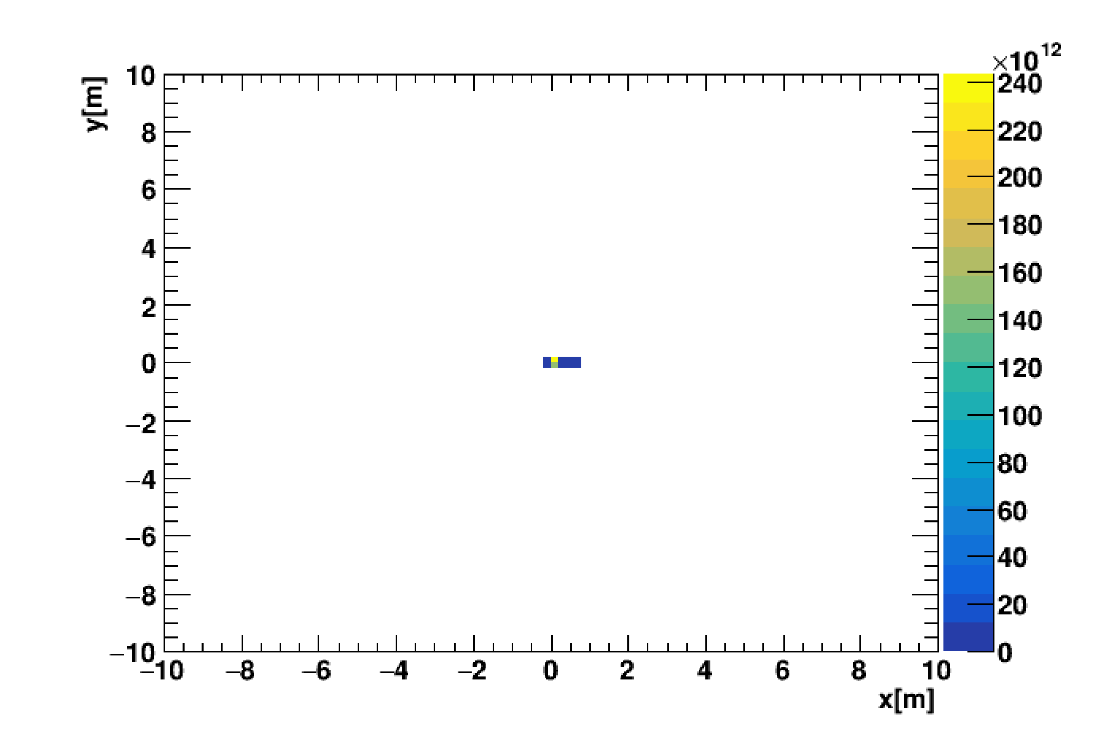
z = 0.5 m



BEAM PROPAGATION

B = 0.9 T

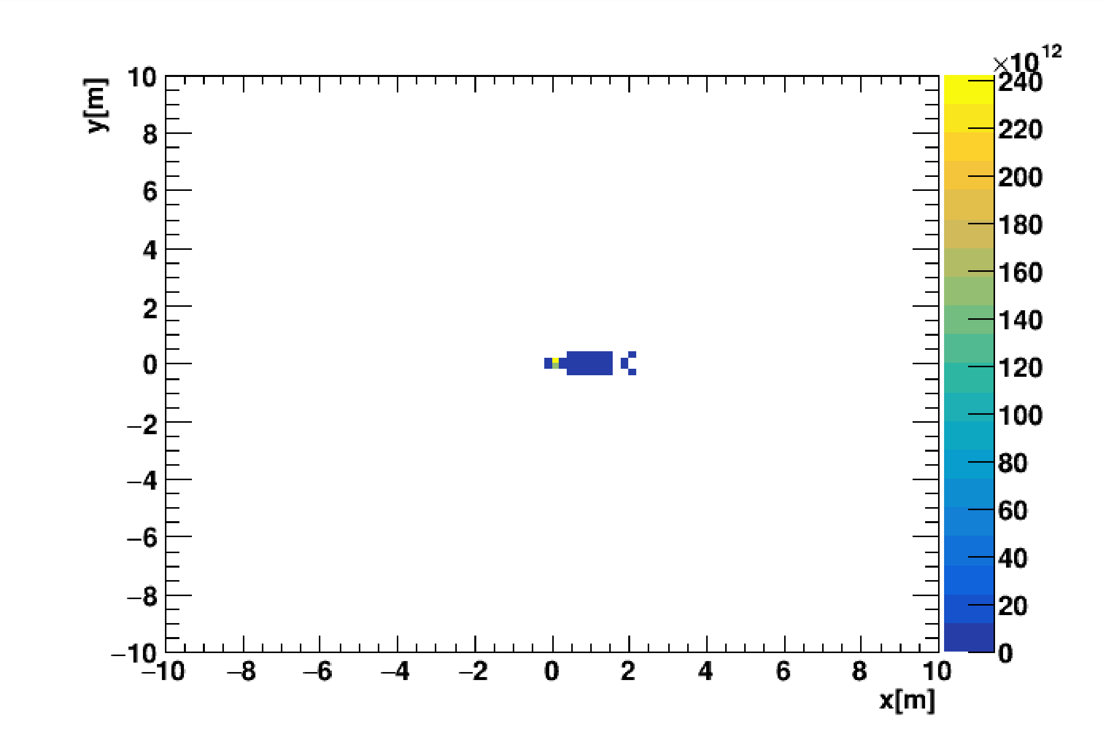
z = 0.6 m



BEAM PROPAGATION

B = 0.9 T

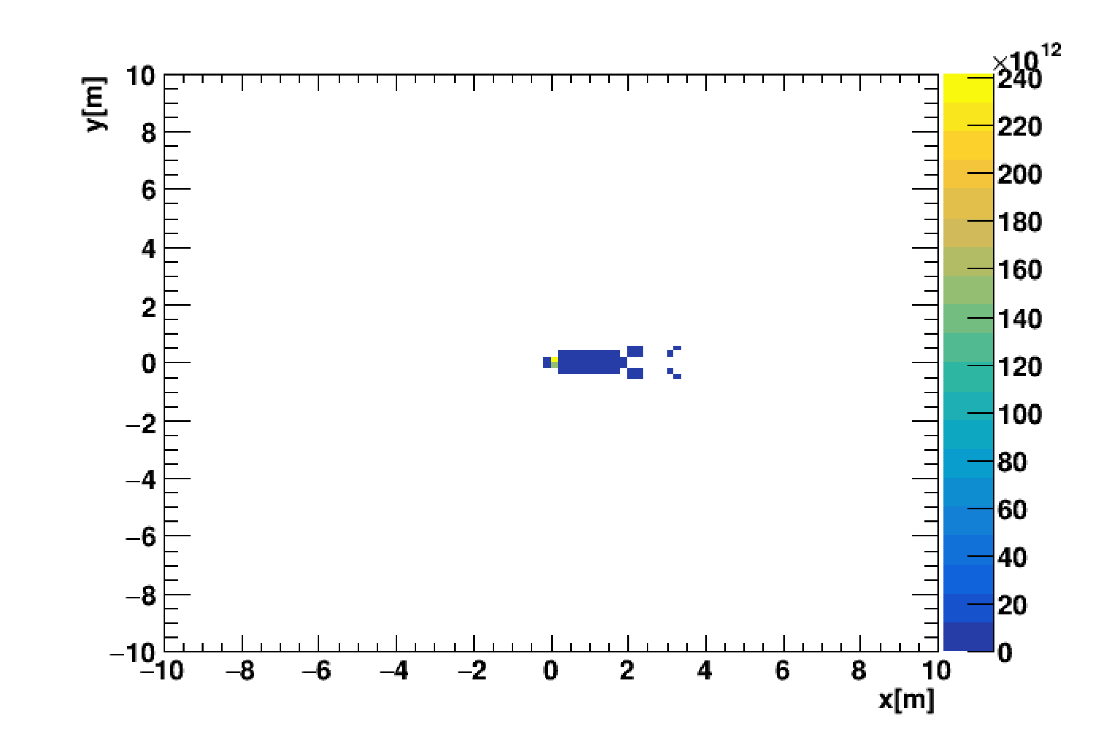
z = 0.7 m



BEAM PROPAGATION

B = 0.9 T

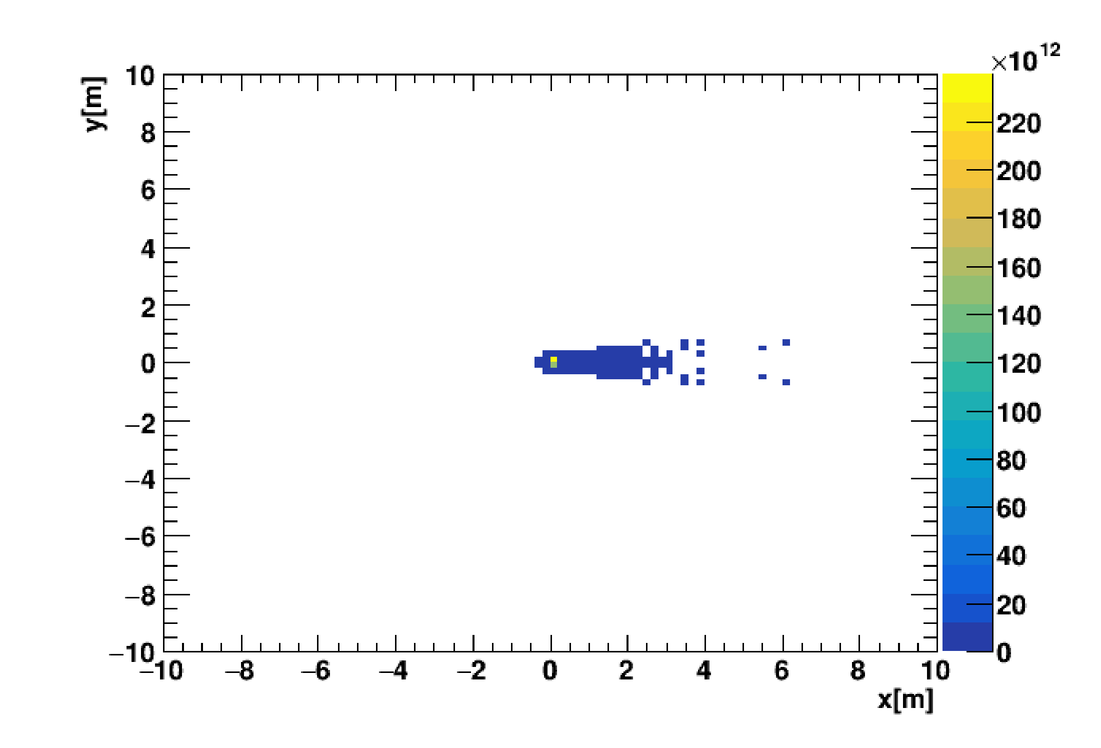
z = 0.8 m



BEAM PROPAGATION

B = 0.9 T

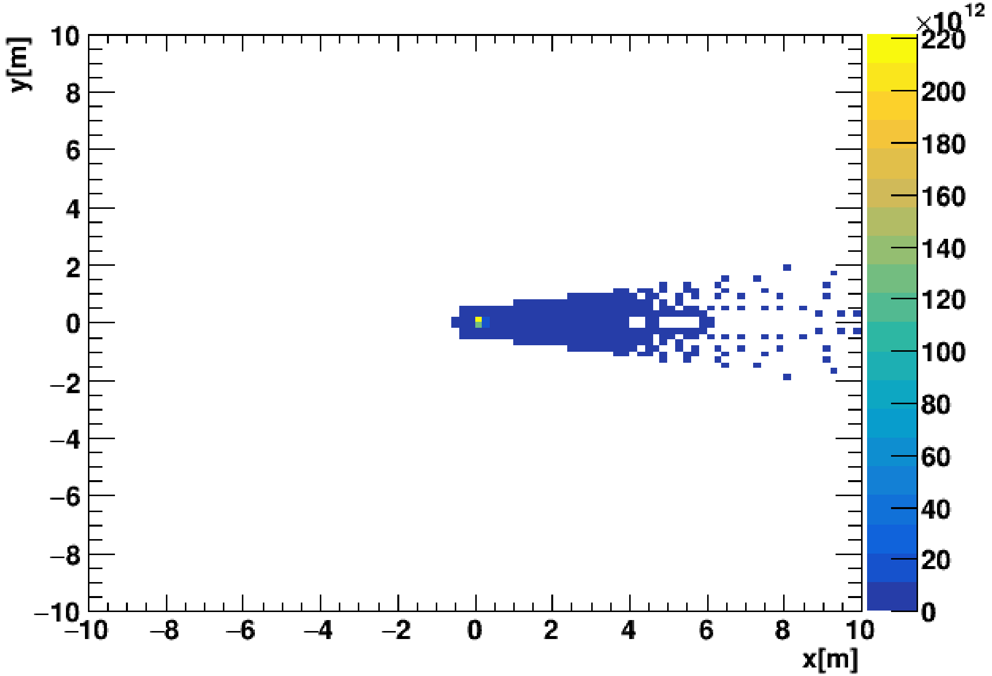
z = 1.5 m



BEAM PROPAGATION

B = 0.9 T

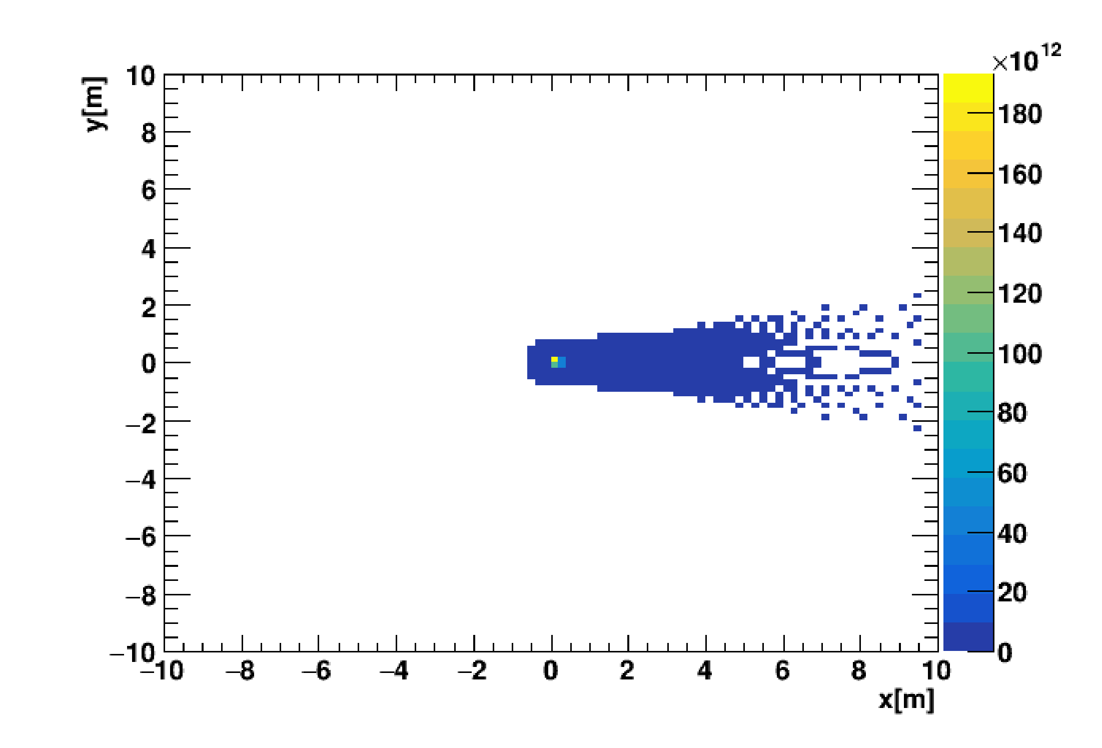
z = 2.2



BEAM PROPAGATION

B = 0.9 T

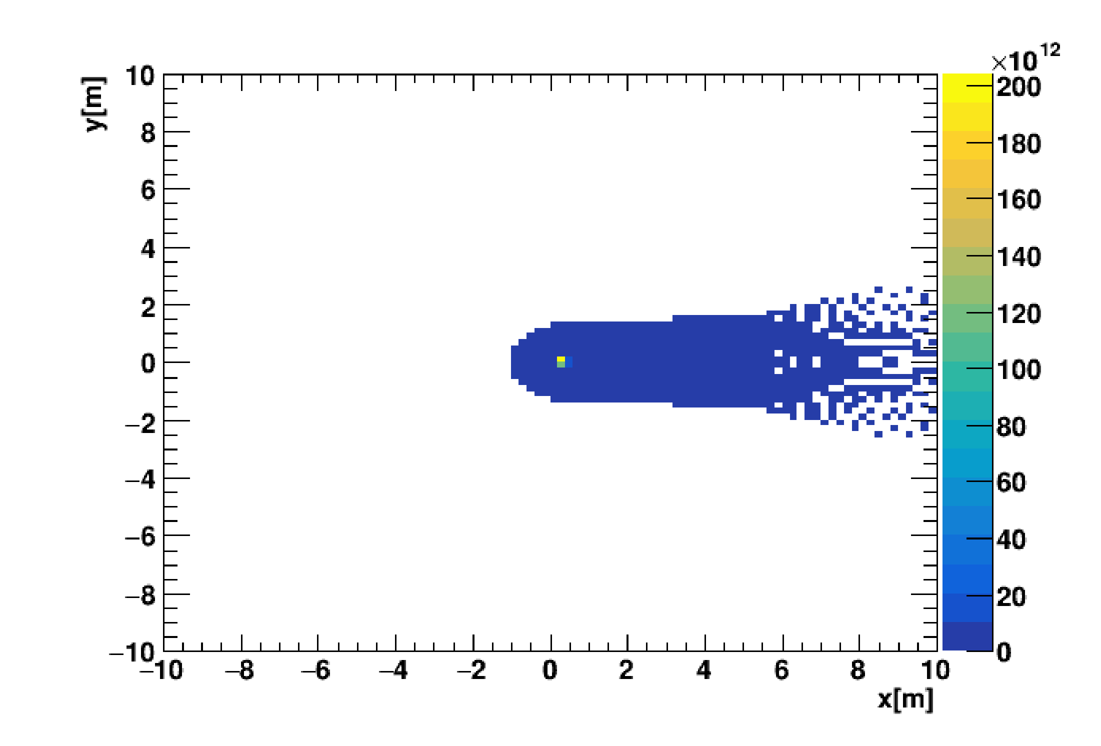
z = 3.0 m



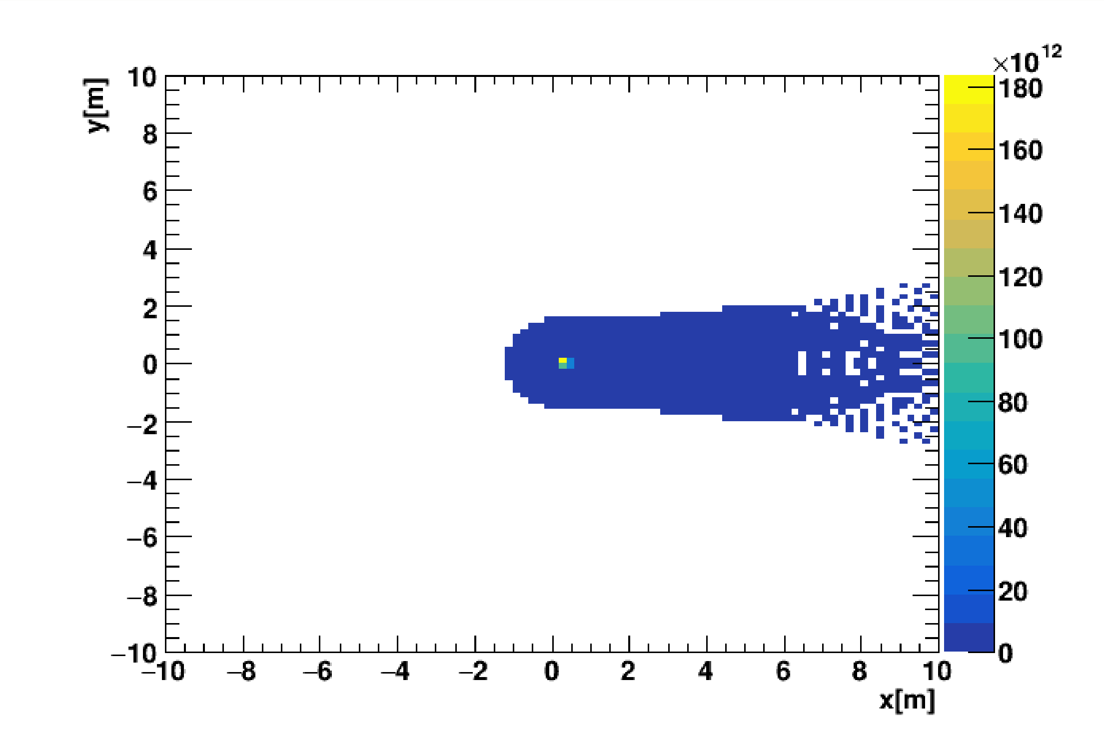
BEAM PROPAGATION

B = 0.9 T

z = 5.0 m



BEAM PROPAGATION



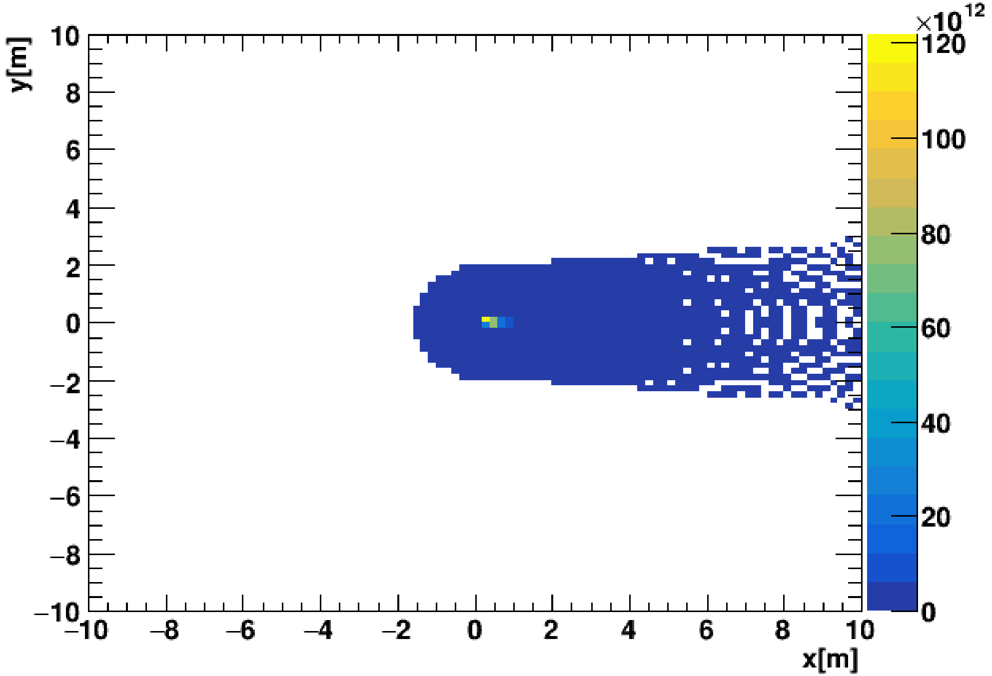
B = 0.9 T

z = 6.0 m

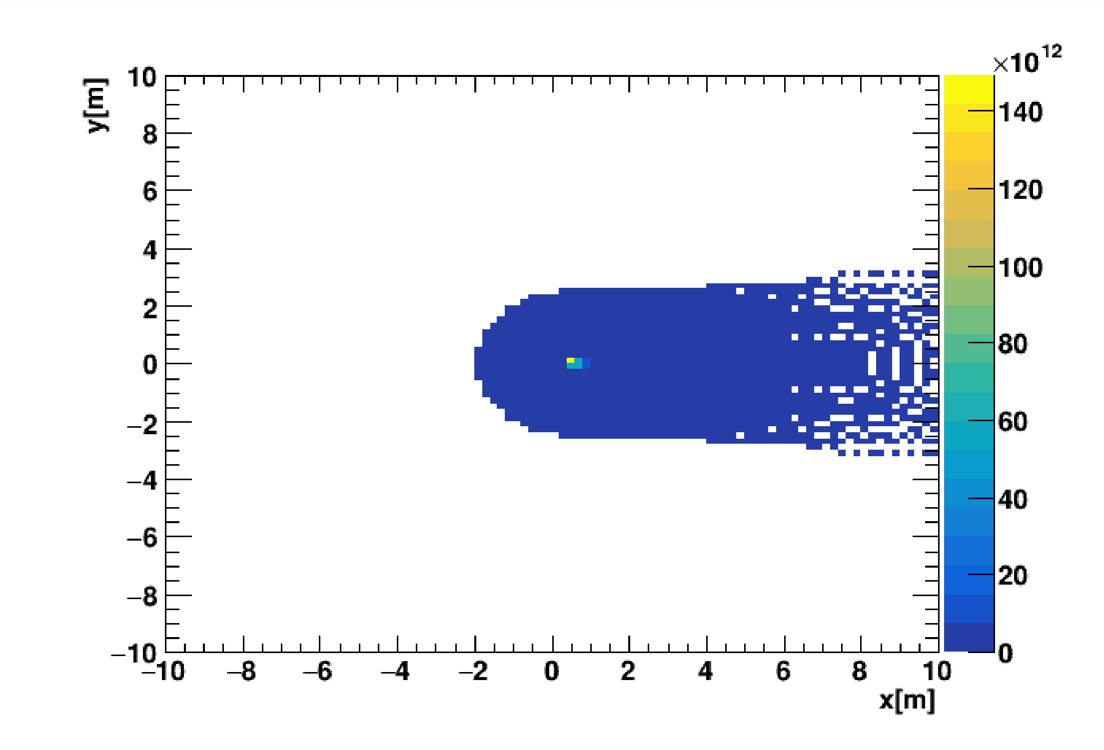
BEAM PROPAGATION

B = 0.9 T

z = 8.0 m



BEAM PROPAGATION



B = 0.9 T

z = 10.0 m

LOHENGRIN

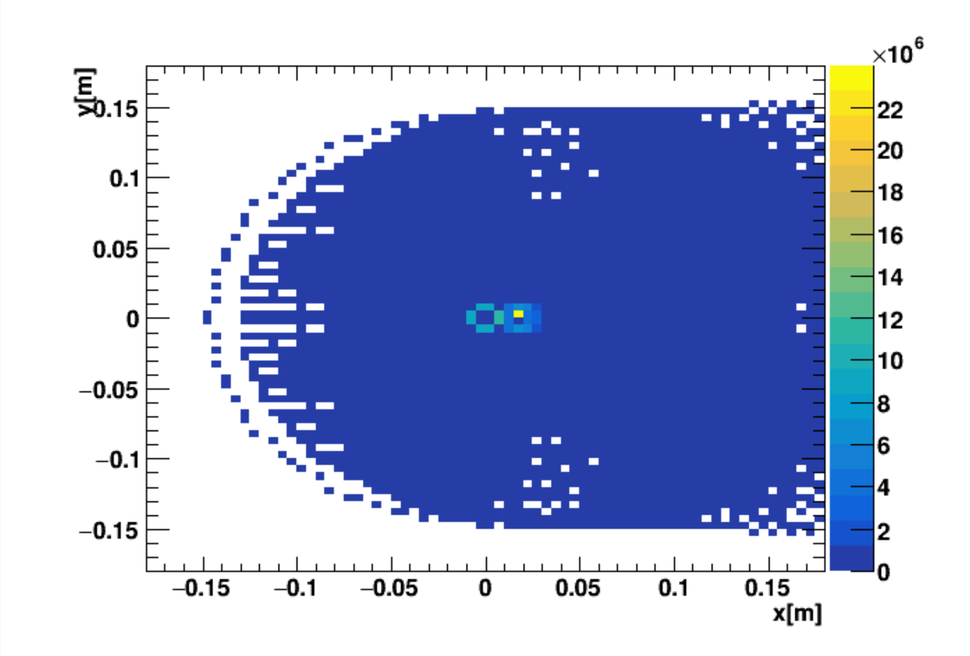
- ECAL counting rates
  - incident electron rate: 100 MHz
  - each photon or electron that hits the ECAL counts as a hit, no matter the energy of said photon or electron
    - actual ECAL threshold: ~MIP

QED bremsstrahlung

TOTAL HIT-RATE IN ECAL

B = 0.9 T

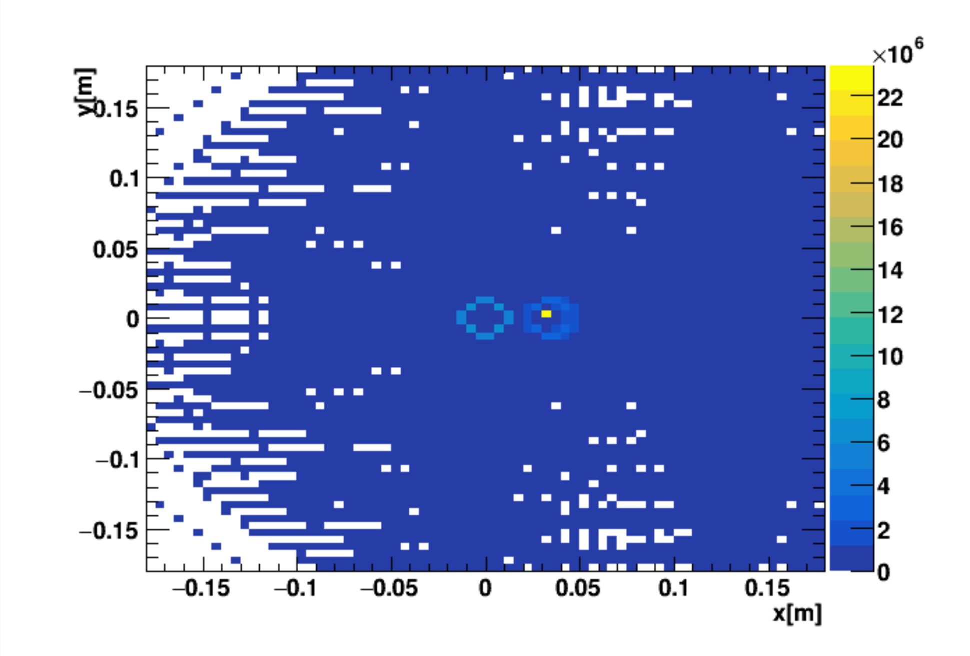
dECAL = 0.6 m



TOTAL HIT-RATE IN ECAL

B = 0.9 T

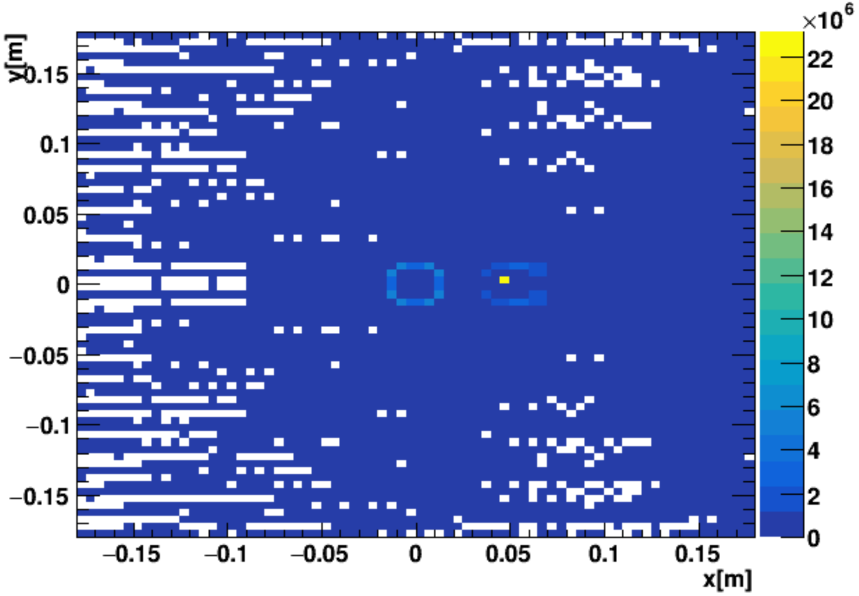
dECAL = 0.9 m



TOTAL HIT-RATE IN ECAL

B = 0.9 T

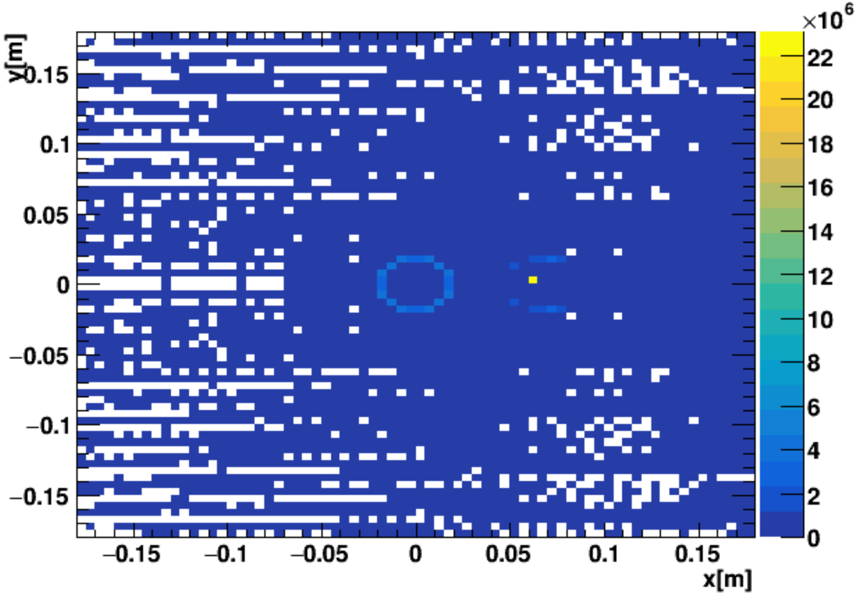
dECAL = 1.2 m



TOTAL HIT-RATE IN ECAL

B = 0.9 T

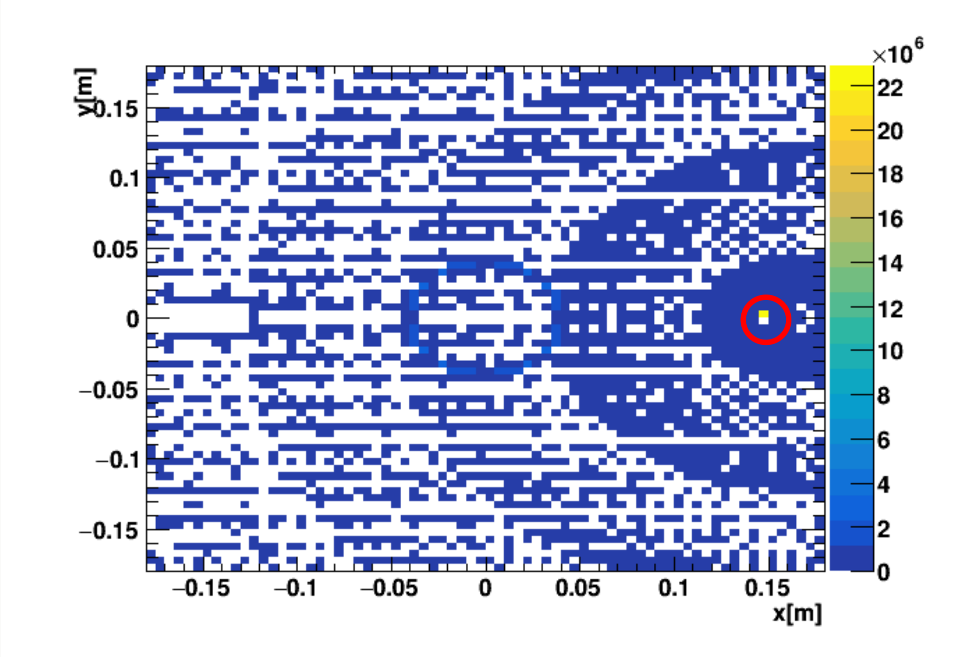
dECAL = 1.5 m



TOTAL HIT-RATE IN ECAL

B = 0.9 T

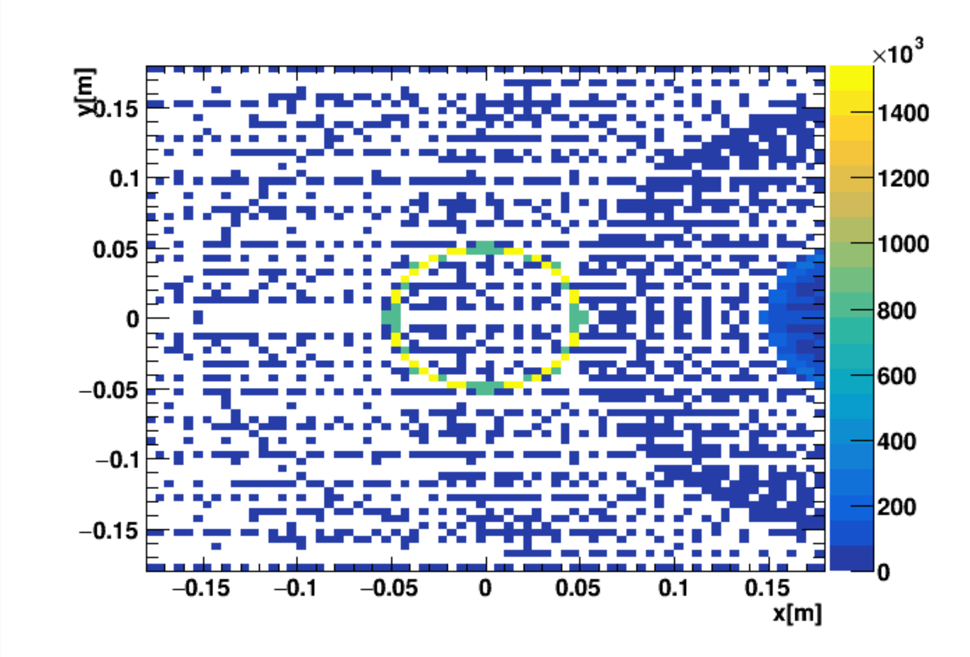
dECAL = 3.2 m



TOTAL HIT-RATE IN ECAL

B = 0.9 T

dECAL = 4.0 m



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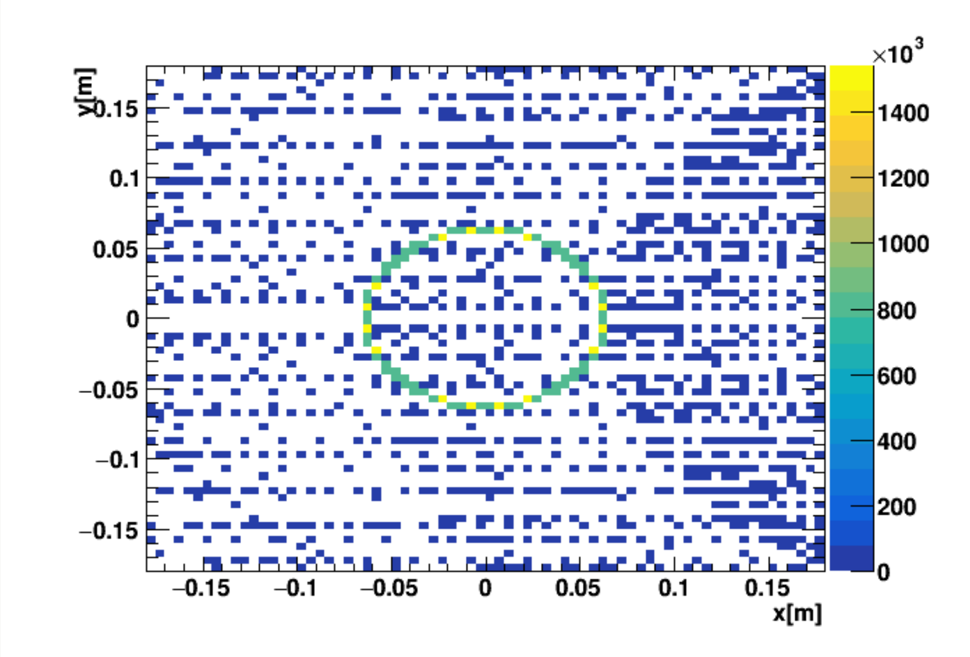
TOTAL HIT-RATE IN ECAL

B = 0.9 T

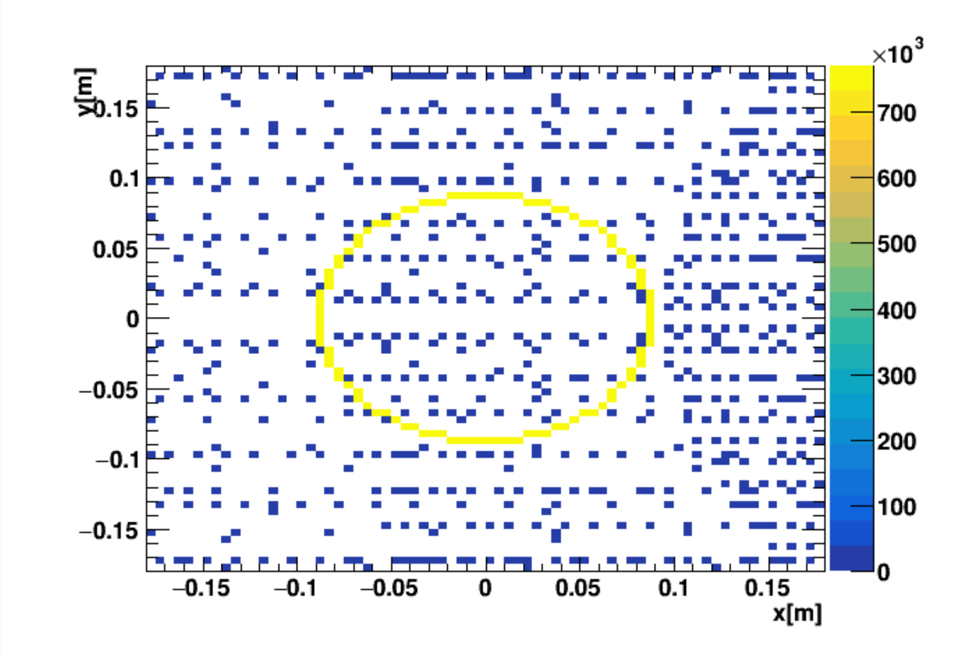
dECAL = 5.0 m



TOTAL HIT-RATE IN ECAL

B = 0.9 T

dECAL = 7.0 m



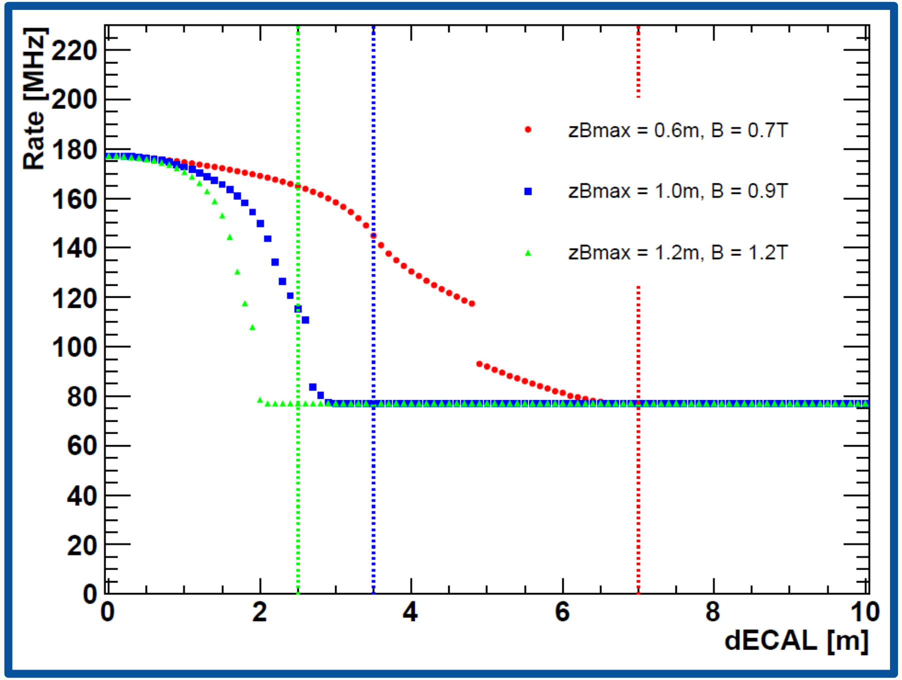
ECAL HITRATE AS FUNCTION OF DECAL

- decided to study 3 benchmark scenarios for a start
  - all assuming rECAL = 0.16 m

    1) zBmax = 0.6 m
       B = 0.7 T
       dECAL = 7 m

    2) zBmax = 1.0 m
       B = 0.9 T
       dECAL = 3.5 m

    3) zBmax = 1.2 m
       B = 1.2 T
       dECAL = 2.5 m



rBmax [m]	zBmax [m]	$\theta_\gamma^{max} = \theta_\gamma^{ECAL}$ [rad]	d_{ECAL} [m]	r_{ECAL} [m]	B [T]	θ_e(zBmax, y=1)	r_e(zBmax) [m]	r_e(dECAL) [m]
0.1	0.6	0.165	7	1.167	0.7	0.039	0.012	0.264
0.1	1.0	0.100	3.5	0.350	0.9	0.084	0.042	0.254
0.1	1.2	0.083	2.5	0.208	1.2	0.135	0.081	0.258

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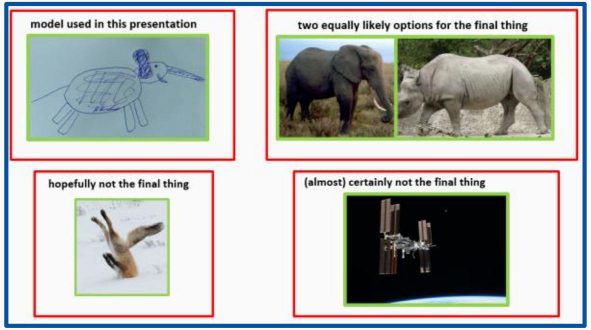
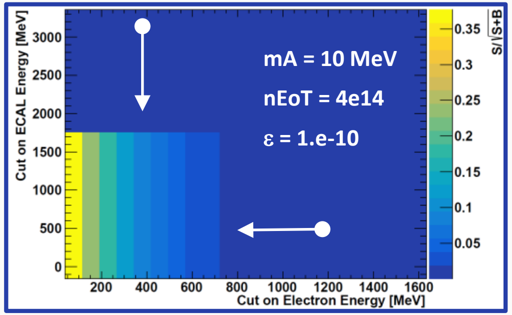
LOHENGRIN

- used benchmark scenarios to get a feeling for the sensitivity reach of Lohengrin
  - used “master-function” to calculate expected number of signal and background events in finer binning, covering the entire phase space
  - geometry based approach to estimate number of fake signal events
  - assuming an HCAL can veto all events with hadronic activity
  - assuming perfect detector resolution

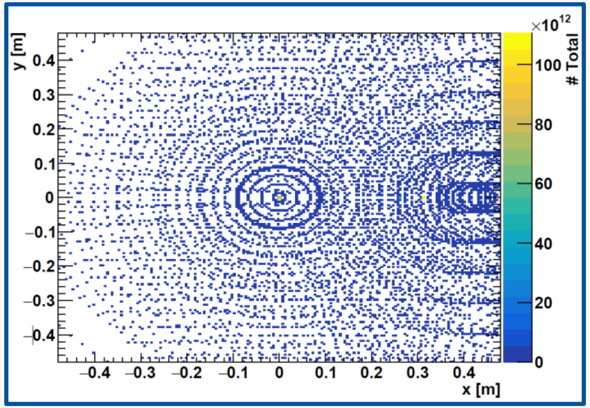
reminder



- **tentative Signal Region** defined using
  - outgoing electron momentum (p and θ)
  - energy of photons that hit the ECAL
  - **TLDR for Lohengrin SR:**
    - **very** tight cut on outgoing electron energy
    - moderate cut on ECAL energy
    - ECAL covering a large polar angle crucial for efficient veto on fake missing E backgrounds

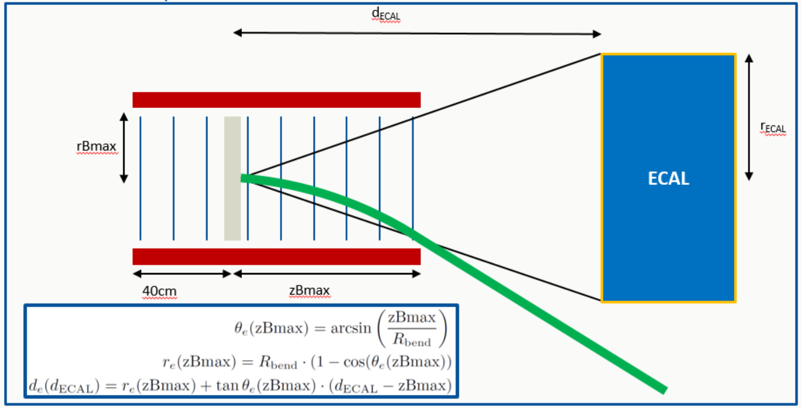


rECAL	0.16	0.24	0.32
SMBG	11506	293	48
S for S/sqrt(S+B) = 1	108	18	7



LOHENGRIN – SENSITIVITY RANGE ESTIMATE

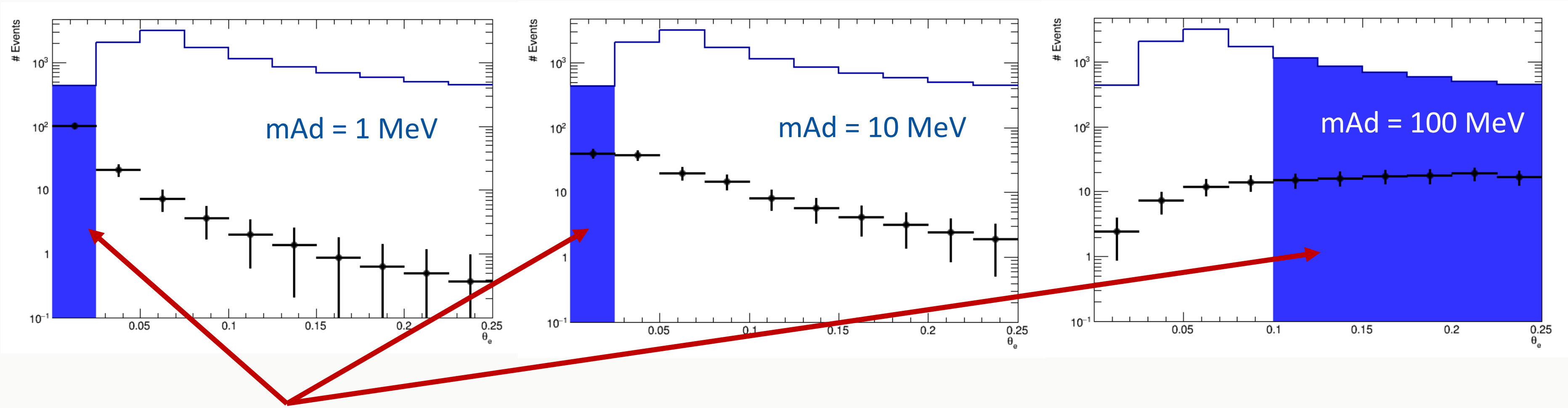
- showing results for benchmark 2
  - mixture of optimistic and conservative choices
- tentative signal region
  - $y < 0.024$
    - $E_e <\sim 75$ MeV
    - bending radius in 0.9 T magnetic field R = 0.5m
    - difficult!
  - $E_{ECAL} < 640$ MeV
  - possibly a mA' dependent, two-sided cut on θ_e
    - "global" SR without this cut
    - "local" SR including this cut



rBmax = 0.1 m
zBmax = 1.0 m
dECAL = 3.5 m
rECAL ∈ (0.16 m, 0.24 m, 0.36 m)
B = 0.9 T

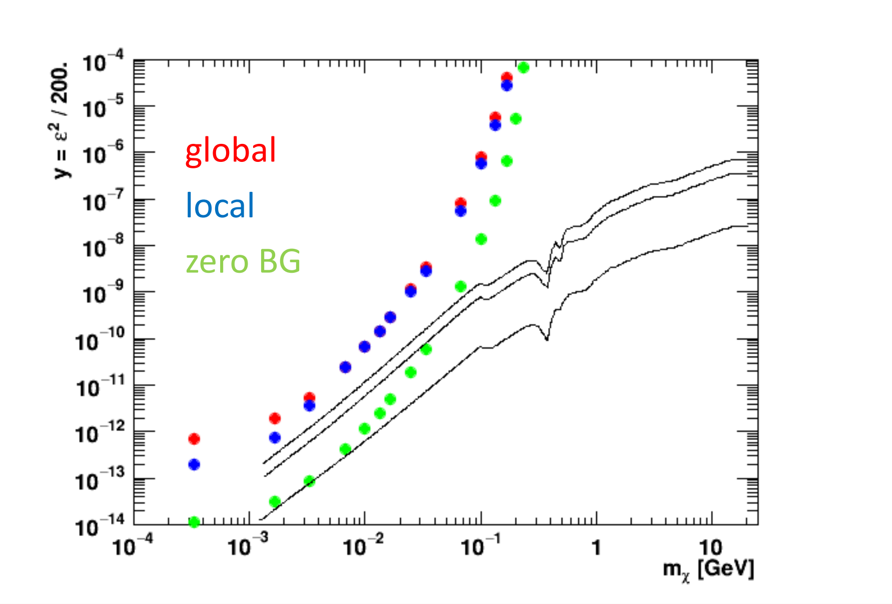
LOHENGRIN – SENSITIVITY RANGE ESTIMATE

- benchmark 2, rECAL = 0.16m, various DM masses
  - ε^2 set to value for which $S/\sqrt{(S+B)} = 1$ for the $\theta_e < 0.25$

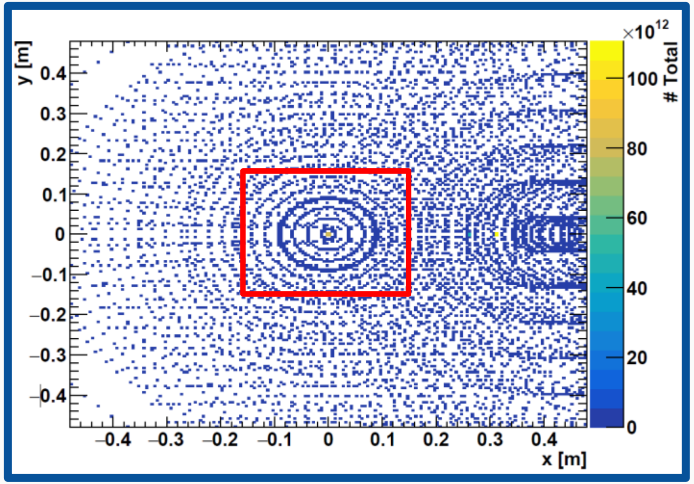


"local" signal regions

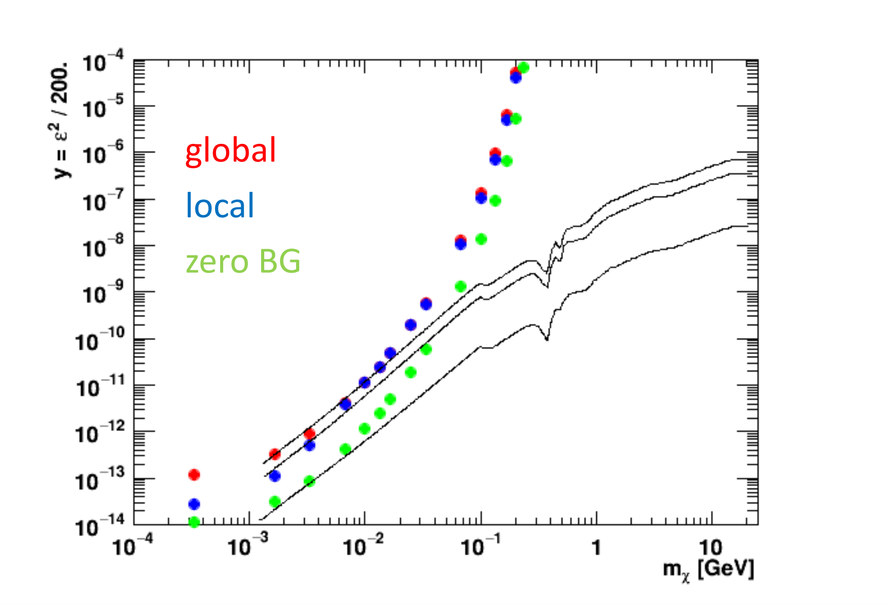
LOHENGRIN – SENSITIVITY RANGE ESTIMATE



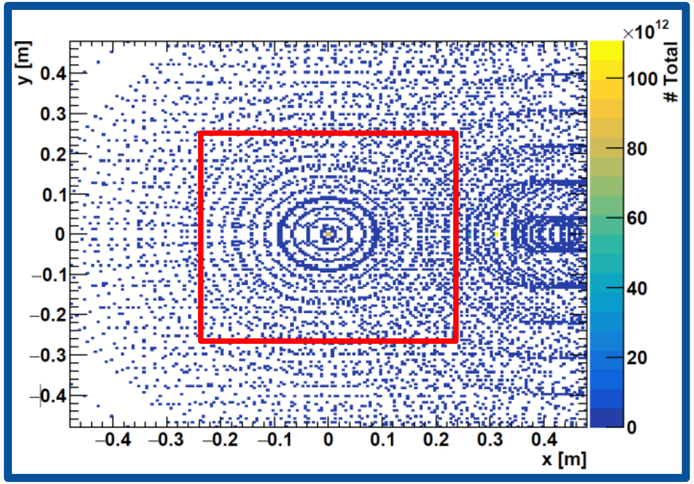
Benchmark 2



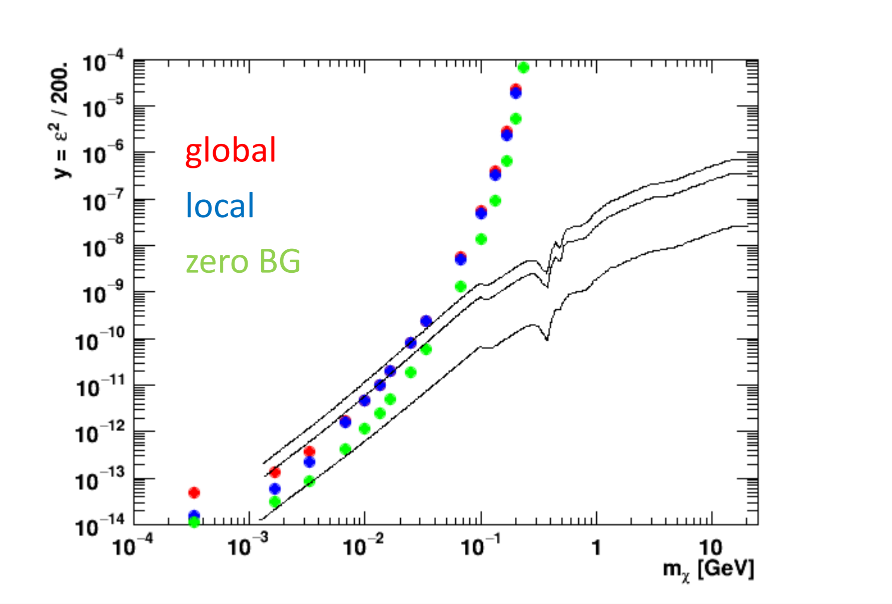
LOHENGRIN – SENSITIVITY RANGE ESTIMATE



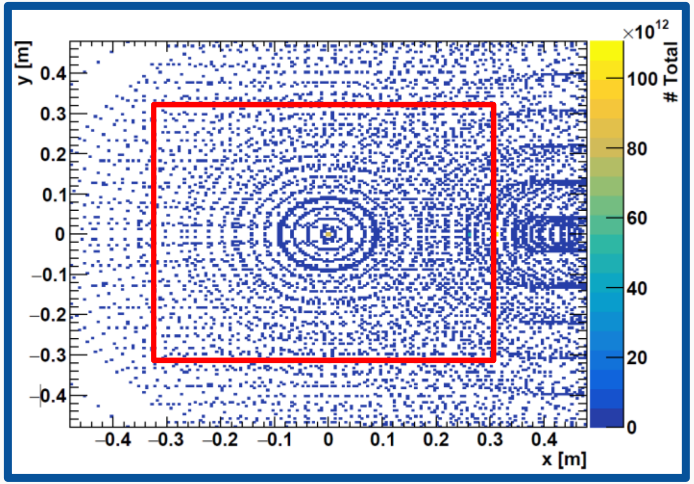
Benchmark 2



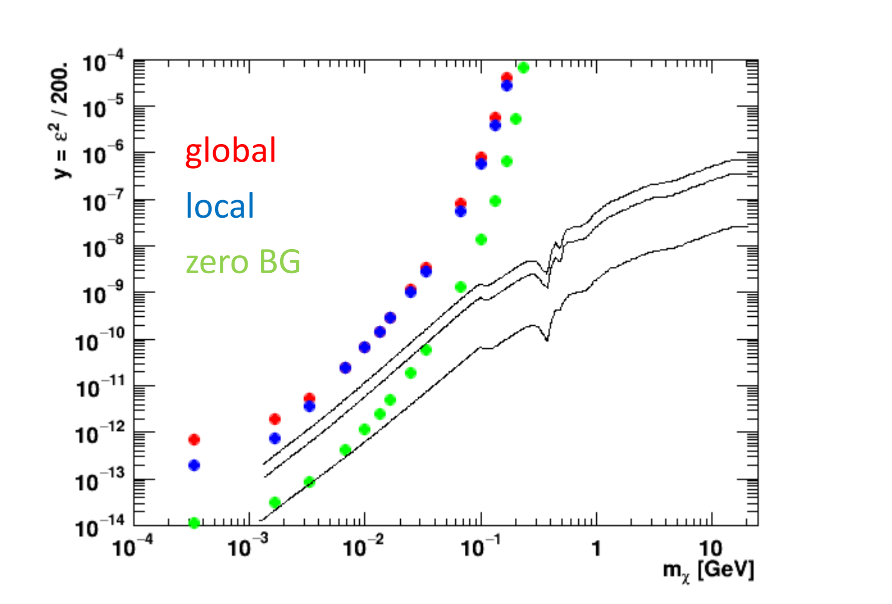
LOHENGRIN – SENSITIVITY RANGE ESTIMATE



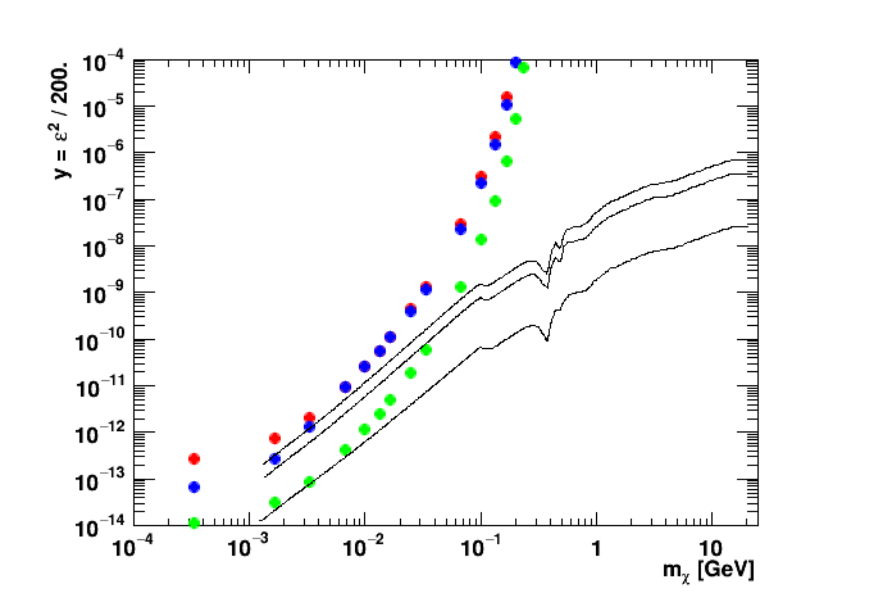
Benchmark 2



LOHENGRIN – SENSITIVITY RANGE ESTIMATE



Benchmark 2 rECAL = 0.16m



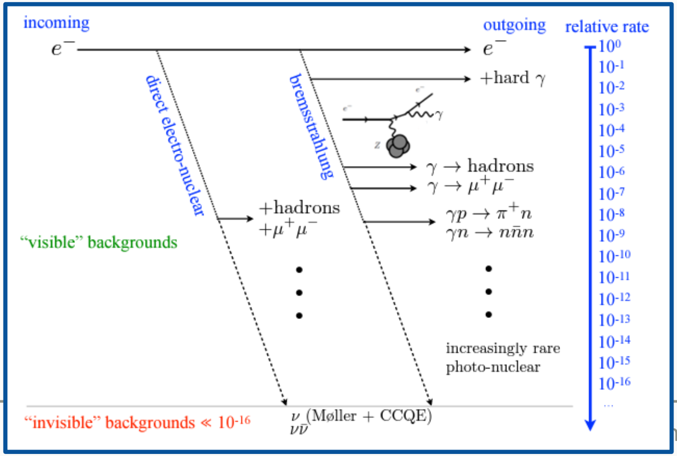
Benchmark 3 rECAL = 0.16m

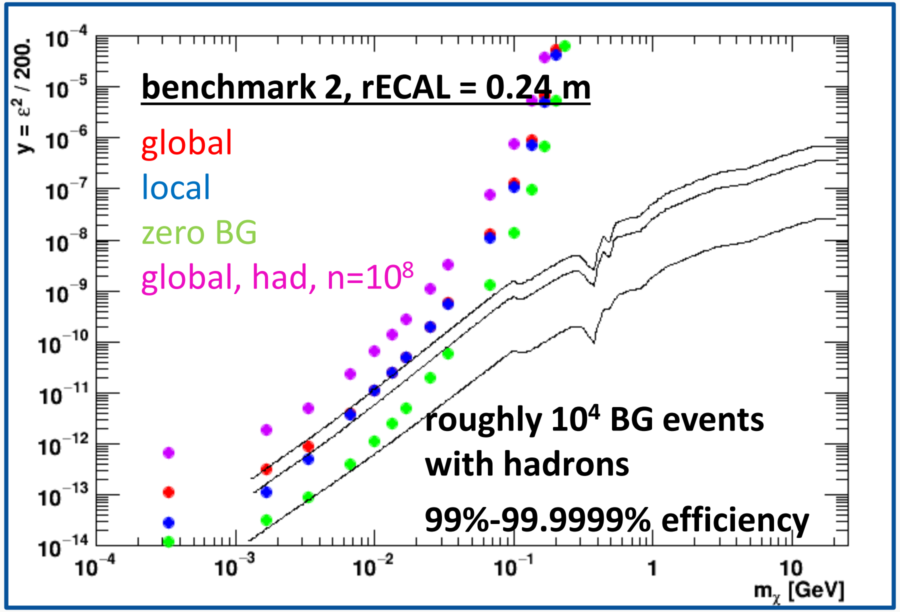
LOHENGRIN – SENSITIVITY RANGE ESTIMATE

– rejection of hadronic backgrounds

- keeping cuts on electron and ECAL (**global SR**)
- assuming the energy of 1 in n radiated photons that would normally hit the ECAL is missed in the reconstruction
- n is a blackbox for electro-nuclear, photo-nuclear cross-sections and the veto efficiency of the HCAL

reminder



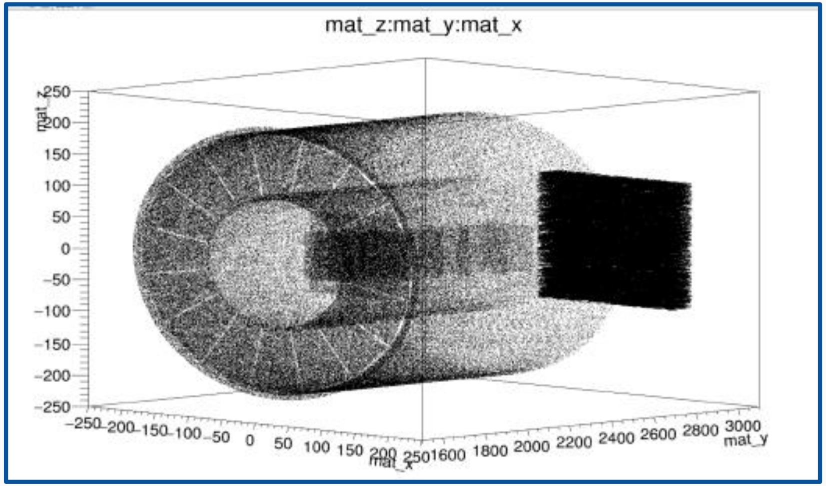


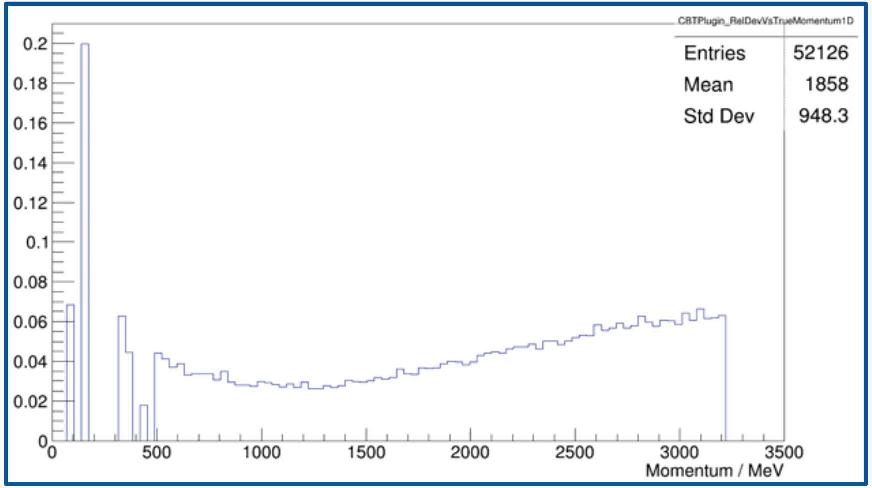
hadronic backgrounds clearly need a dedicated study

Jan Heinrichs
Andreas Salzburger

LATEST DEVELOPMENTS

- focus to implement ACTS in our analysis framework for tracking

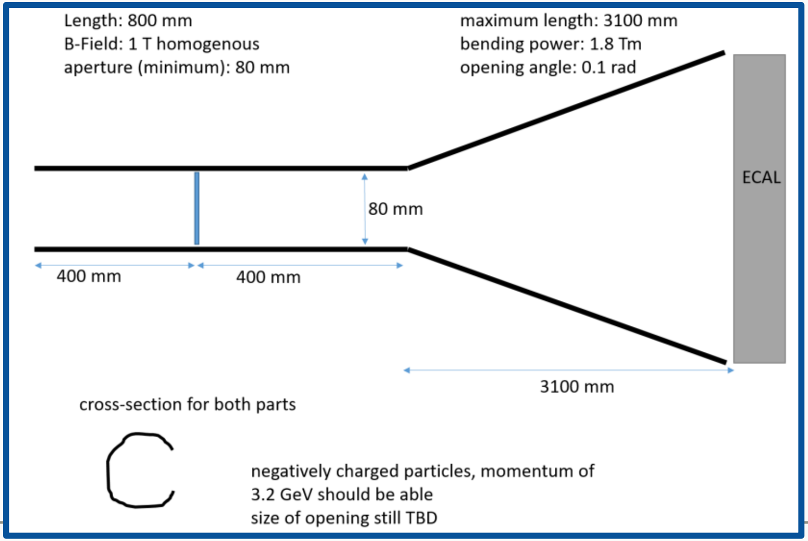




Pierre Thonet

LATEST DEVELOPMENTS

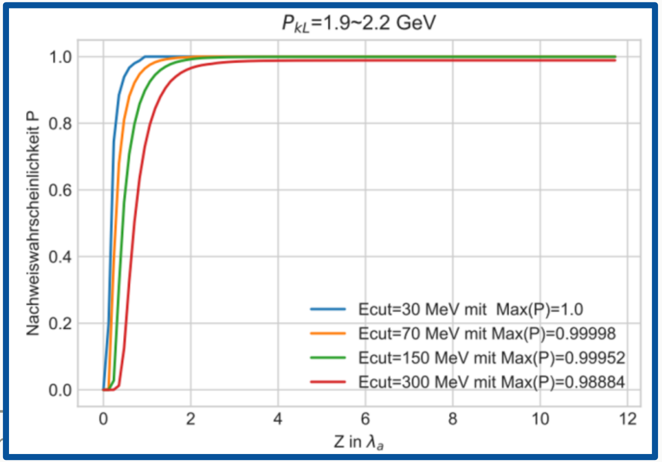
- focus to implement ACTS in our analysis framework for tracking
- started feasibility study on magnet with CERN TE-MSC-NSM (P. Thonet)



Hazem Hajjar

LATEST DEVELOPMENTS

- focus to implement ACTS in our analysis framework for tracking
- started feasibility study on magnet with CERN TE-MSC-NSM (P. Thonet)
- scheduled a test beam with our collaborators from LAL Orsay for the CALICE ECAL prototype at ELSA (rate capability, resolution)
- started looking into requirements for the HCAL



LATEST DEVELOPMENTS

- focus to implement ACTS in our analysis framework for tracking
- started feasibility study on magnet with CERN TE-MSC-NSM (P. Thonet)
- scheduled a test beam with our collaborators from LAL Orsay for the CALICE ECAL prototype at ELSA (rate capability, resolution)
- started looking into requirements for the HCAL
- continue to follow alternative approaches (hole in calorimeter, magnet shape and size, etc....)

LATEST DEVELOPMENTS

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- started feasibility study on magnet with CERN TE-MSC-NSM (P. Thonet)
- scheduled a test beam with our collaborators from LAL Orsay for the CALICE ECAL prototype at ELSA (rate capability, resolution)
- started looking into requirements for the HCAL
- continue to follow alternative approaches (hole in calorimeter, magnet shape and size, etc....)
- developments for a hardware track trigger proceeding in parallel

SUMMARY

- a light dark matter search experiment at ELSA (Lohengrin) could be sensitive in the cosmologically preferred phase space

- feasibility study and layout optimization for Lohengrin yield promising results

- still in the very early stage of conceiving a conceptual design for Lohengrin

- studying possible technical solutions for our requirements

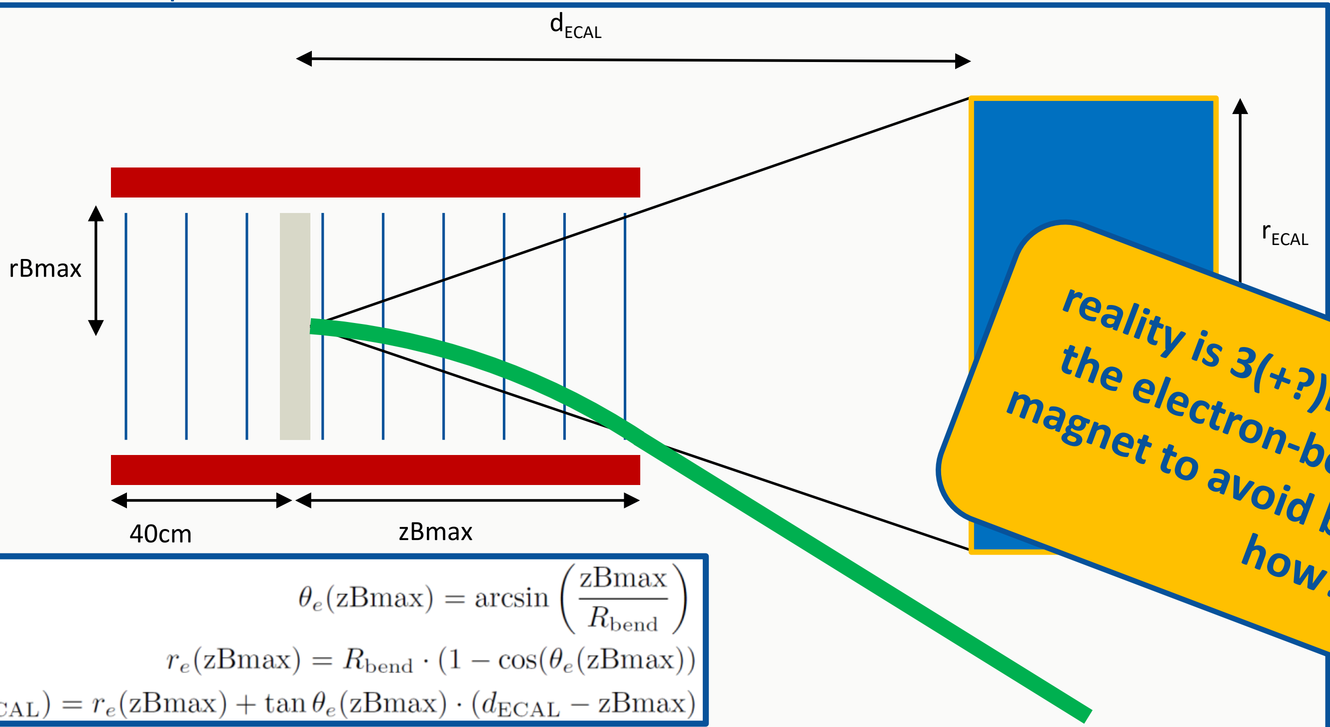
  - ultrathin, ultrafast, triggerless tracker
  - AI driven L1 track trigger
  - magnetic field strong enough to allow ~100 MeV electron tracking and bend primary beam around the ECAL
  - ECAL and HCAL with appropriate rate capabilities
  - DAQ system with online capabilities to be competitive with single EoT rate in the GHz regime

  - hope to publish a whitepaper soon
  - working on securing funding for a full blown CDR

Bonus slides

LOHENGRIN – LAYOUT AND SENSITIVITY STUDY

– assumed setup:



$$\tan\theta_\gamma^{\max} = \frac{\text{rBmax}}{\text{zBmax}}$$

$$\tan\theta_\gamma^{\text{ECAL}} = \frac{r_{\text{ECAL}}}{d_{\text{ECAL}}}$$

$$\theta_e(\text{zBmax}) = \arcsin\left(\frac{\text{zBmax}}{R_{\text{bend}}}\right)$$

$$r_e(\text{zBmax}) = R_{\text{bend}} \cdot (1 - \cos(\theta_e(\text{zBmax})))$$

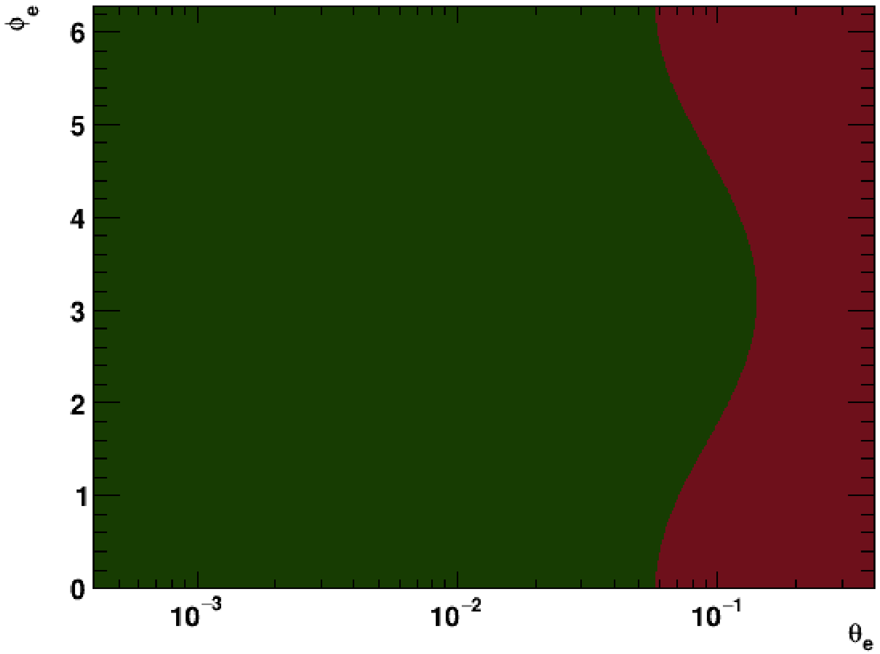
$$d_e(d_{\text{ECAL}}) = r_e(\text{zBmax}) + \tan\theta_e(\text{zBmax}) \cdot (d_{\text{ECAL}} - \text{zBmax})$$

reality is 3(+?)D – have to avoid the electron-beam hitting the magnet to avoid backscattering – how?

LOHENGRIN – LAYOUT AND SENSITIVITY STUDY

- as an example:
  - B = 0.9 T   zBmax = 1.0 m
    - green: electron escapes the magnet
    - red: electron hits the magnet somewhere

y = 1.0

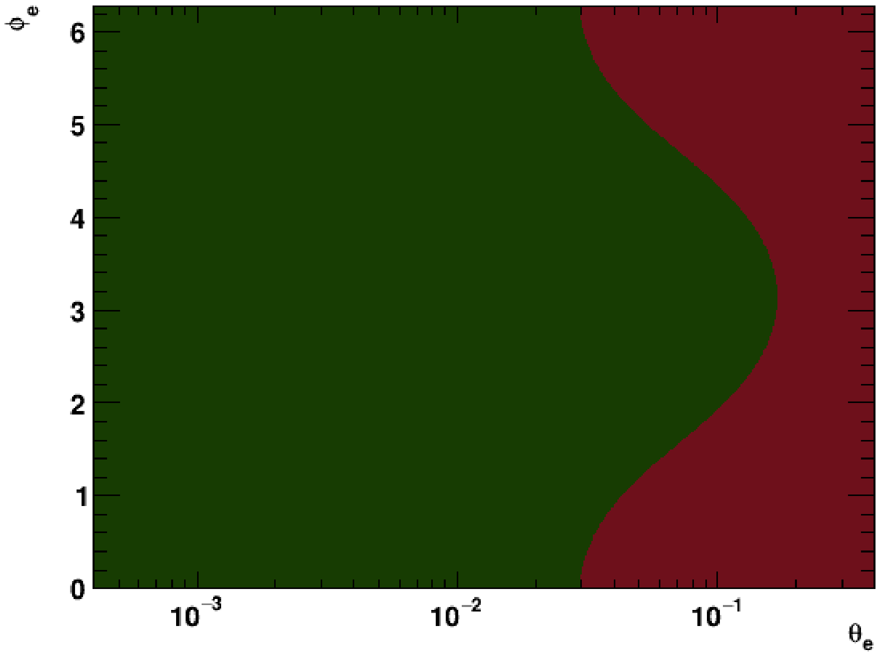


LOHENGRIN – LAYOUT AND SENSITIVITY STUDY

- as an example:
  - B = 0.9 T zBmax = 1.0 m

    - green: electron escapes the magnet
    - red: electron hits the magnet somewhere

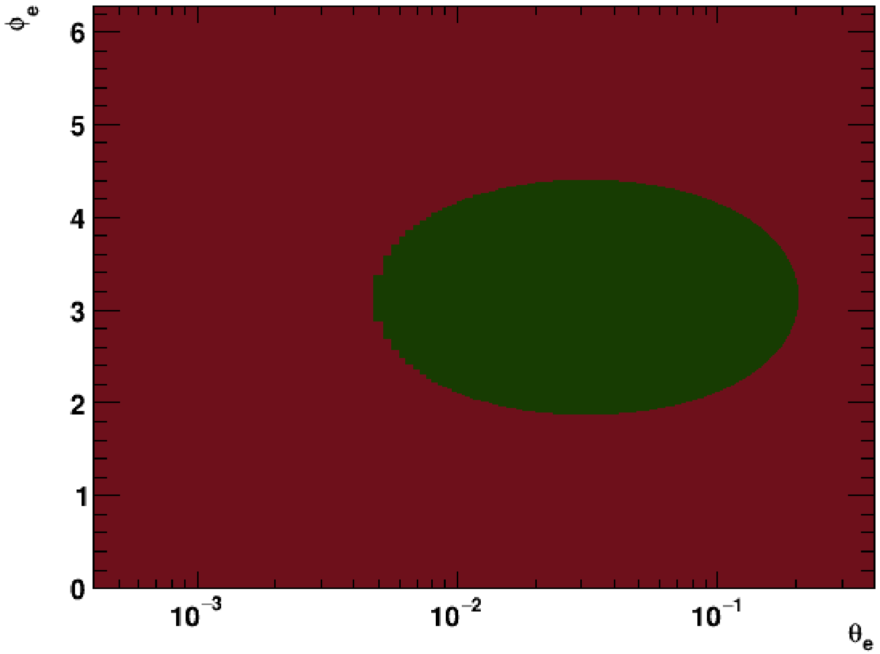
y = 0.6



LOHENGRIN – LAYOUT AND SENSITIVITY STUDY

- as an example:
  - B = 0.9 T zBmax = 1.0 m
    - **green: electron escapes the magnet**
    - **red: electron hits the magnet somewhere**

y = 0.4



LOHENGRIN – LAYOUT AND SENSITIVITY STUDY

- as an example:
  - B = 0.9 T   zBmax = 1.0 m

    - **green: electron escapes the magnet**
    - **red: electron hits the magnet somewhere**

y = 0.2