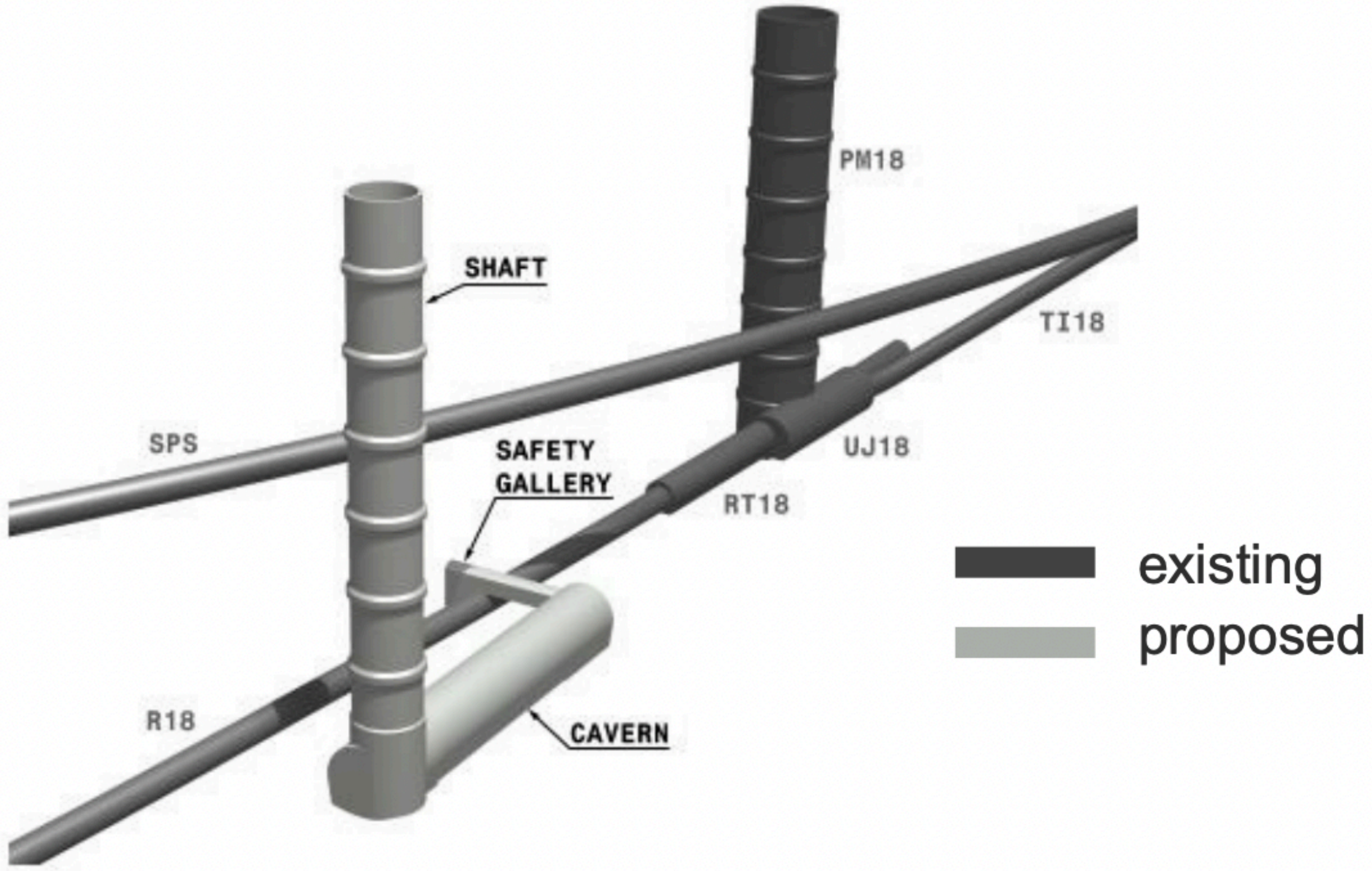
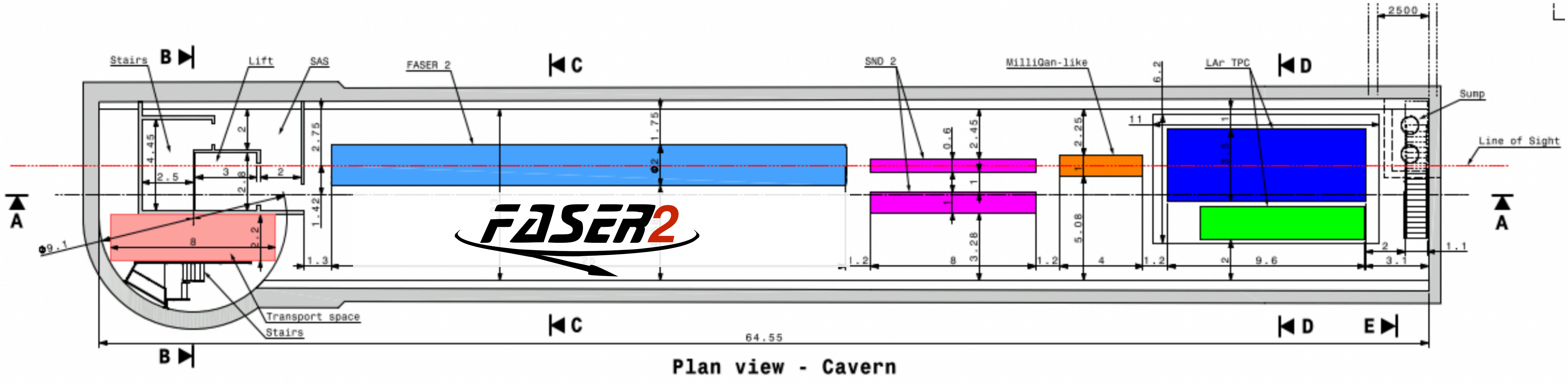


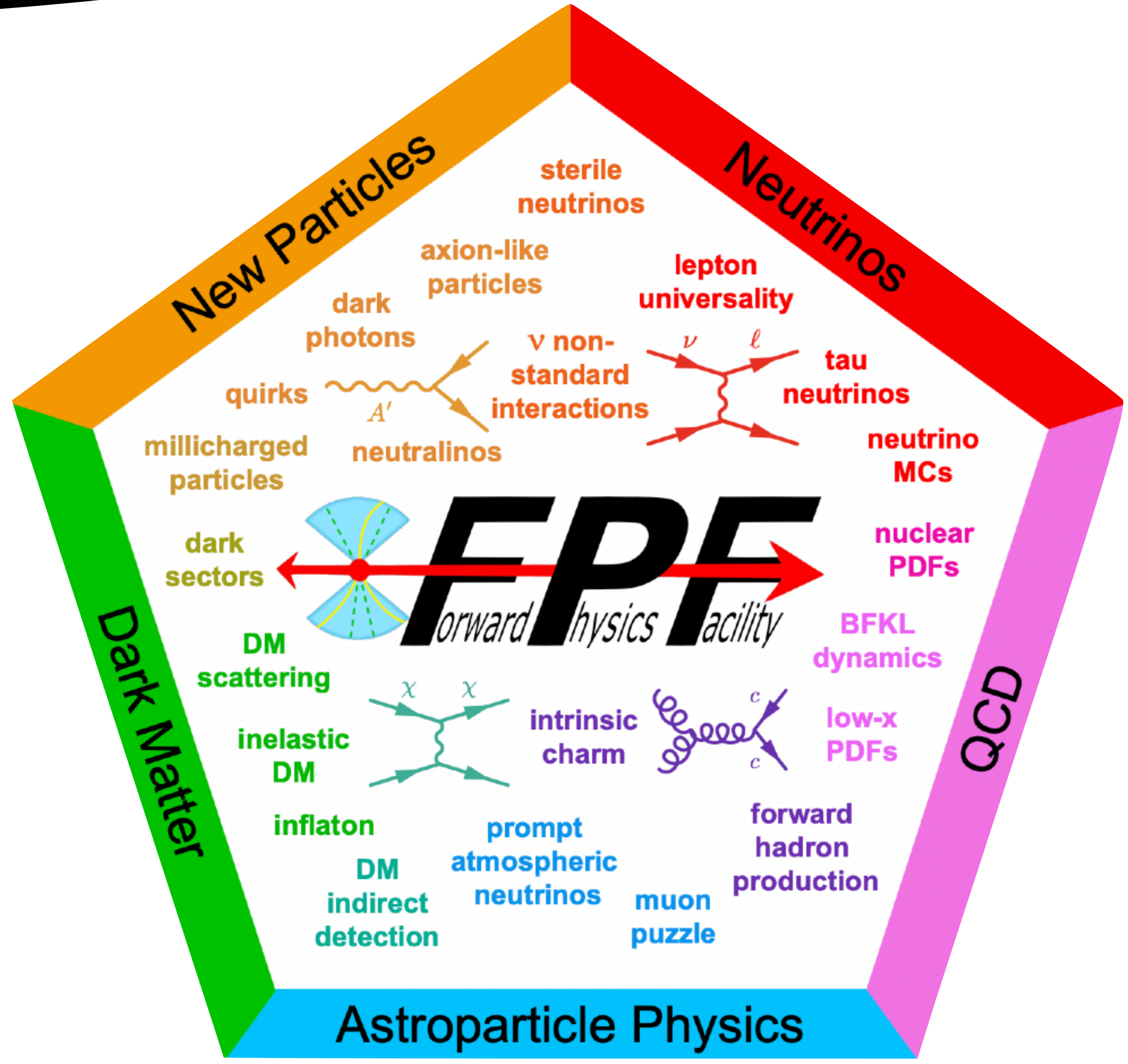


FASER2

Update on Baseline Detector

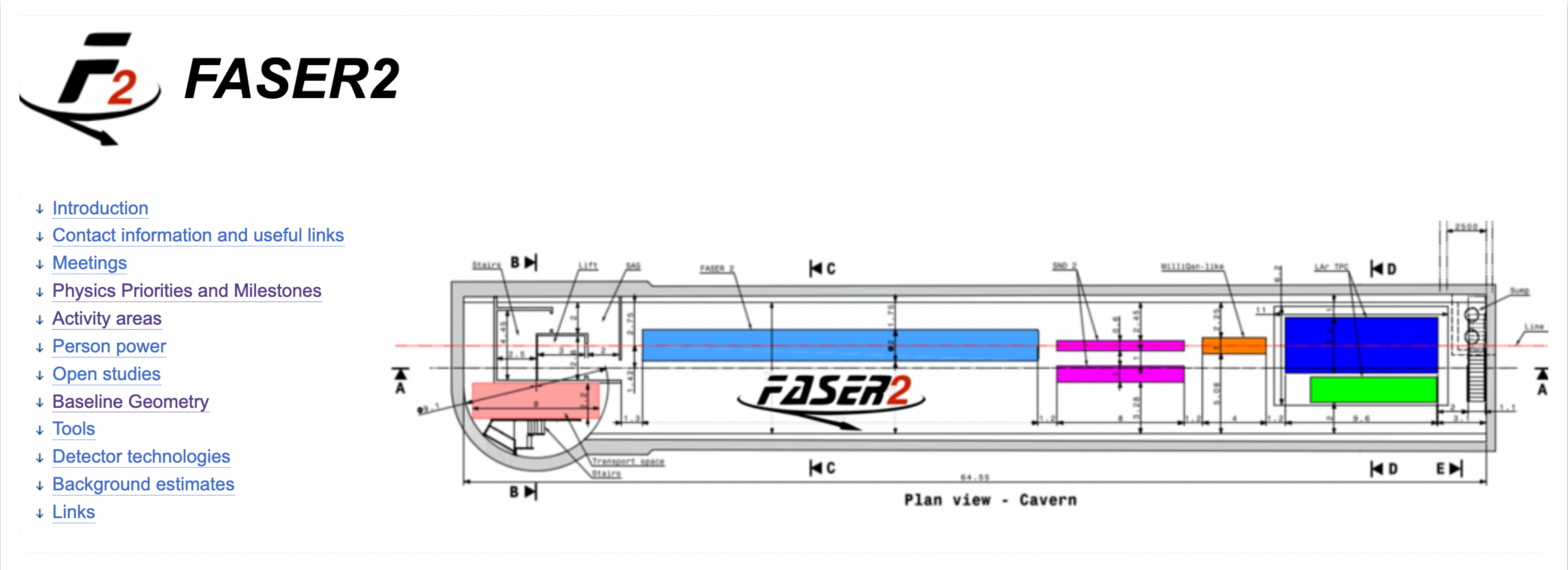
FPF5 Workshop

15/11/2022



Introduction

- Formalising structure a little
  - Regular meetings
  - Activity areas with responsibles
  - FASER2 Twiki
- Finalising new baseline detector
  - Driven by magnet
- Development of sub-detector designs
  - First look at costings
- Starting work on more sophisticated analysis techniques



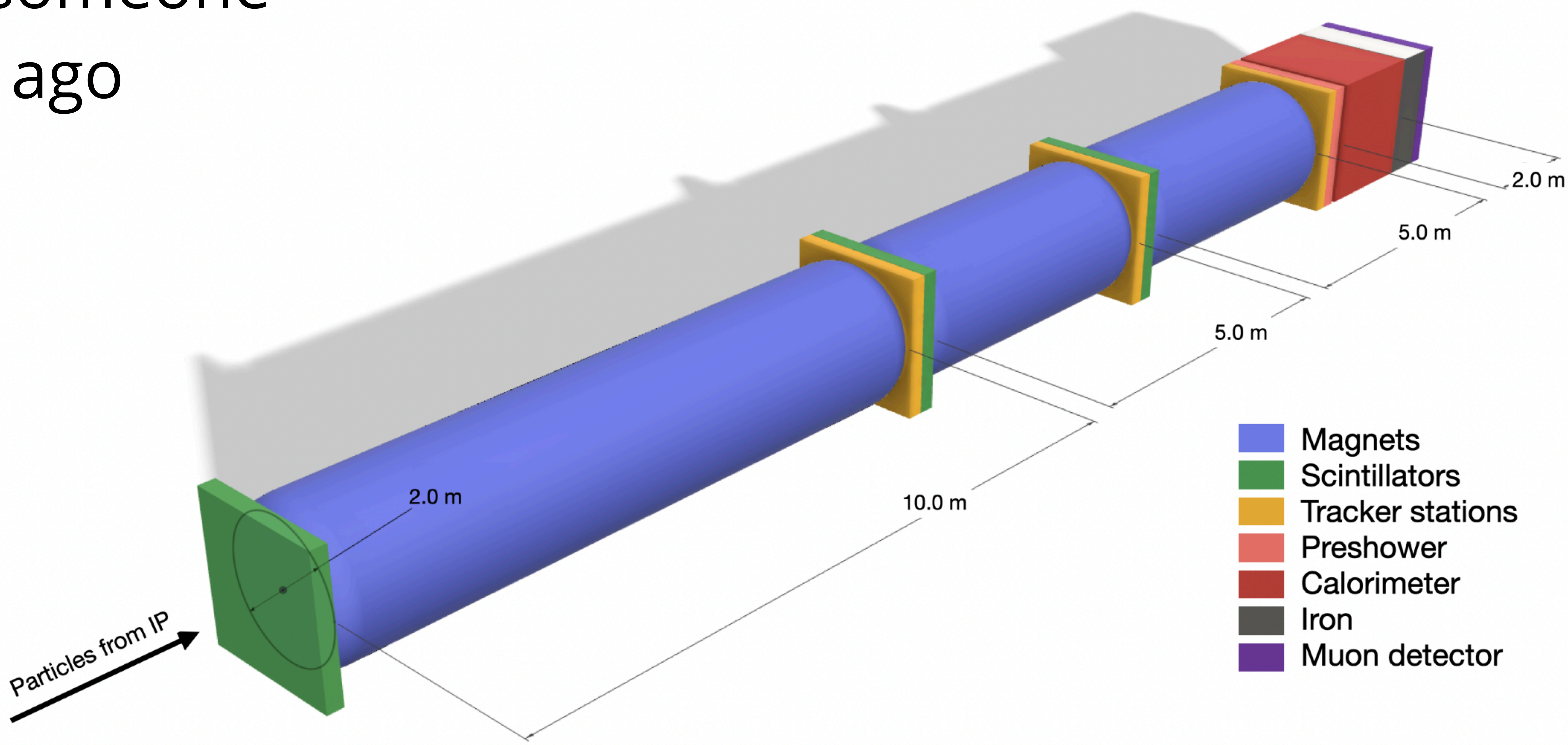
Activity area	Sub-area	Responsible
Magnet		Jamie/Hide
Tracker	SciFi	Sune
	Other R&D	Monica
Interface Tracker	SCT	Hide/Yosuke
Scintillator		Sune
Calorimeter	Dual-readout	Josh, Iacopo
Support structures		
TDAQ		Anna/Claire
Physics Sim studies	Size/Shape	Josh/Alan/Olivier
	Physics signatures	Anna /Monica
	Generation	Josh/Carl

Benchmark geometry | Magnet

- Original plan to have most of FASER2 under a B~1T magnetic field
  - Three (10m,5m,5m) 1T 1m radius superconducting magnets

[arXiv:2109.10905]

- This seemed feasible after discussion with someone in CERN accelerator group quite some time ago
  - Proposed a Canted-Cosine-Theta (CCT) Dipole
  - Appeared affordable to create metre-scale cylindrical magnets (r~1m, B~1T).



- More recent discussions with other magnet experts much less positive
  - CCT dipole never used as a detector magnet
  - Design not suited for larger radius/stored energy

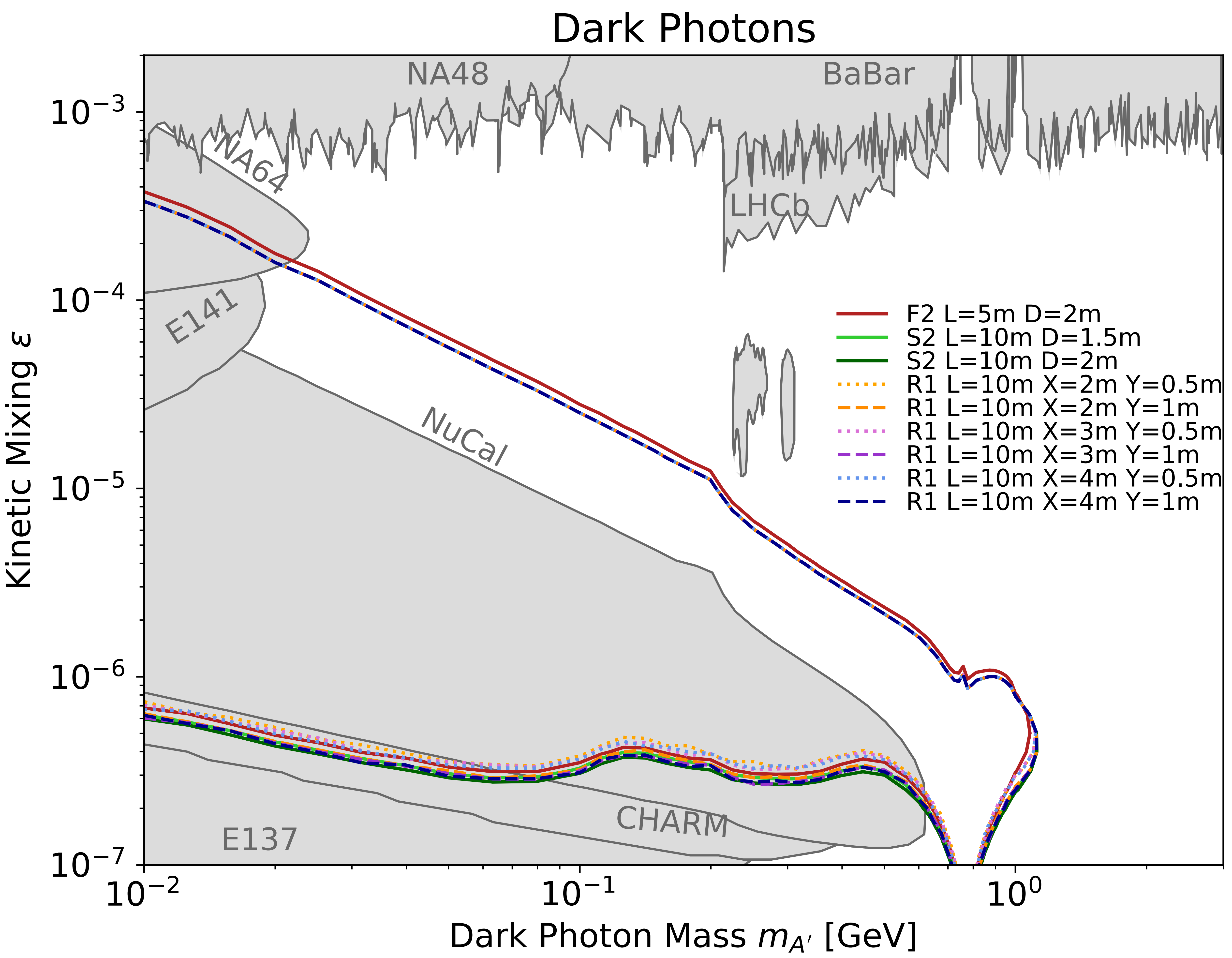
- New plan to have single magnets with ~4 Tm of bending power
  - Implies an LHCb-like geometry

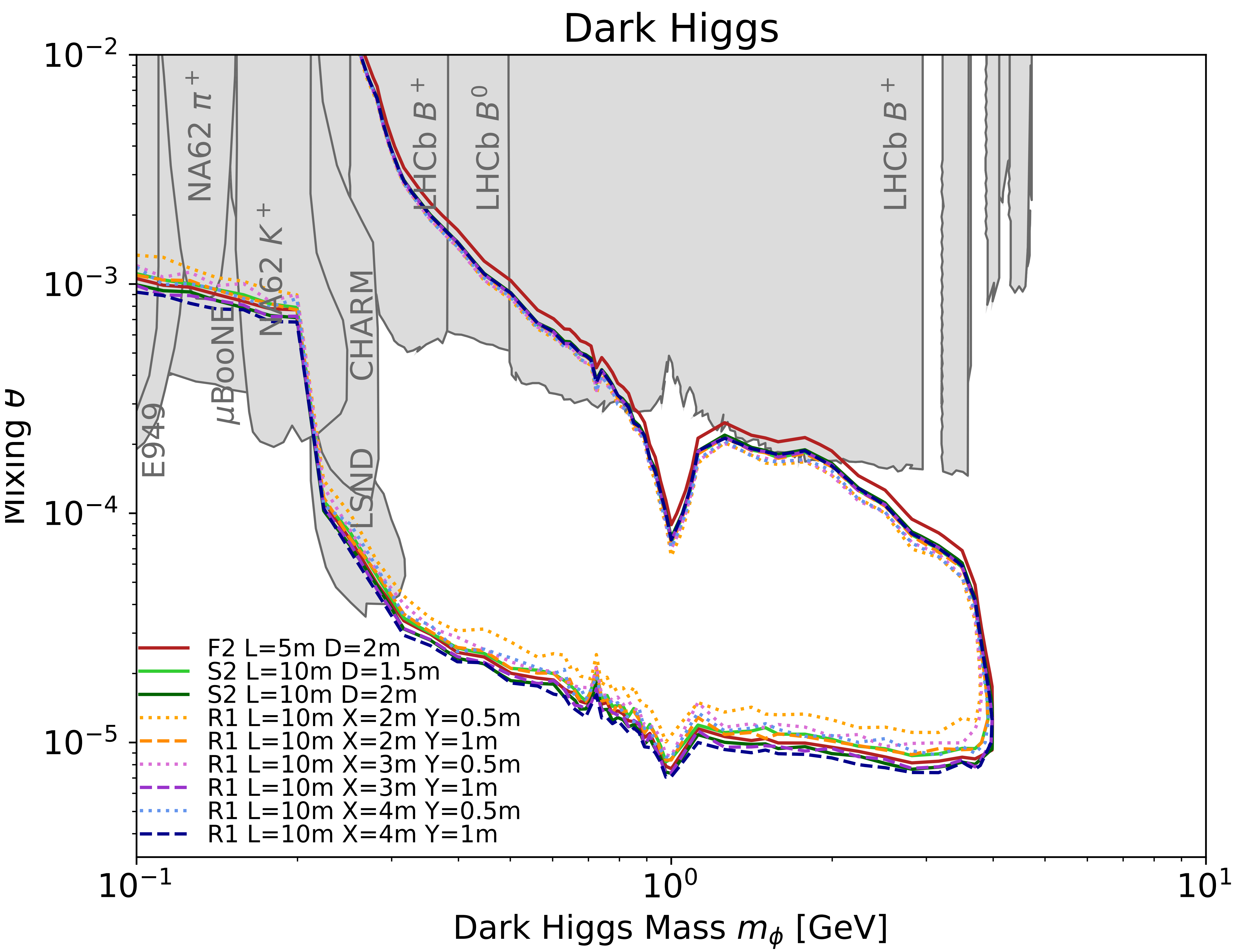
Benchmark geometry

- Converging on baseline geometry
  - Driven by available magnet technology
    - Rectangular aperture seems more straightforward construction
  - Comparable sensitivity to FASER2 default design

Arriving at new baseline

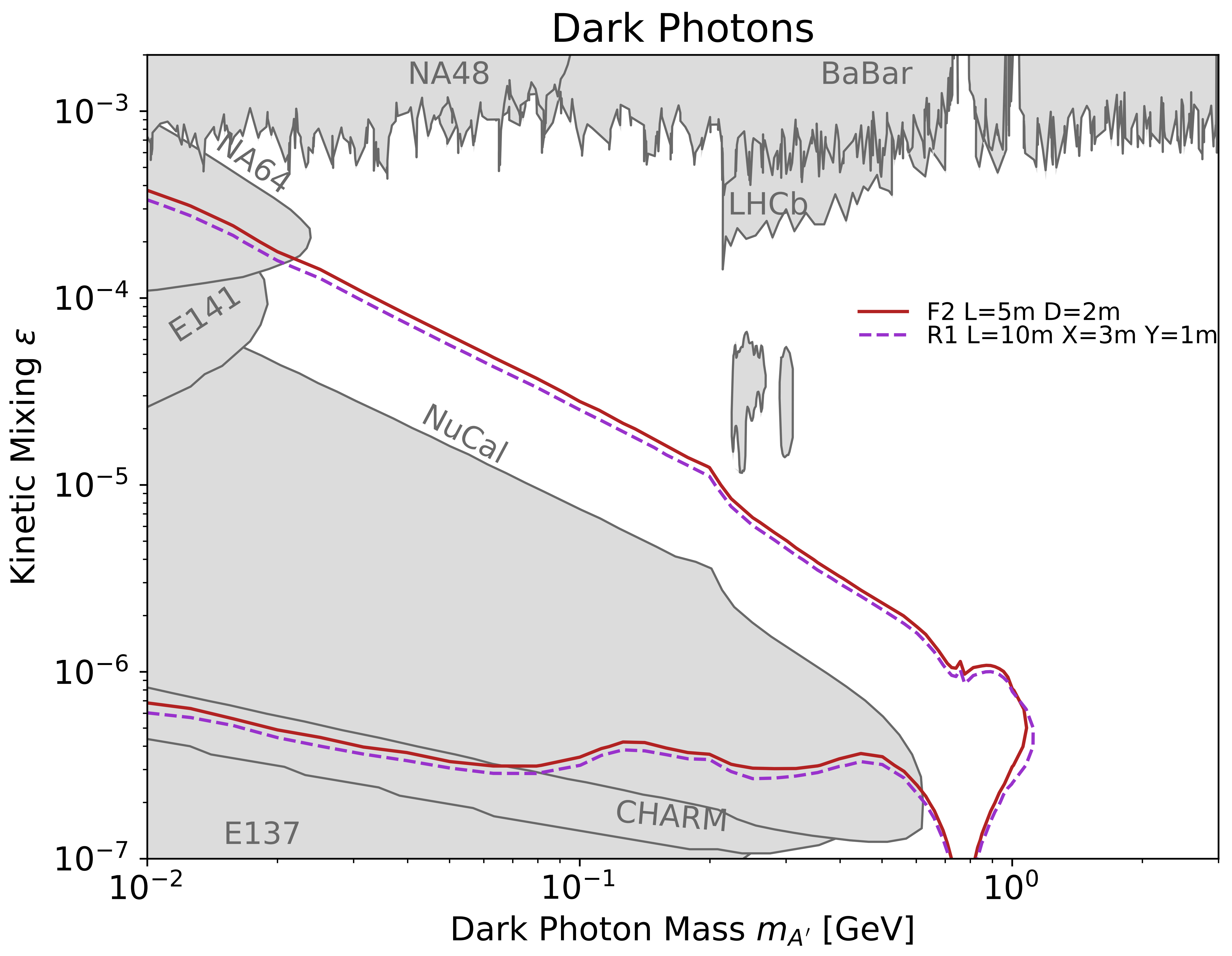
- Investigating new options compared to original and previous FASER2 designs

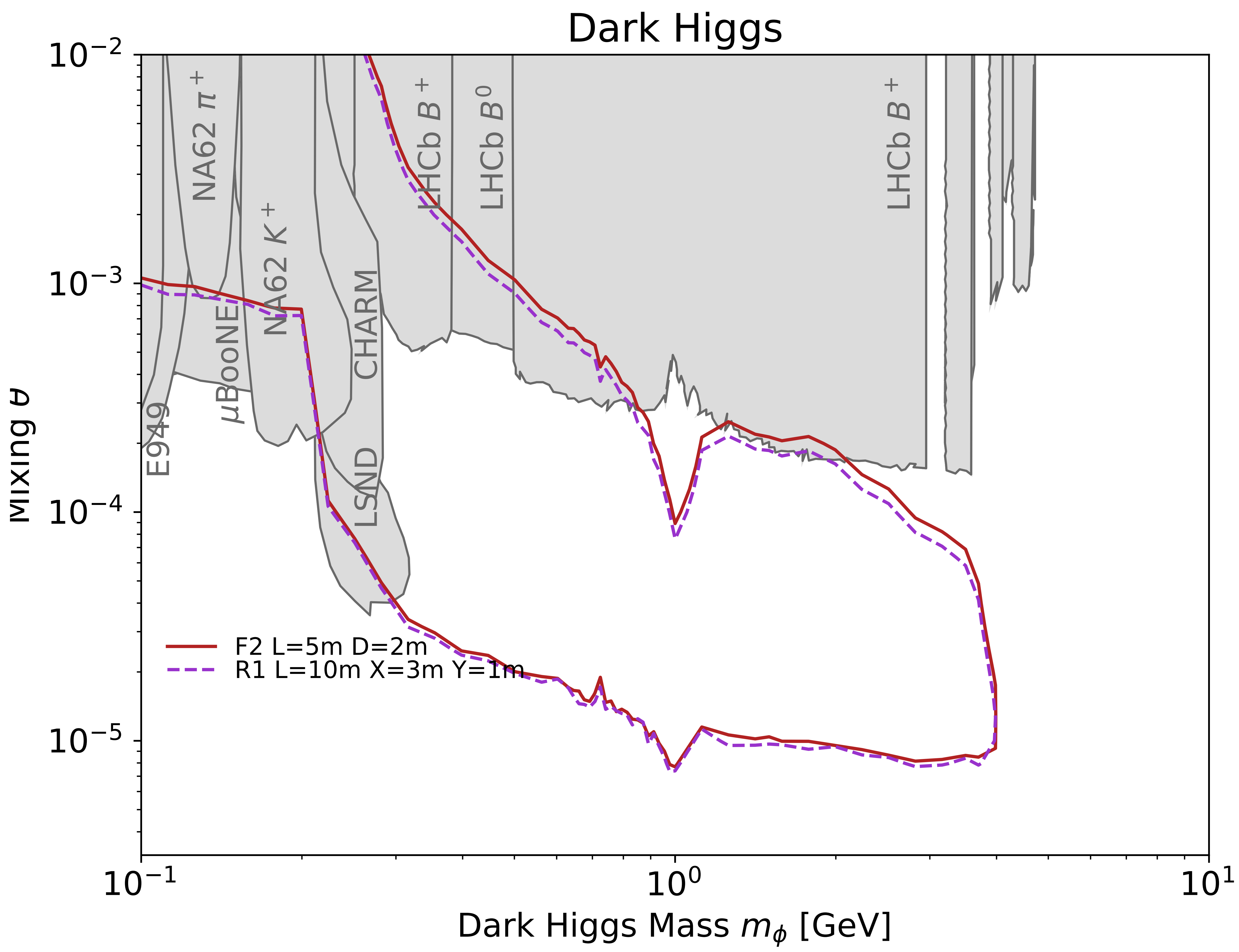




Arriving at new baseline

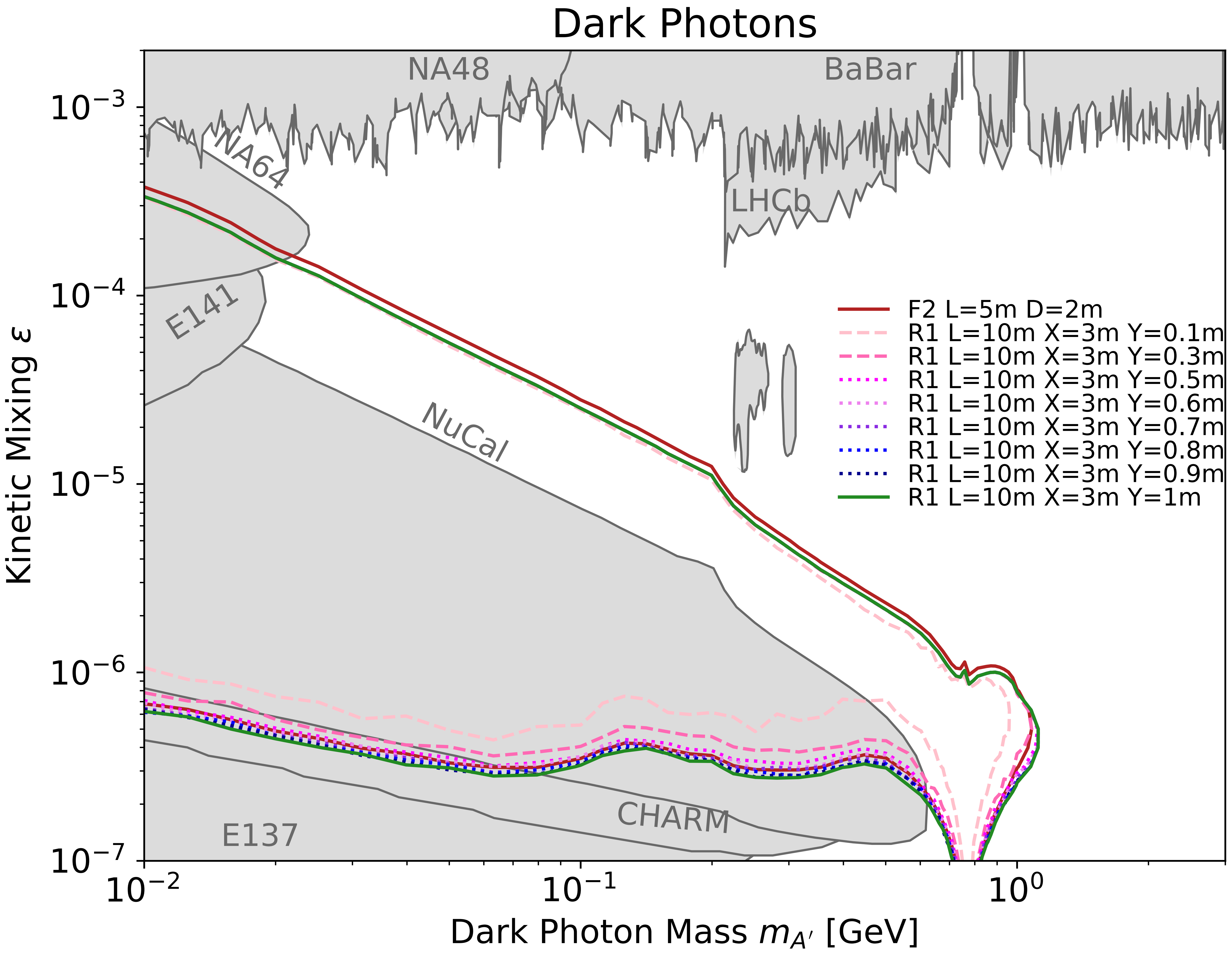
- Investigating new options compared to original and previous FASER2 designs
  - Comparable sensitivity for 3 x 1m aperture

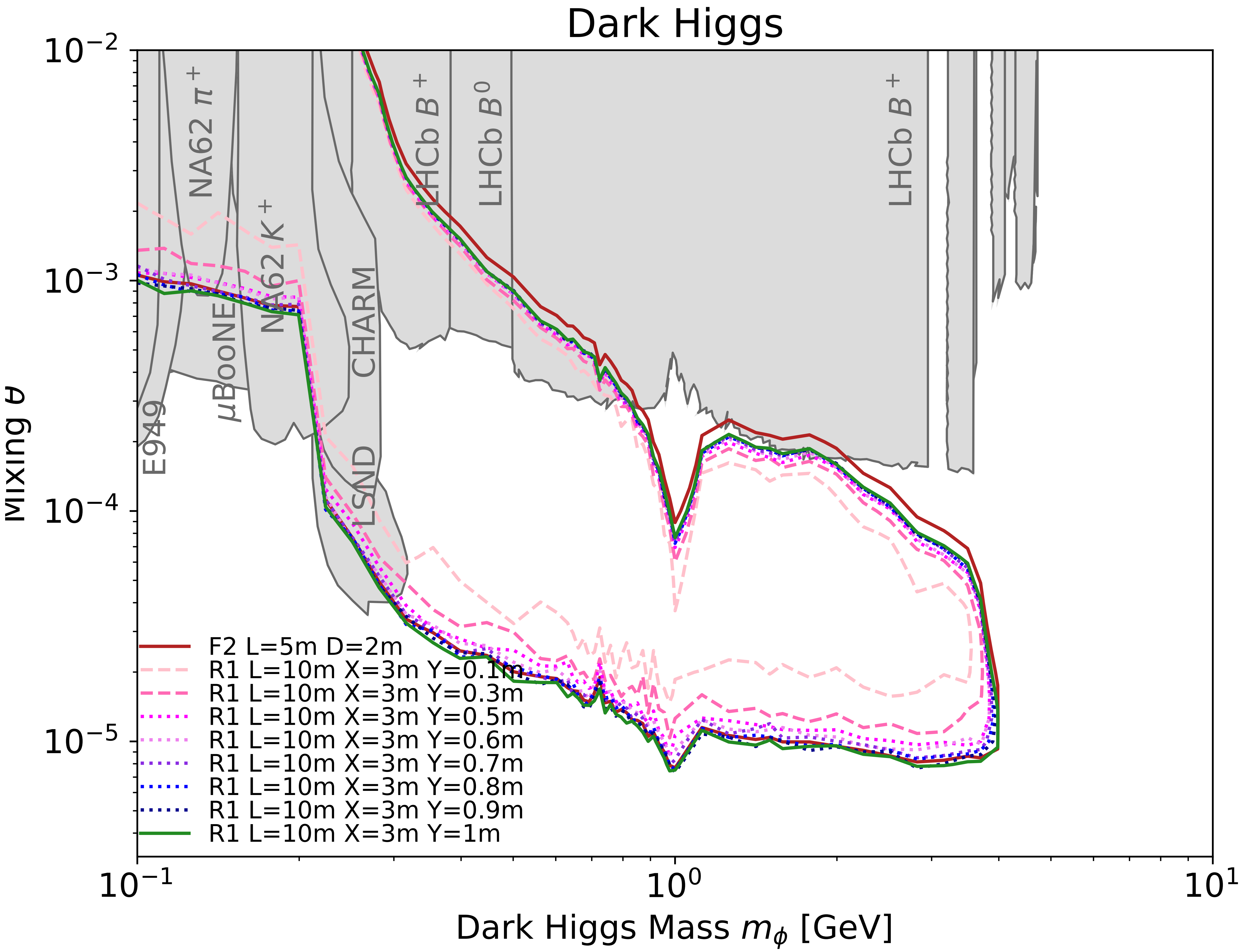




Test of aperture vertical height

- Investigating new options compared to original and previous FASER2 designs
  - Vertical height of down to ~75. cm could be acceptable



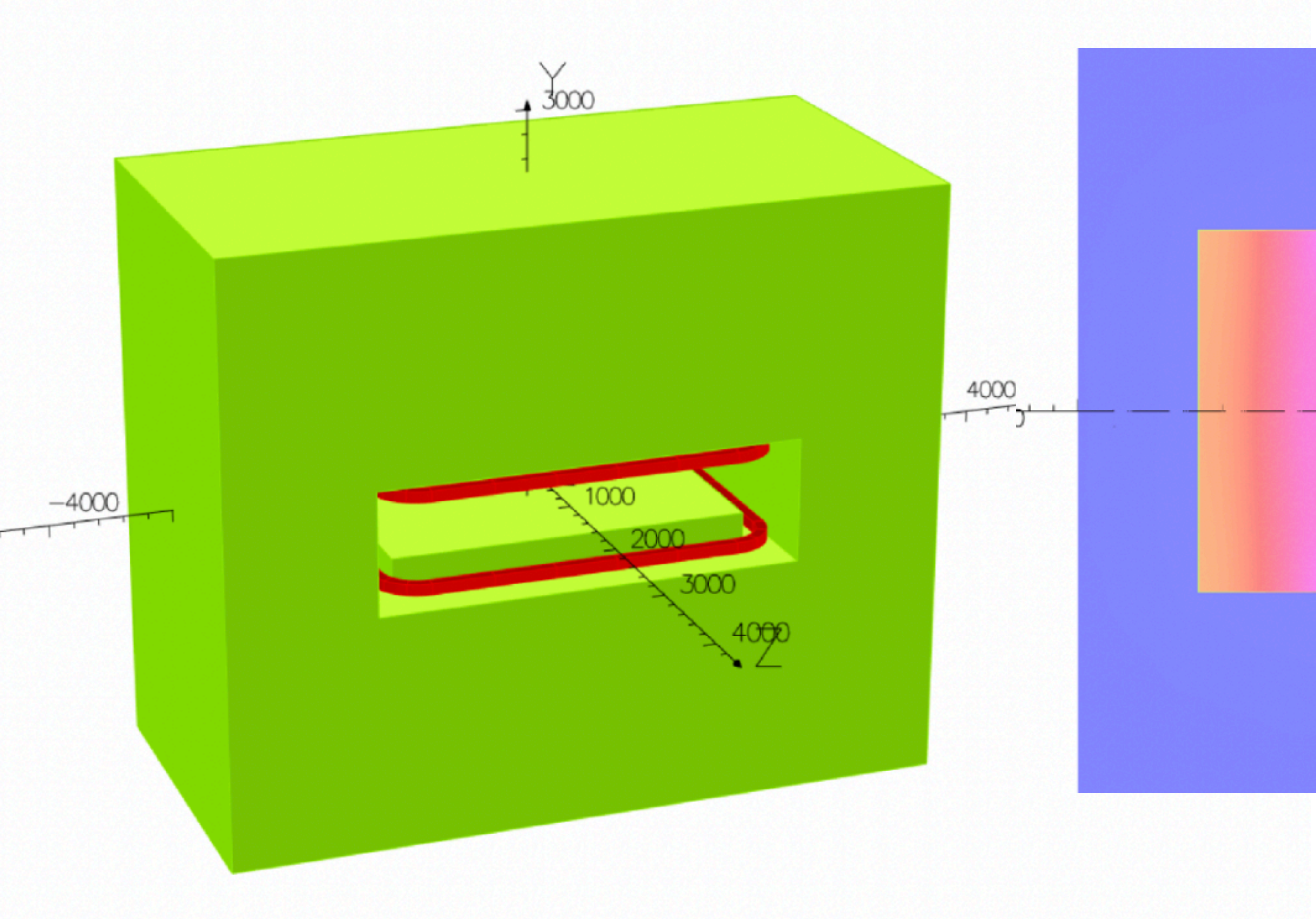


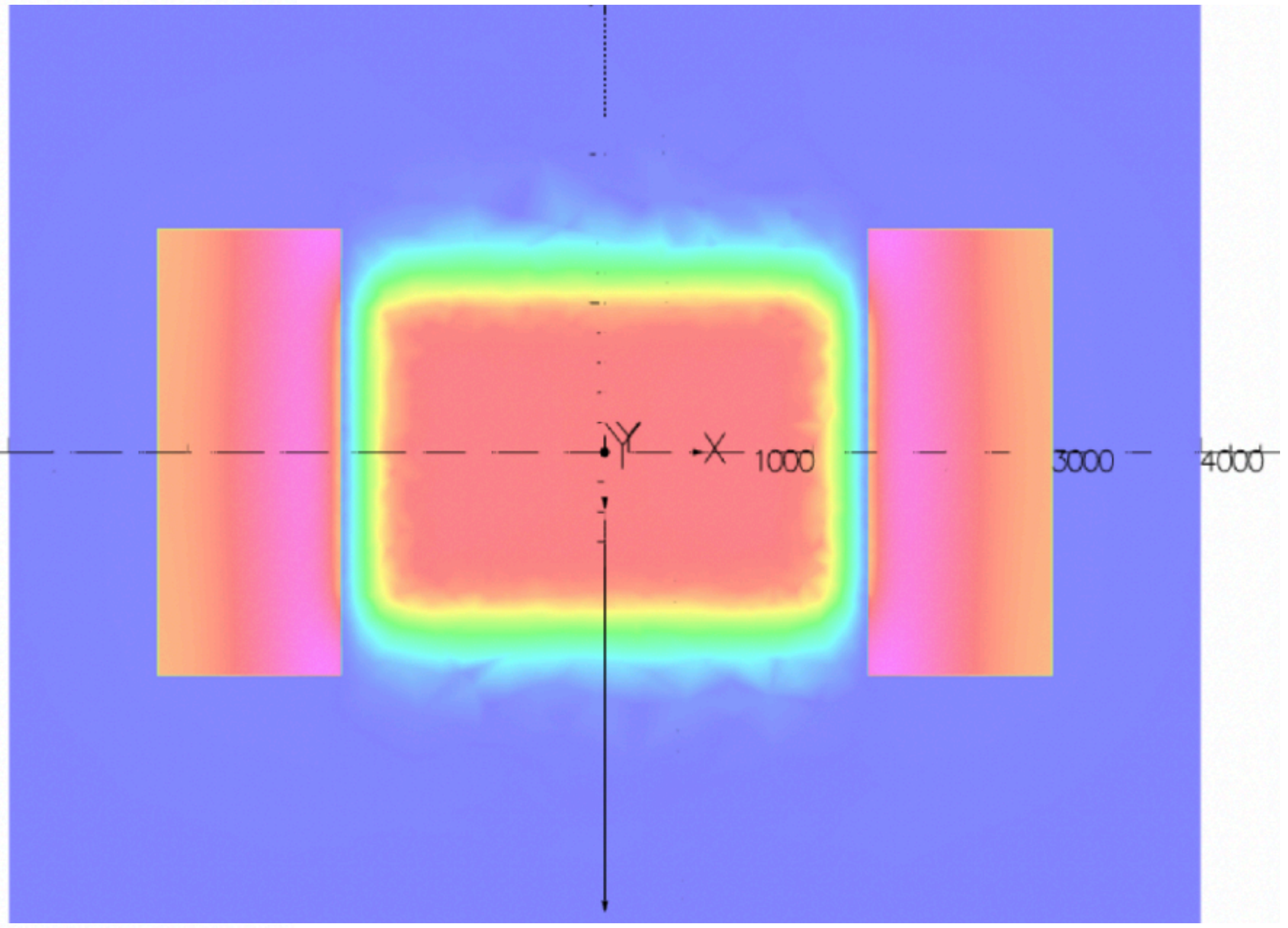
Magnet requirements

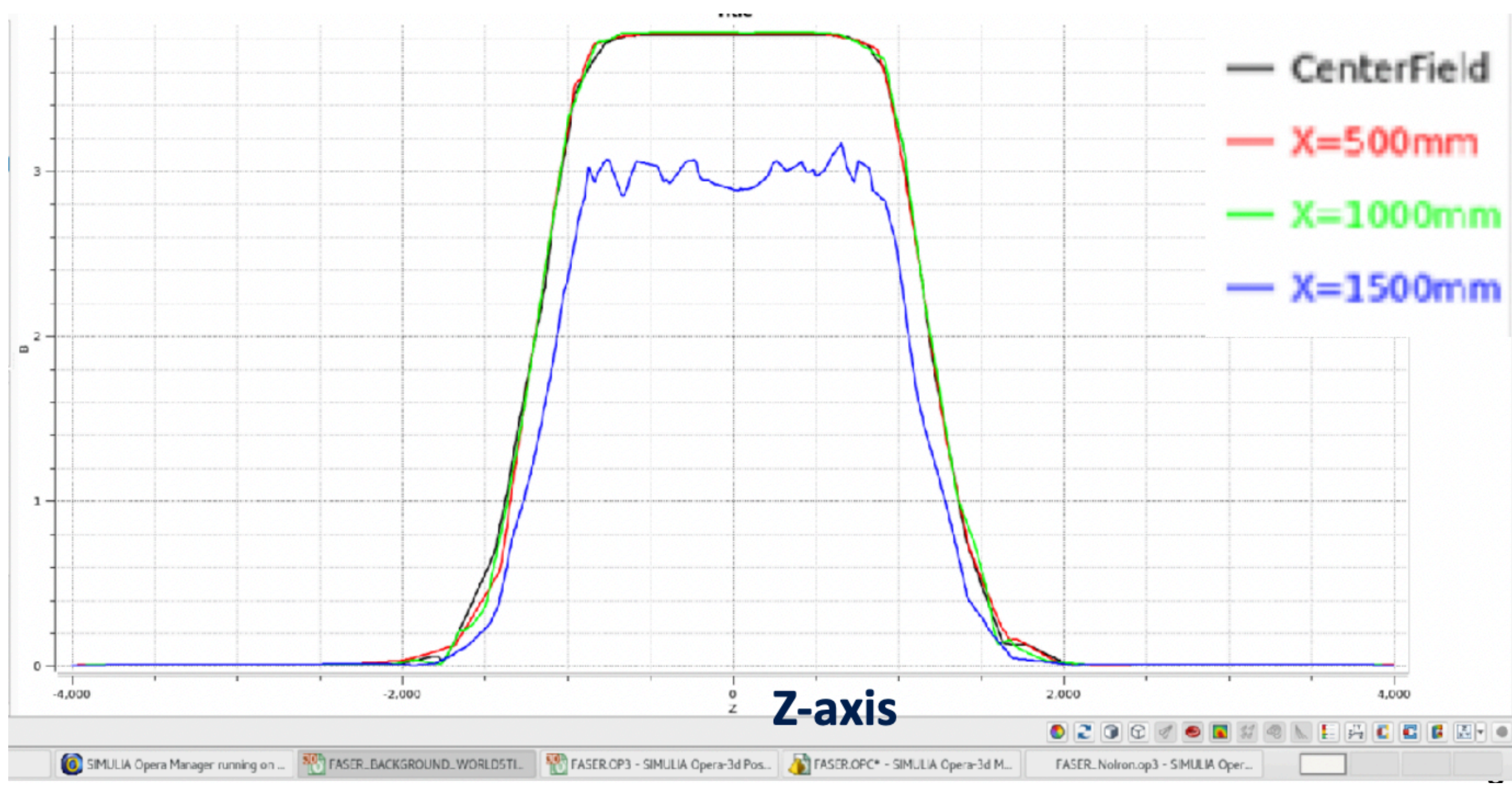
- Requirements
  - Expect to need bending power in range 2 - 4 Tm. Bending power may be driven by need to measure charge of high energy muons for FASERv2.
  - Largest aperture possible
    - Cost and construction difficulty increases with stored energy
- New Baseline: 3 x 1 x 4m with 1T field
- Have been in contact with a number of institutes and companies about possible magnets.
  - Currently most promising option through contact with KEK
    - Design and costings today from KEK magnet expert and Toshiba
- Possible back-up Morpurgo magnet
  - Currently being used by the MadMax experiment at CERN

Magnet

- Rectangular magnet 3 x 0.5 x 2m
- 2 T bending in horizontal direction



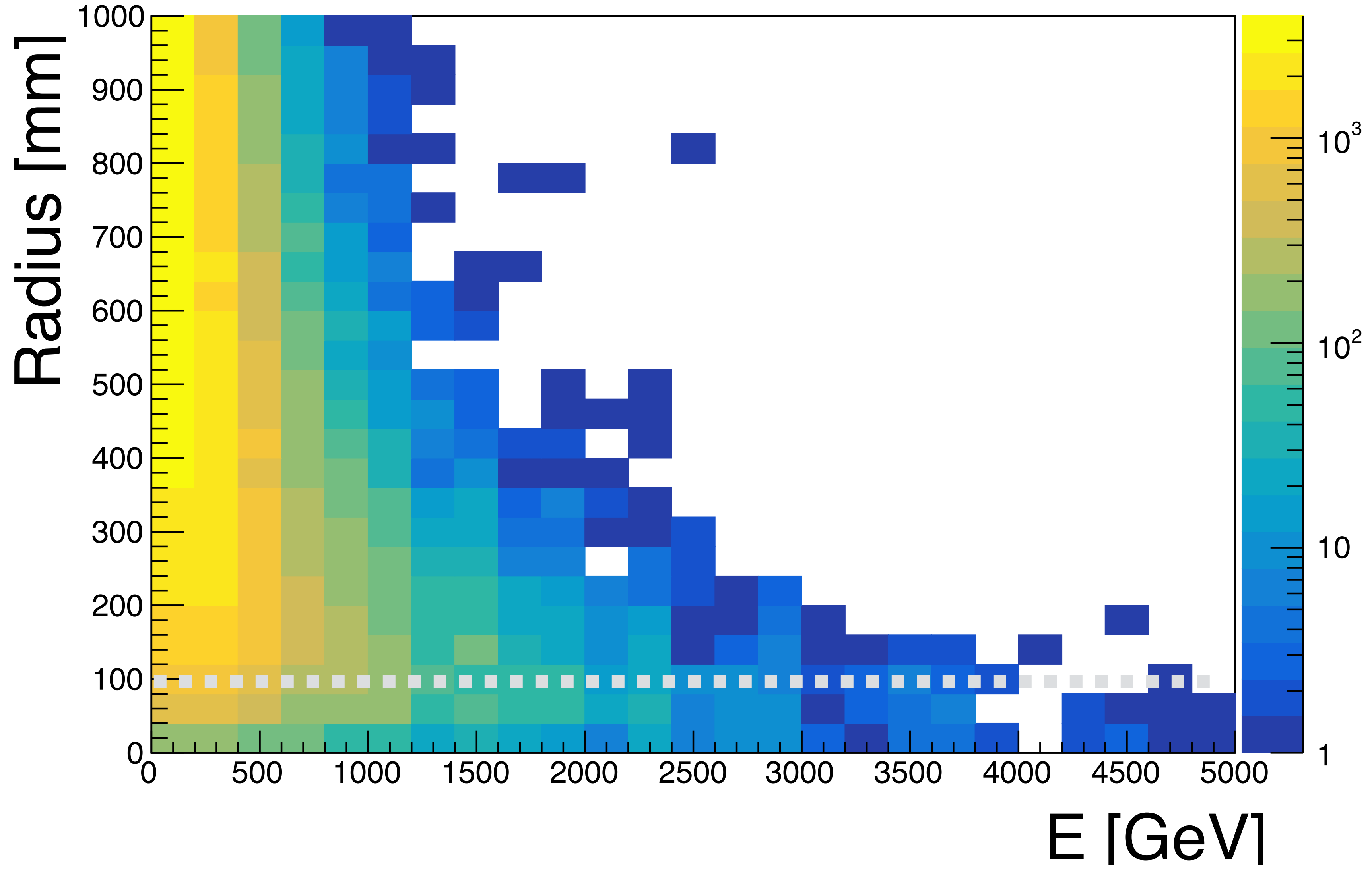


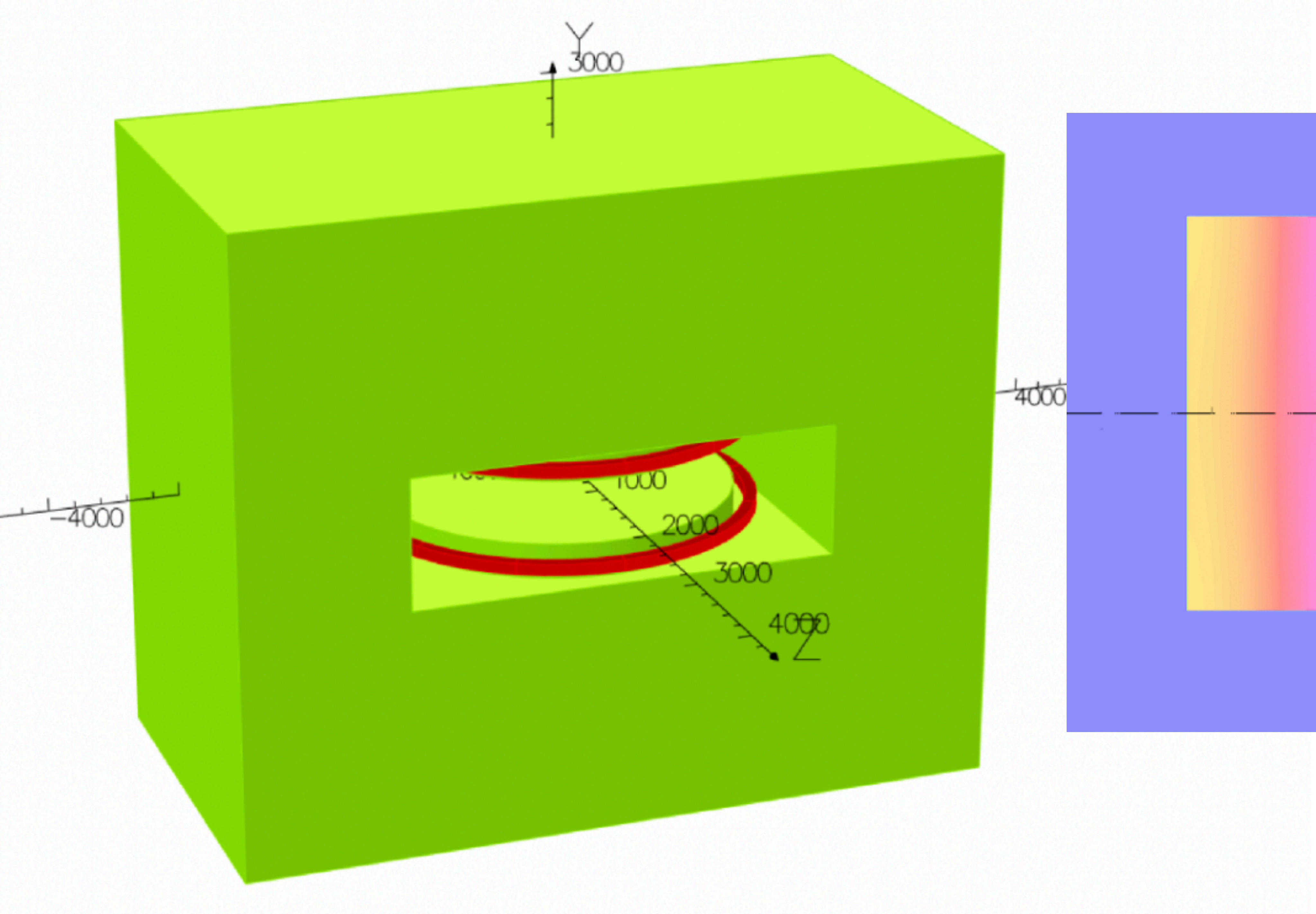


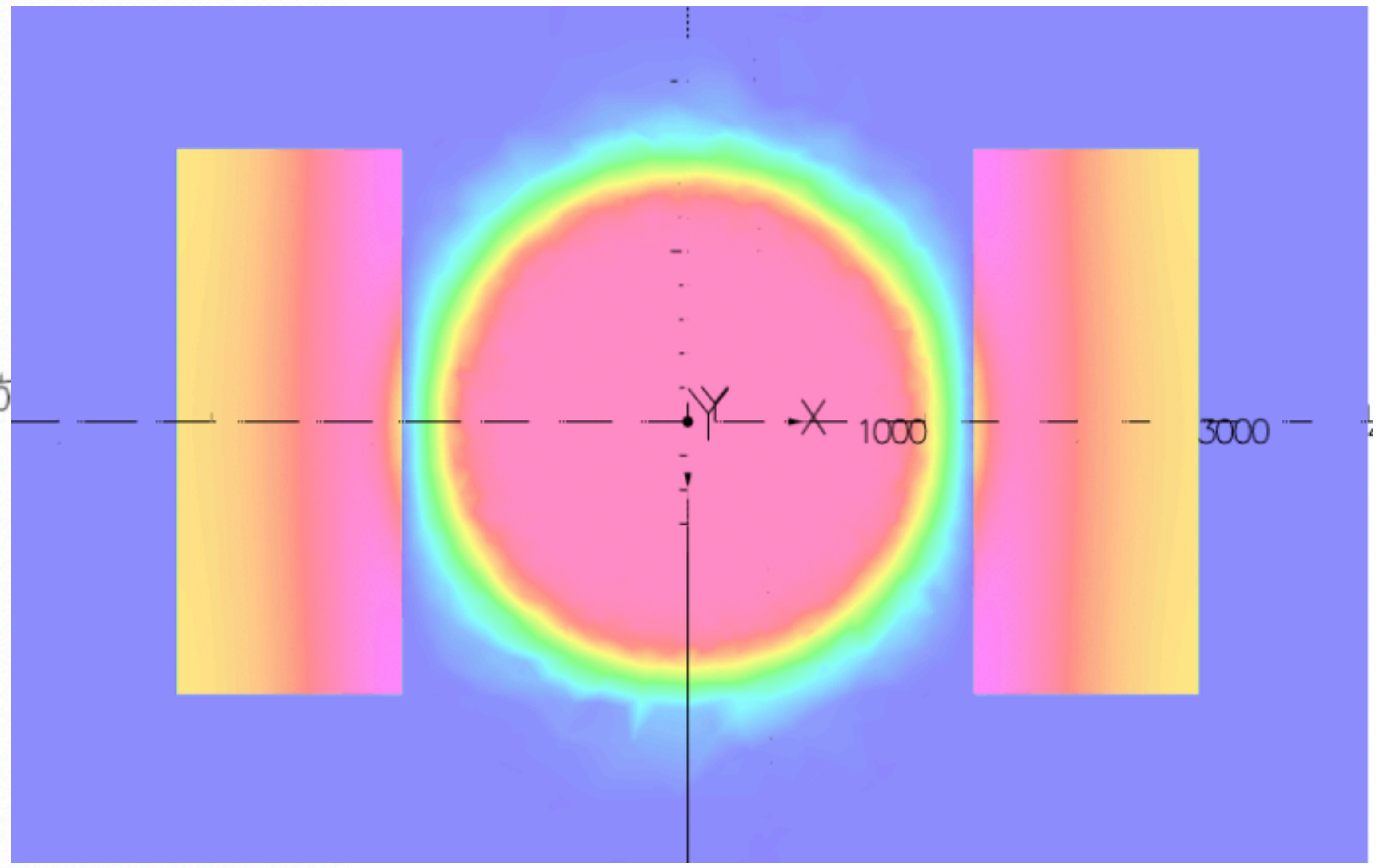
Hide Otono

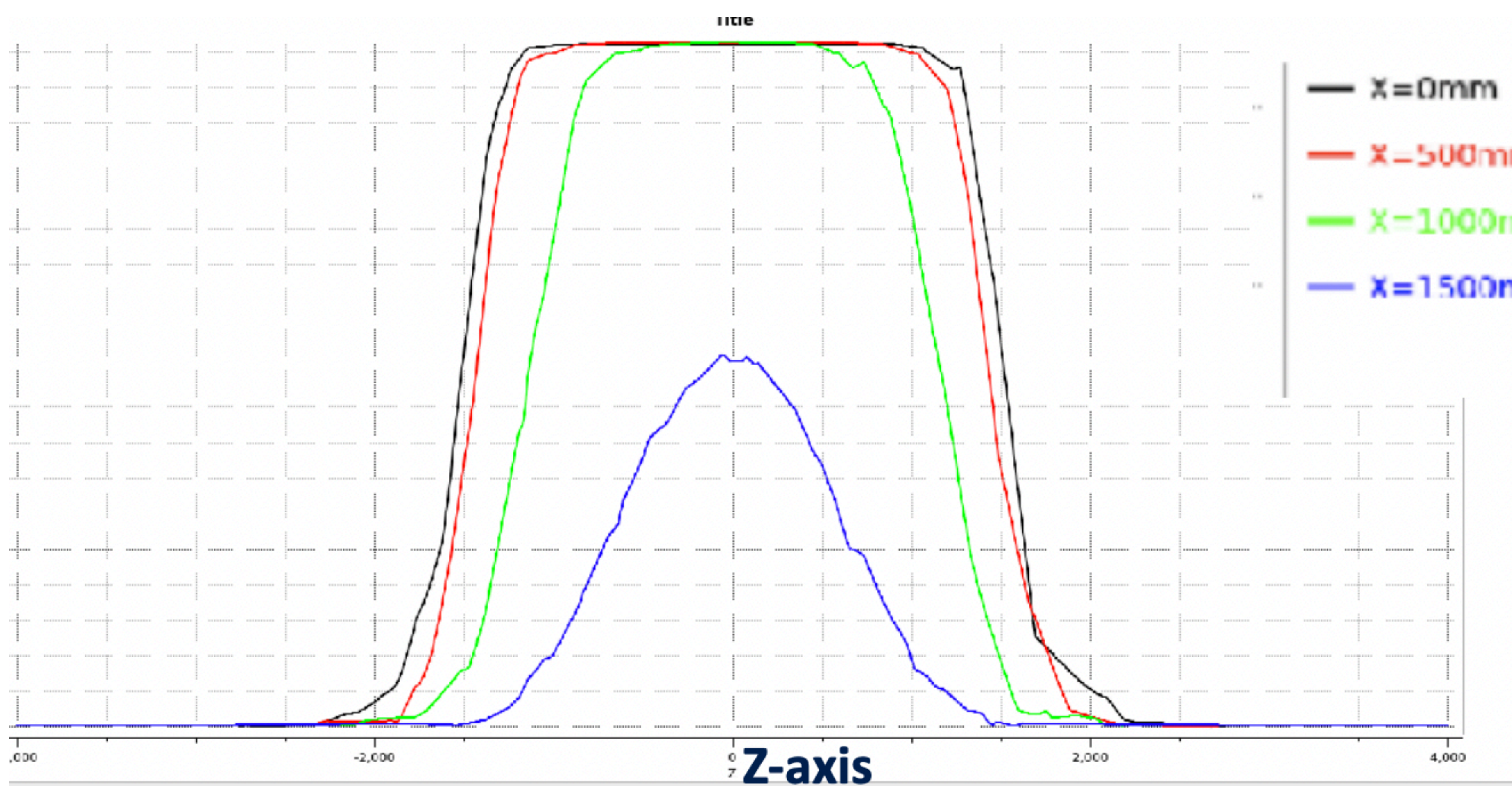
Magnet

- Circular magnet 1m radius, 0.5m high
  - More bending power in centre - highest energy
  - Less stored energy
- 2 T bending in horizontal direction









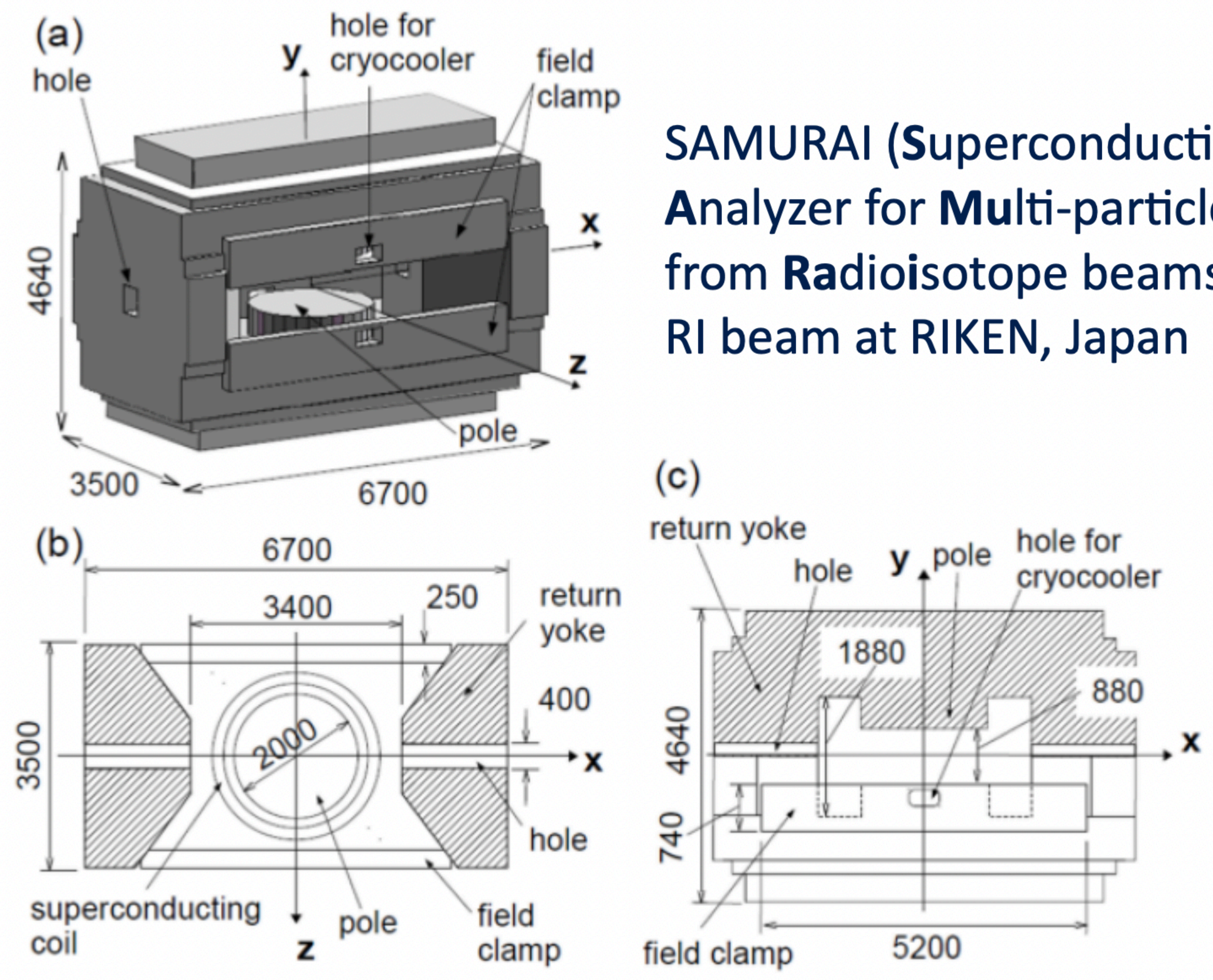
Hide Otono

Magnet

Cost estimation from TOSHIBA

Roughly 10 MCHF
based on their experience on SAMURAI

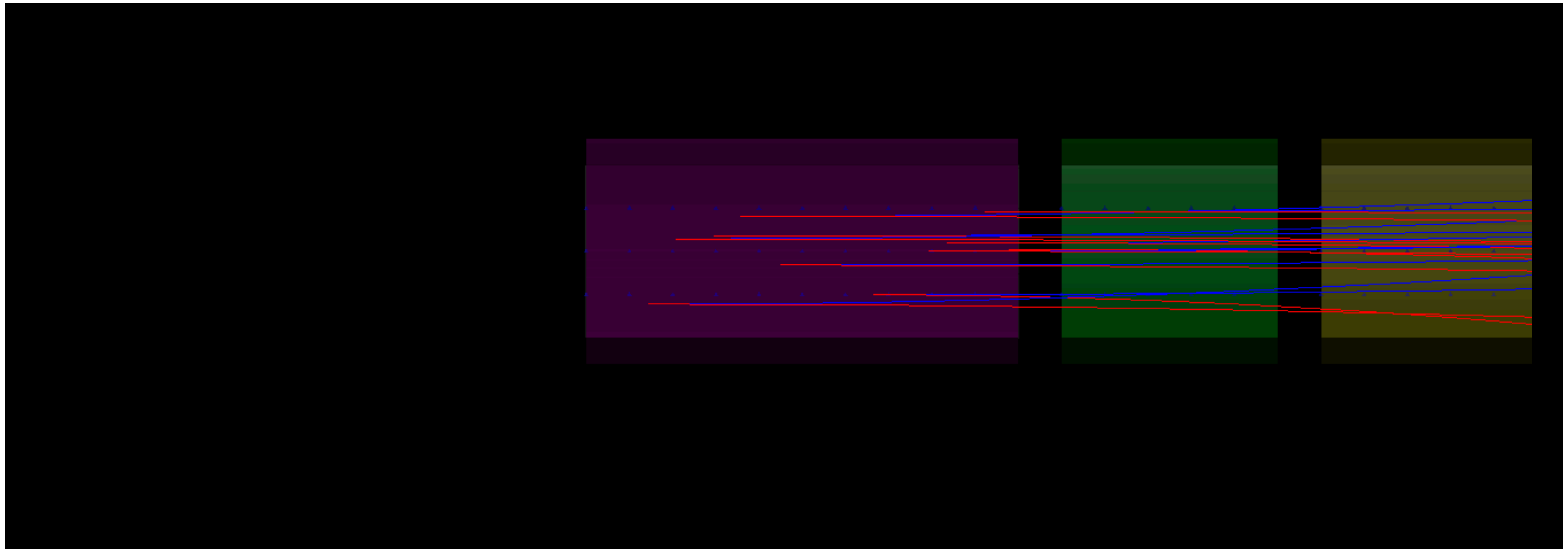
Item	Unit	Value	Remarks
Magnet		Dipole magnet	
Magnetic field	T	2	
Magnetic path length	T・m	4.7	Rough estimation from SAMURAI
Stored energy	MJ	15	
Magnetic pole gap distance	mm	880	same as SAMURAI
Magnetic pole radius	mm	2000	circular poles
Coil		Solenoid	
Total weight	ton	400	



SAMURAI (**S**uperconducting **A**nalyzer for **Mu**lti-particles from **Ra**dio**i**sotope beams) RI beam at RIKEN, Japan

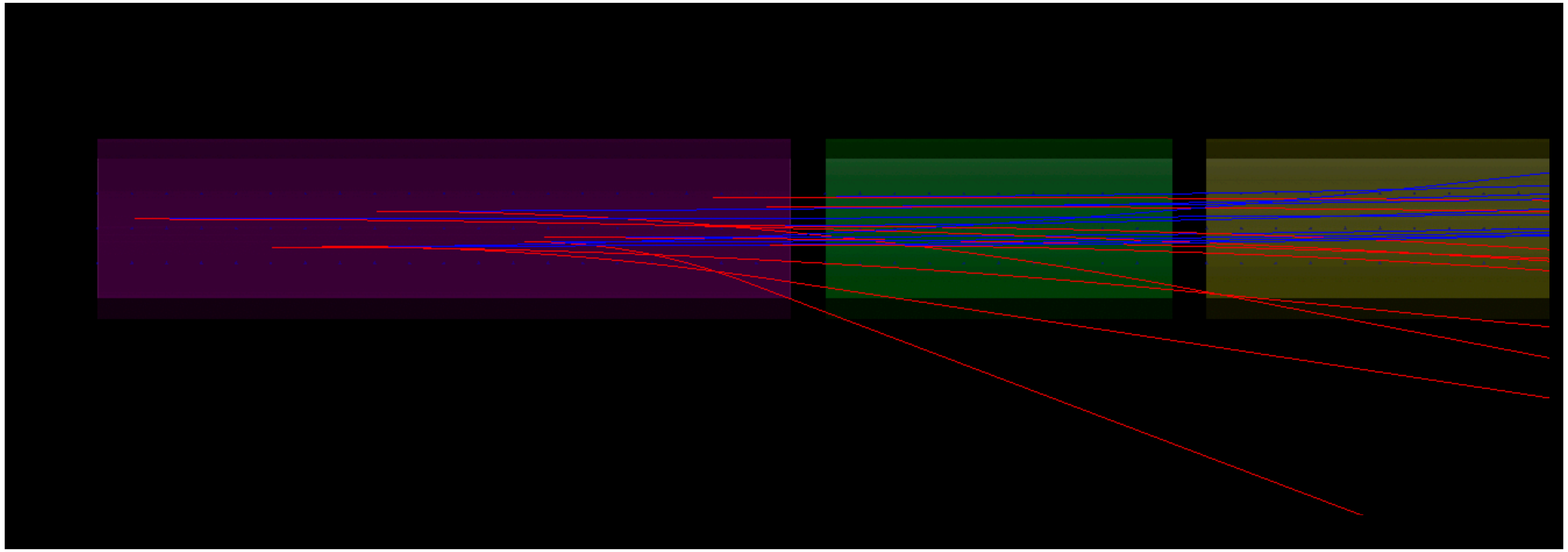
FASER2 scenarios based

- Five scenarios compared
  - **Original FASER2 layout**
    - Circular aperture, DV L=5m D=2m, 3 magnets, total 6 Tm bending vertical



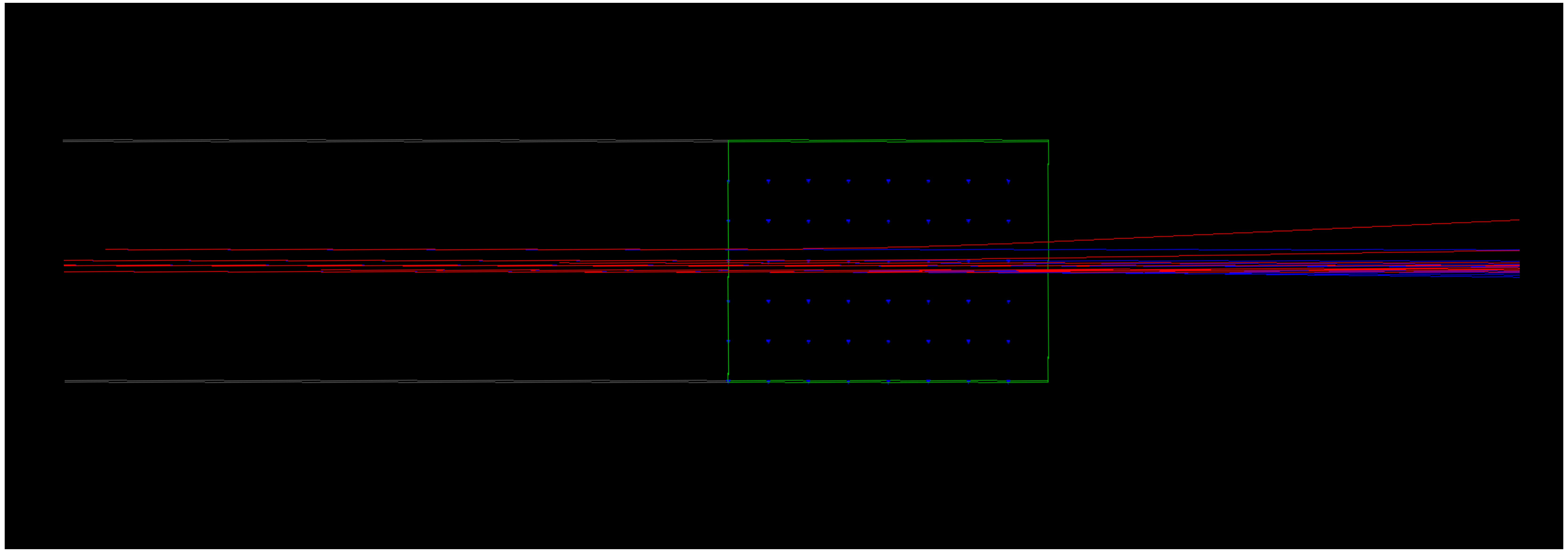
FASER2 scenarios based

- Five scenarios compared
  - **Original FASER2 layout**
  - **Old FPF Cavern Baseline**
    - Circular aperture, DV L=10m D=2m, 3 magnets, total 20 Tm bending vertical



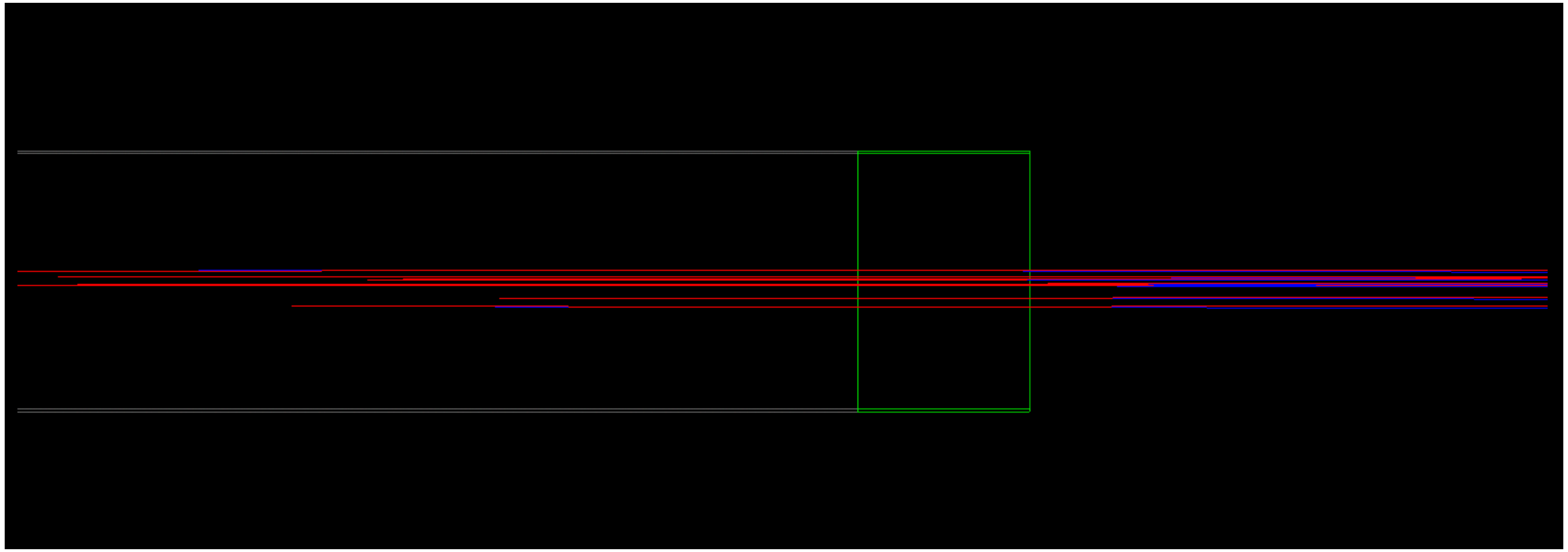
FASER2 scenarios based

- Five scenarios compared
  - **Original FASER2 layout**
  - **Old FPF Cavern Baseline**
  - **New FPF Cavern Baseline**
    - Rectangular aperture, DV L=10m X=3m Y=1m, 1 magnet, total 4 Tm bending horizontal



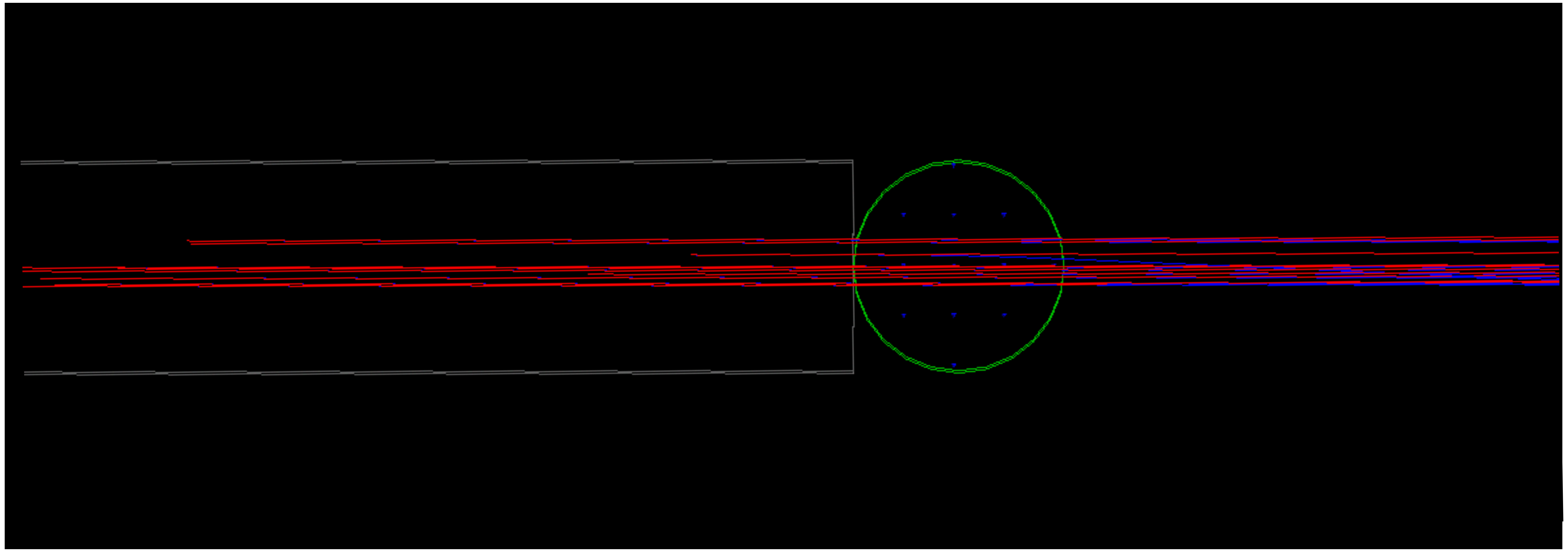
FASER2 scenarios based

- Five scenarios compared
  - **Original FASER2 layout**
  - **Old FPF Cavern Baseline**
  - **New FPF Cavern Baseline**
  - **New baseline KEK rectangular**
    - Rectangular aperture, DV L=10m X=3m Y=0.5m, 1 magnet, total 4 Tm bending horizontal



FASER2 scenarios based

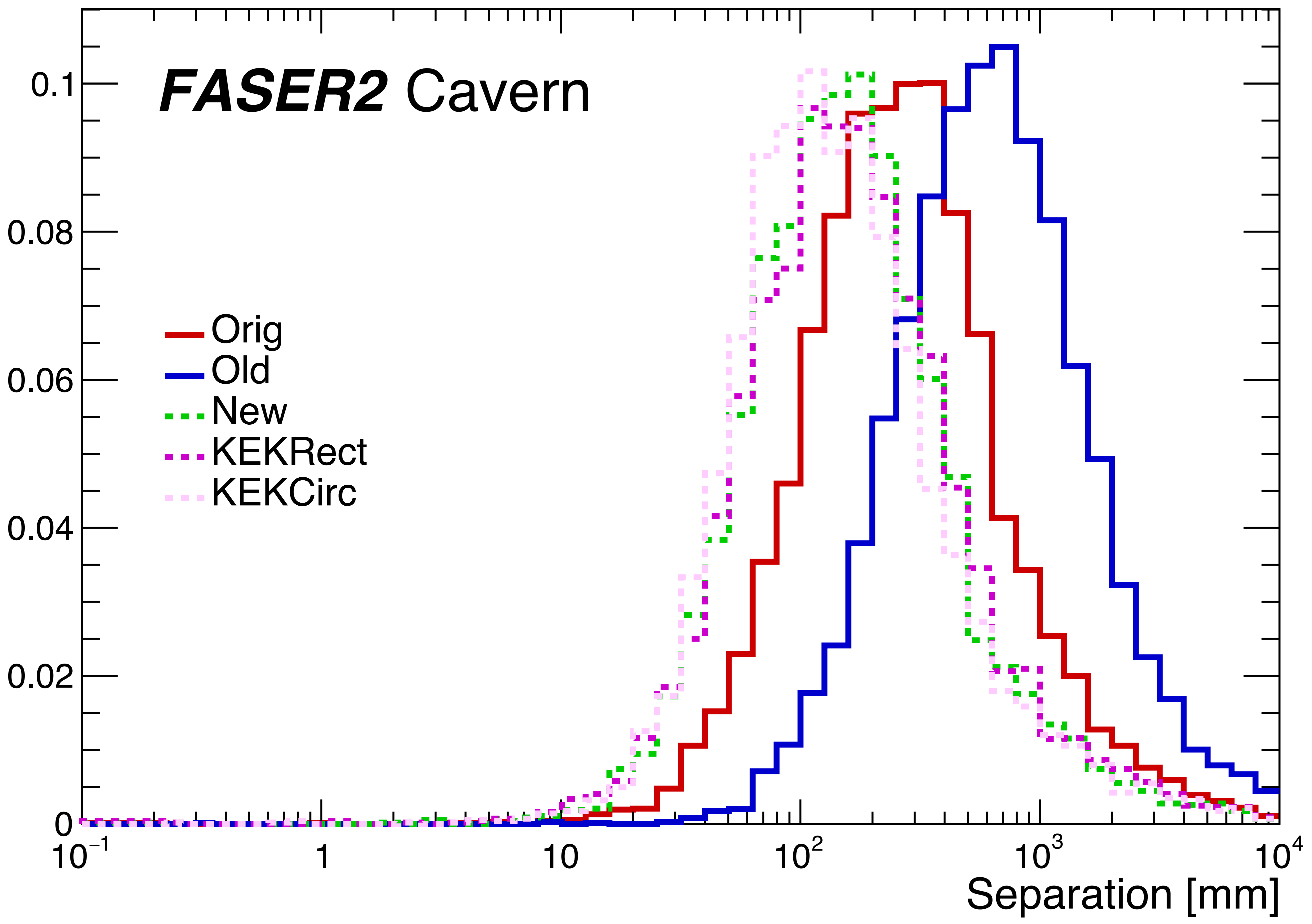
- Five scenarios compared
  - **Original FASER2 layout**
  - **Old FPF Cavern Baseline**
  - **New FPF Cavern Baseline**
  - **New baseline KEK rectangular**
  - **New baseline KEK circular**
    - Rectangular aperture, DV L=10m X=3m Y=1m, 1 circular magnet, 4 Tm bending (on LoS) horiz.



Particle separations

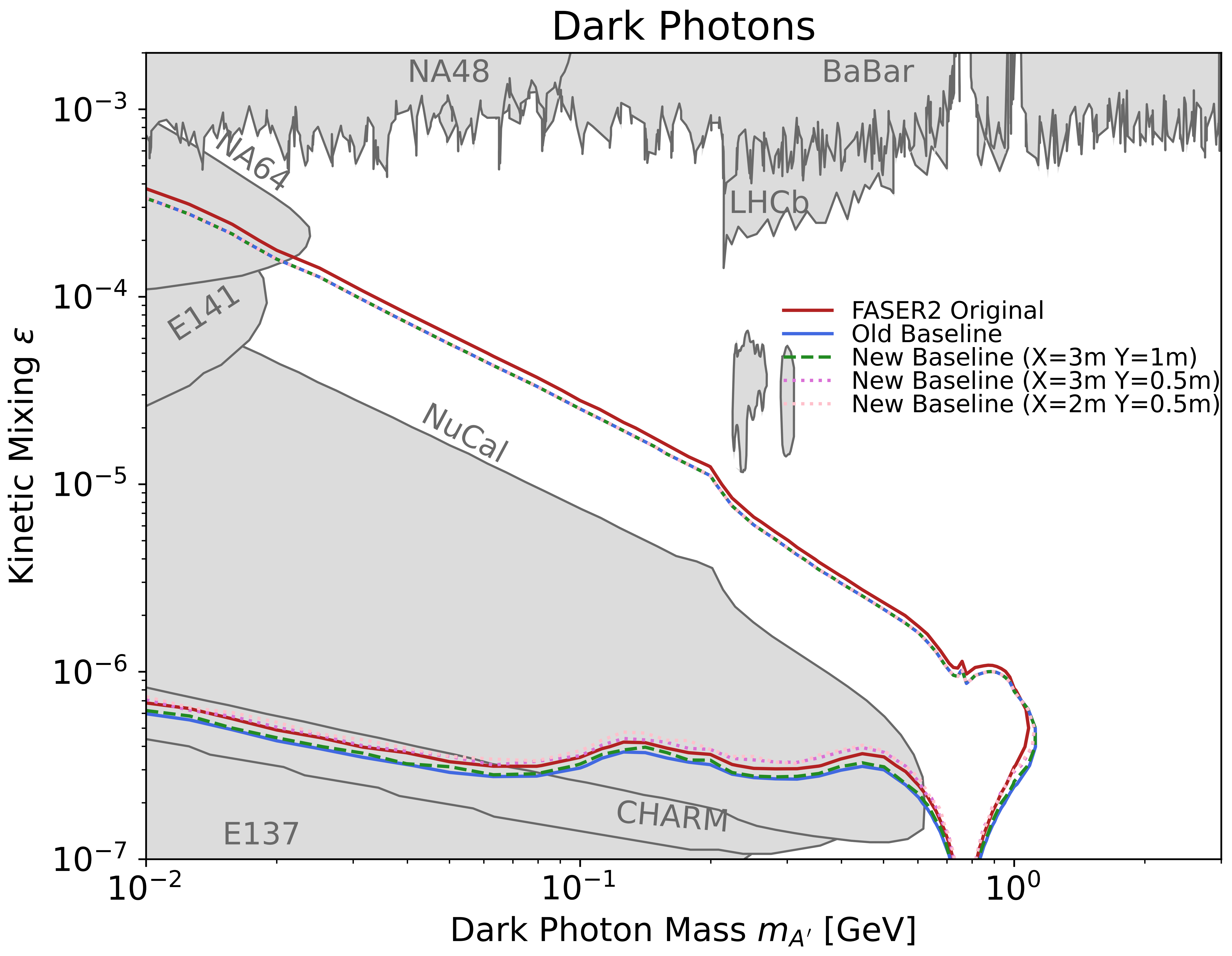
- A quick look at particle separations for a specific example
  - Dark Photon signal with m=0.1 GeV, ε=1.27e-06, A'→ee
- Particle separations a key input to detector resolution needs
  - Shown here final station separations in bending plane
- As expected, reduced fields reduce the separation
  - But still acceptable for detector technologies being investigated.

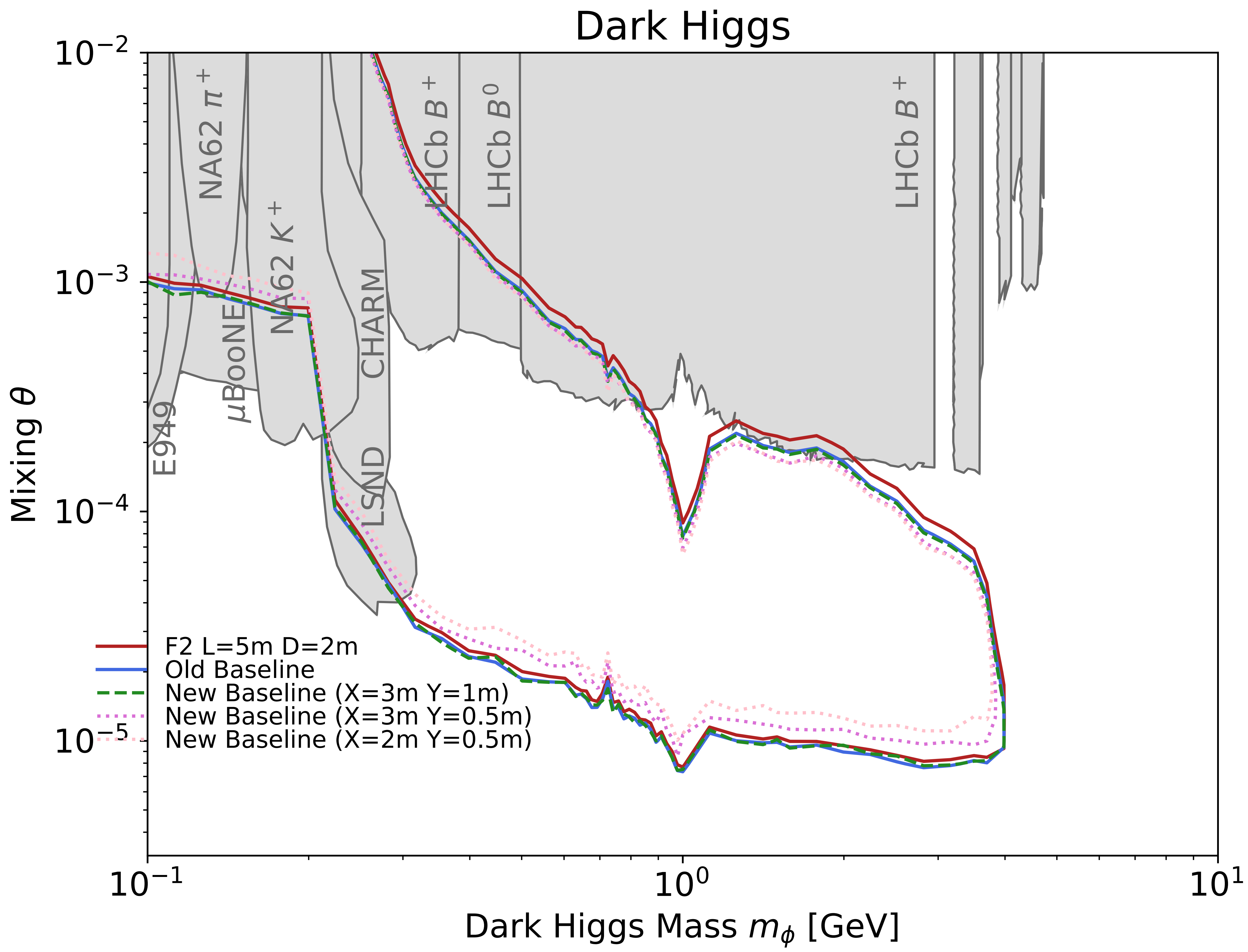
Dark Photon m=0.1 GeV, ε=1.27e-06, A'→ee



Reach

- Comparing the reach of the five scenarios
  - Some sensitivity loss for smaller apertures, mainly in Dark Higgs model

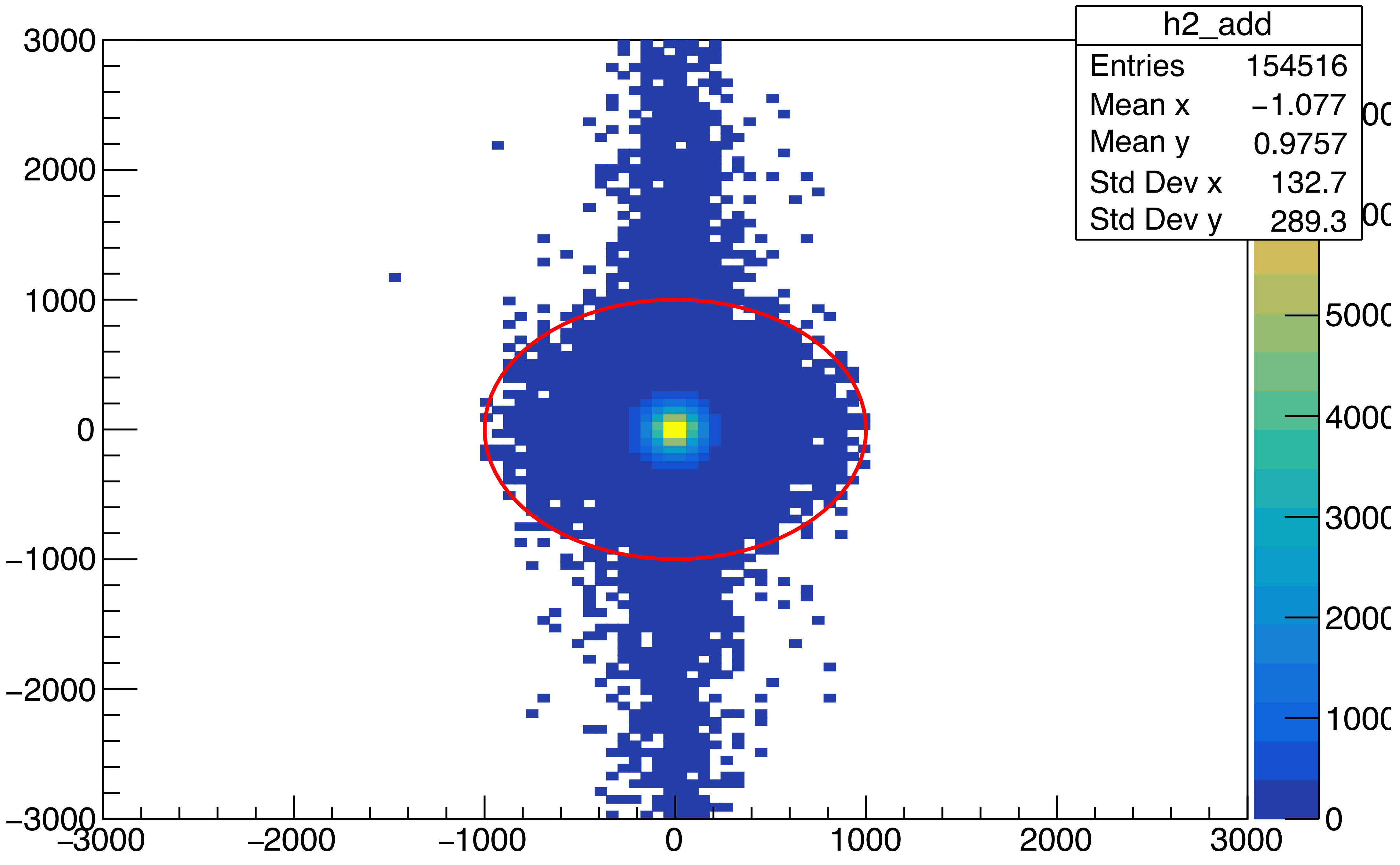




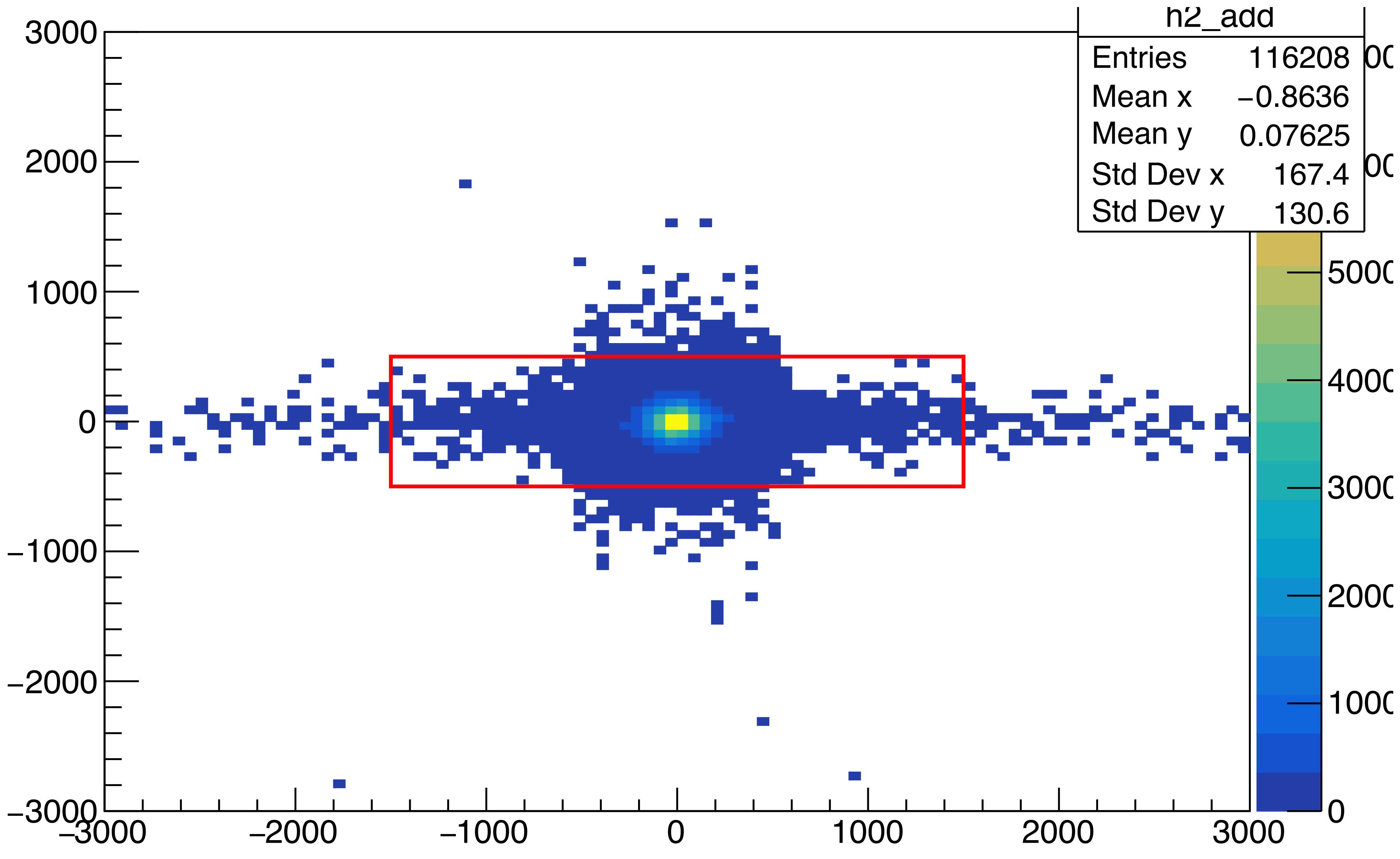
Particle envelopes

- Started to look at envelope of charged particles (position at last tracker)
- Extent of the A'→ee decay products for old a new baseline designs shown
  - Gives an idea of the needed instrumented detector cross section

Old FPF Cavern Baseline



New FPF Cavern Baseline

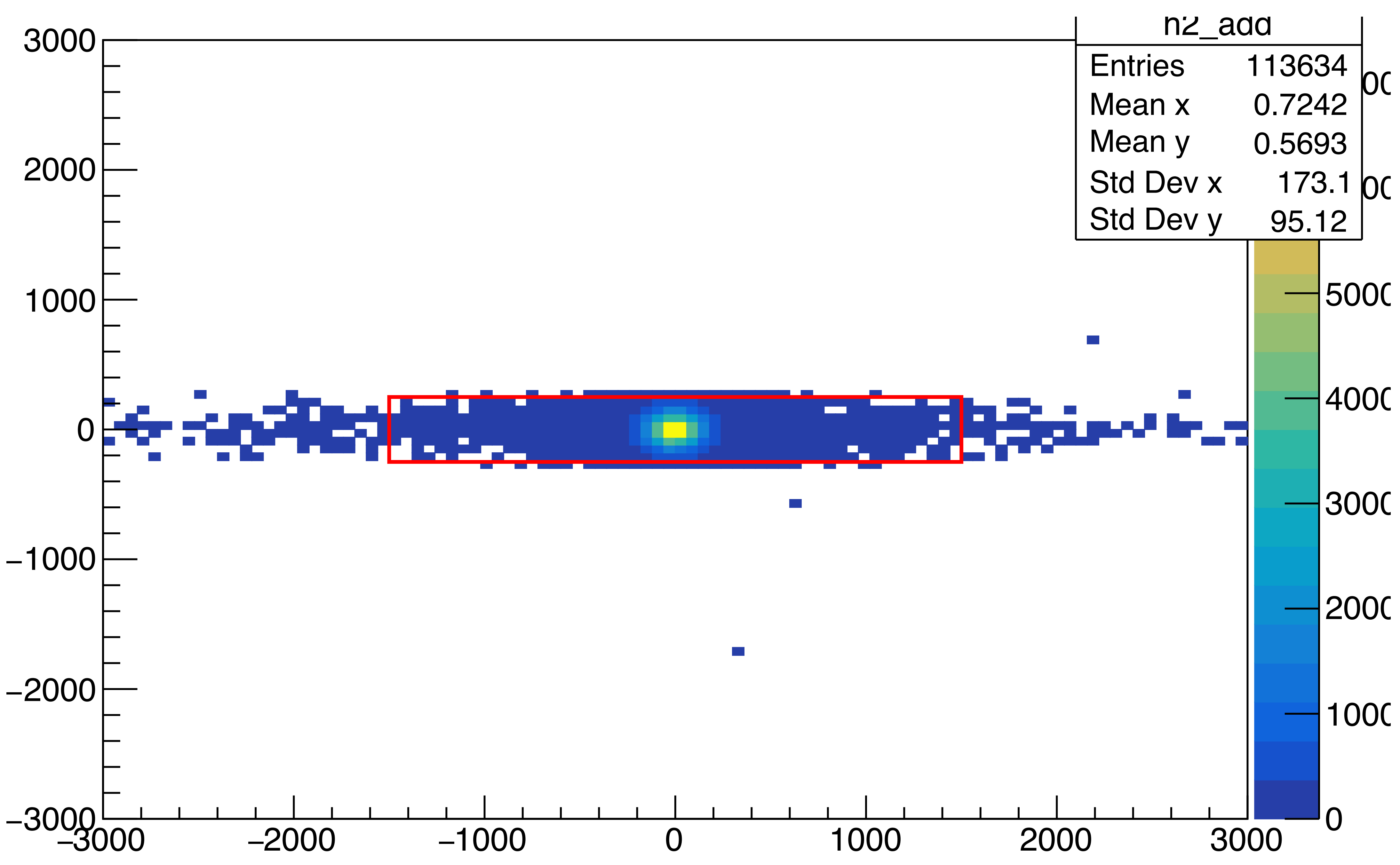


m=0.1 GeV, ε=1e-05, A'→ee

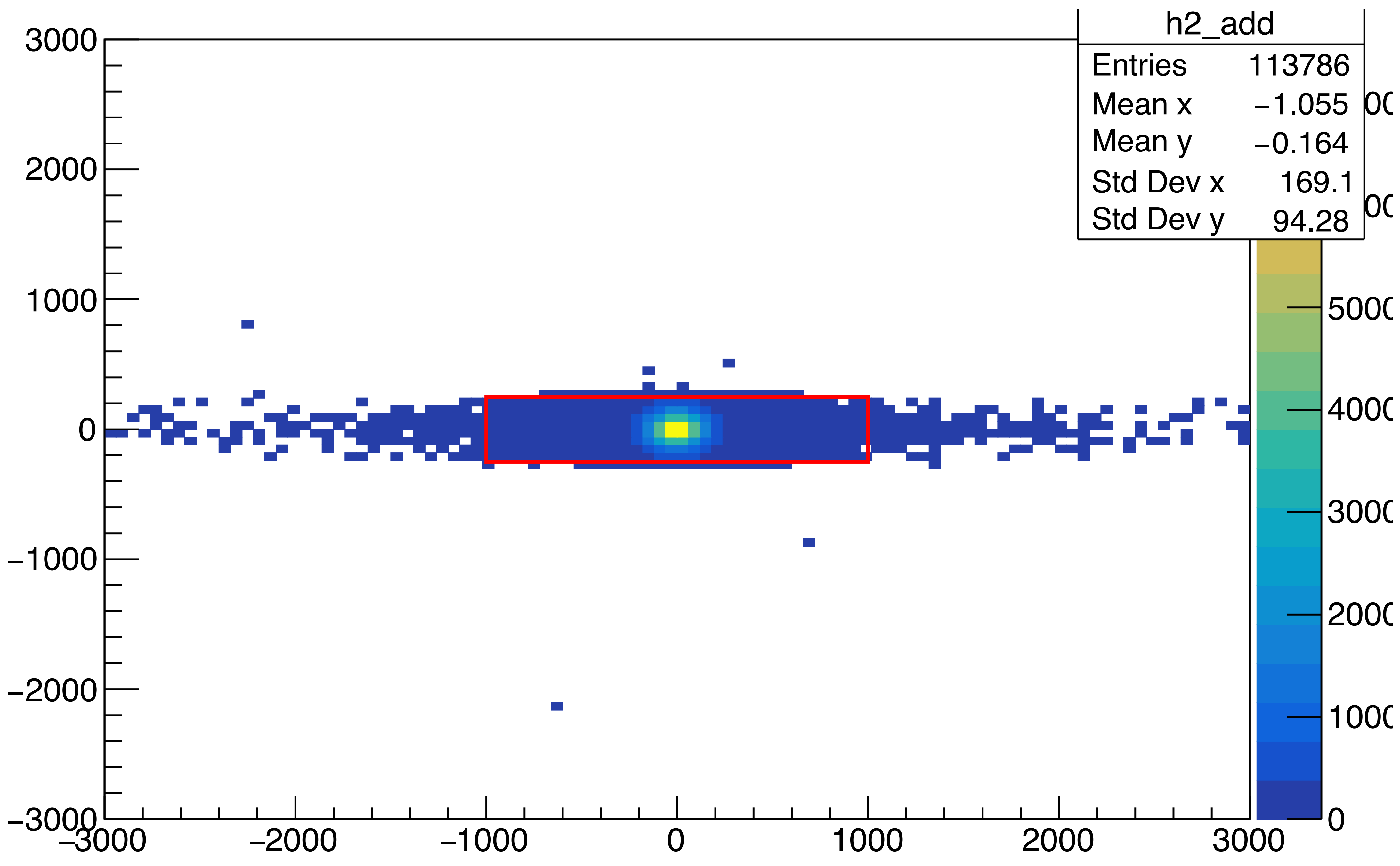
Particle envelopes

- Started to look at envelope of charged particles (position at last tracker)
- Extent of the A'→ee decay products for old a new baseline designs shown
  - Gives an idea of the needed instrumented detector cross section

- **New baseline KEK rectangular**



- **New baseline KEK circular**

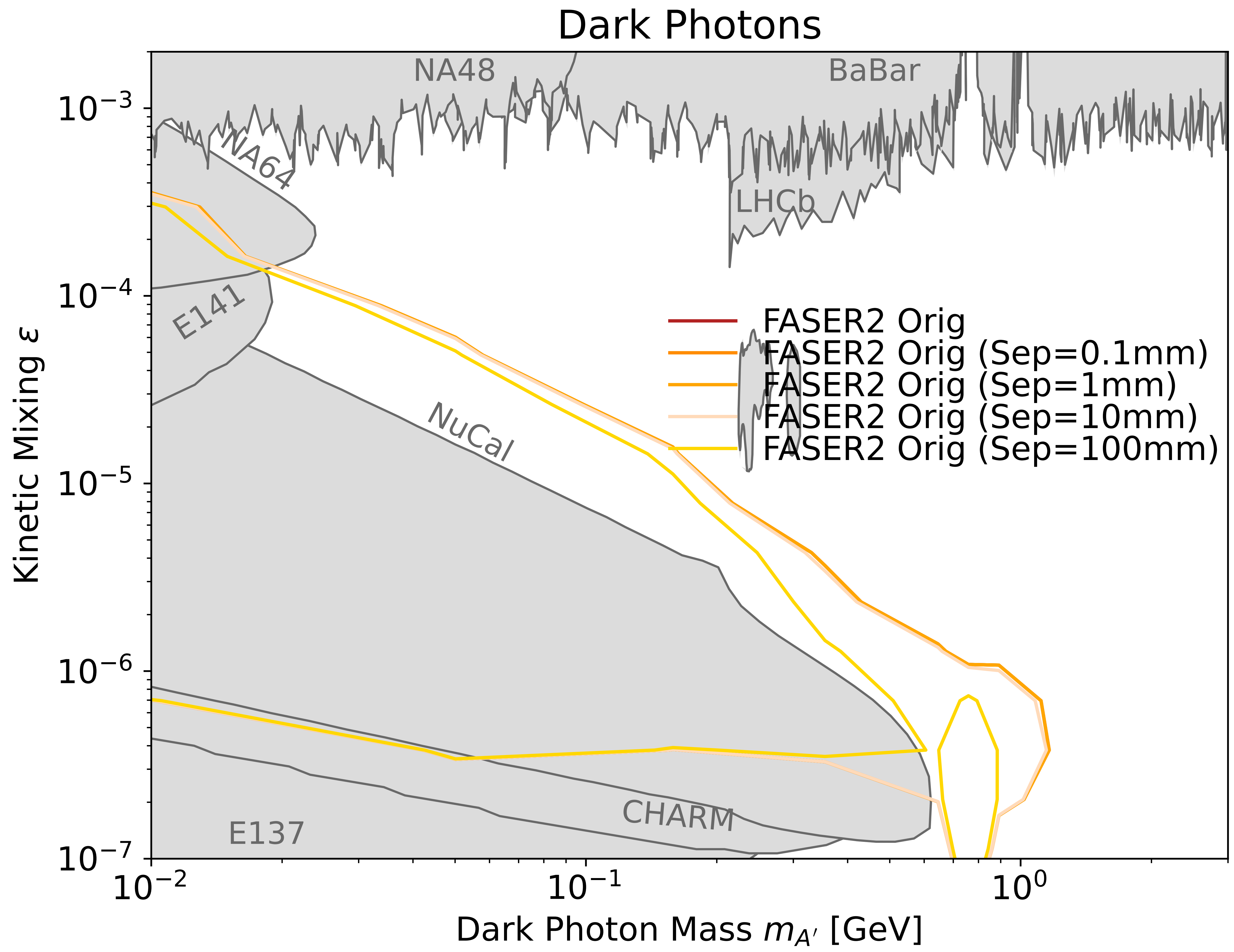


m=0.1 GeV, ε=1e-05, A'→ee

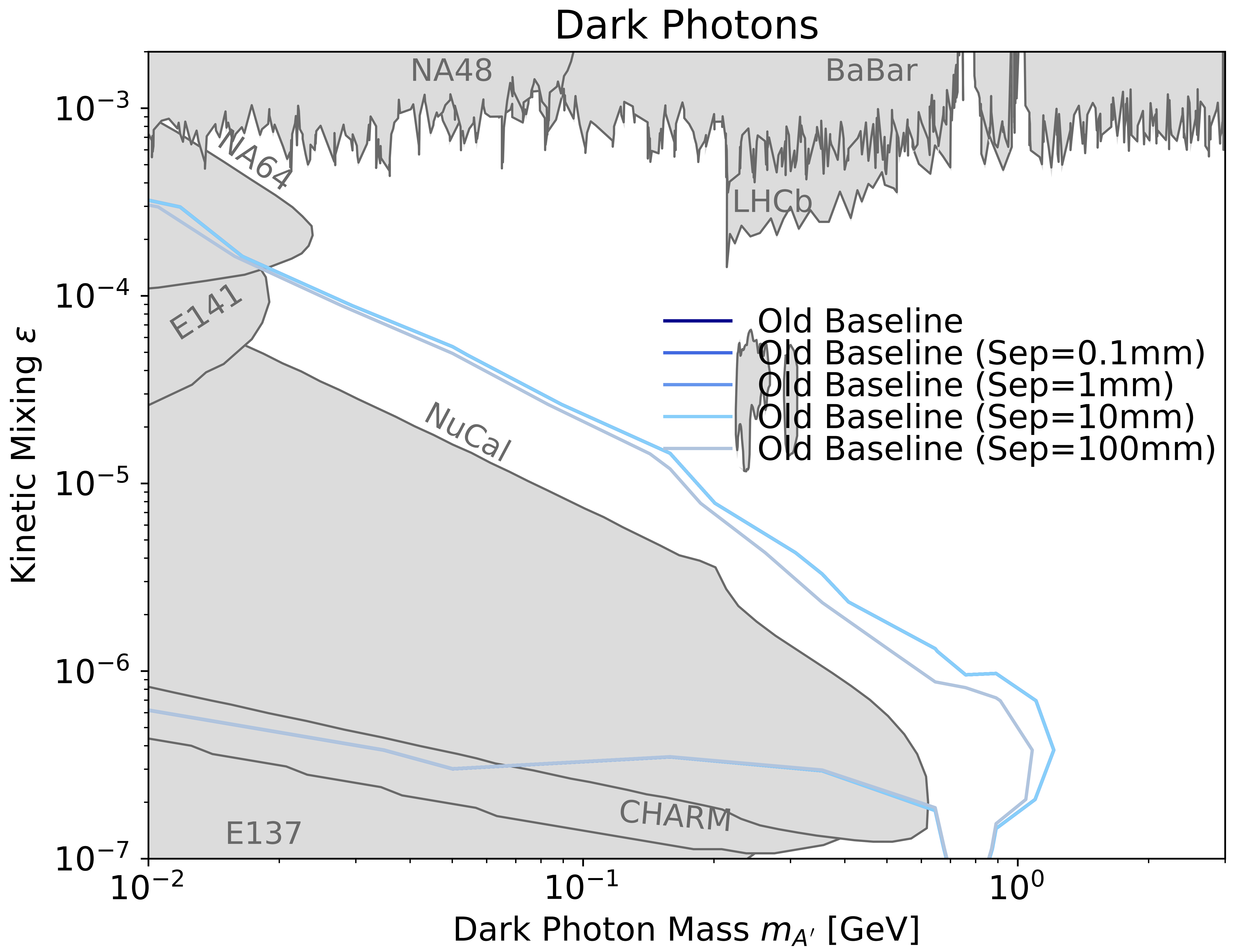
Effect on reach of separation cuts

- Separation at final tracking station/calorimeter

Original FASER2 layout



Old FPF Cavern Baseline



Effect on reach of separation cuts

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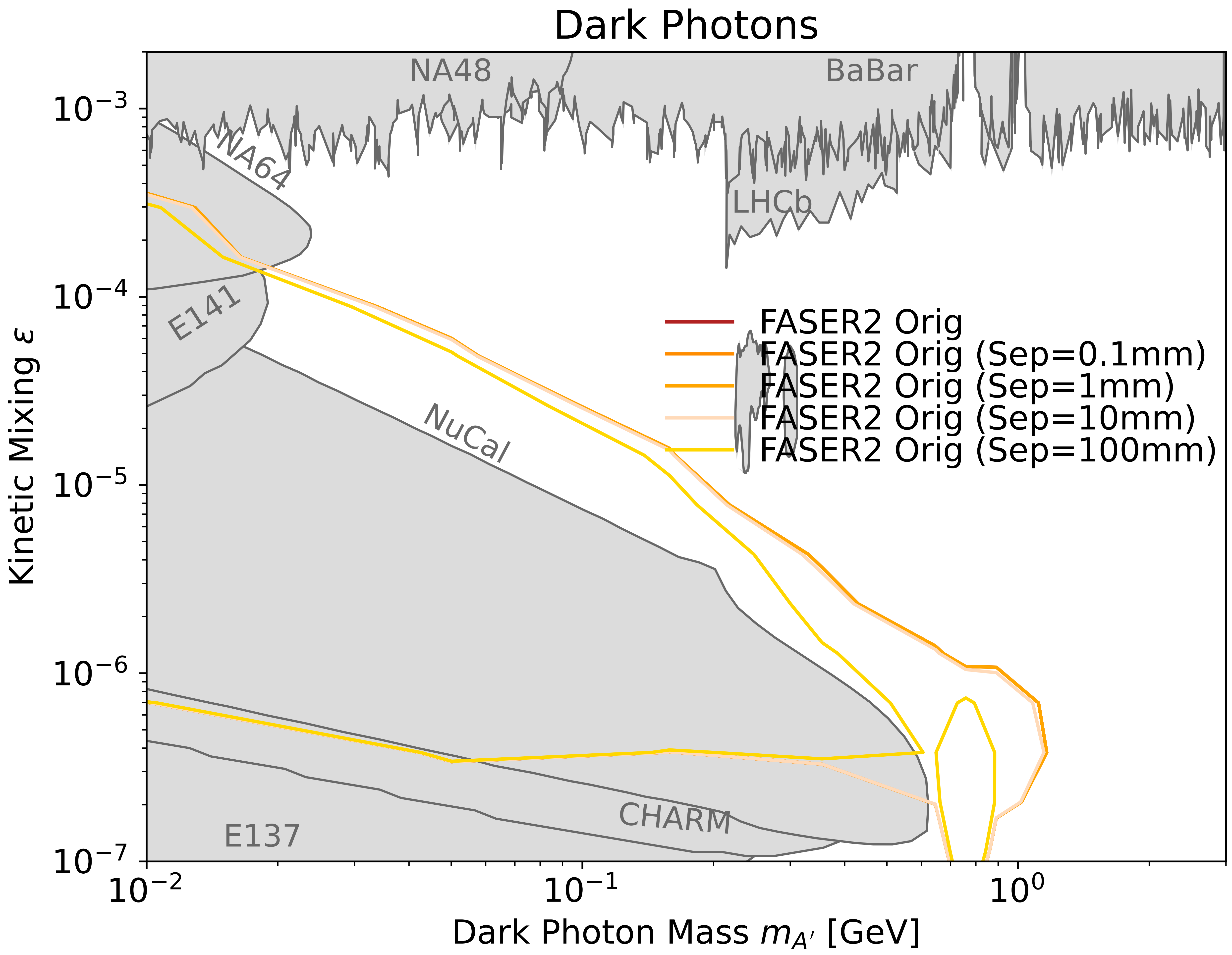
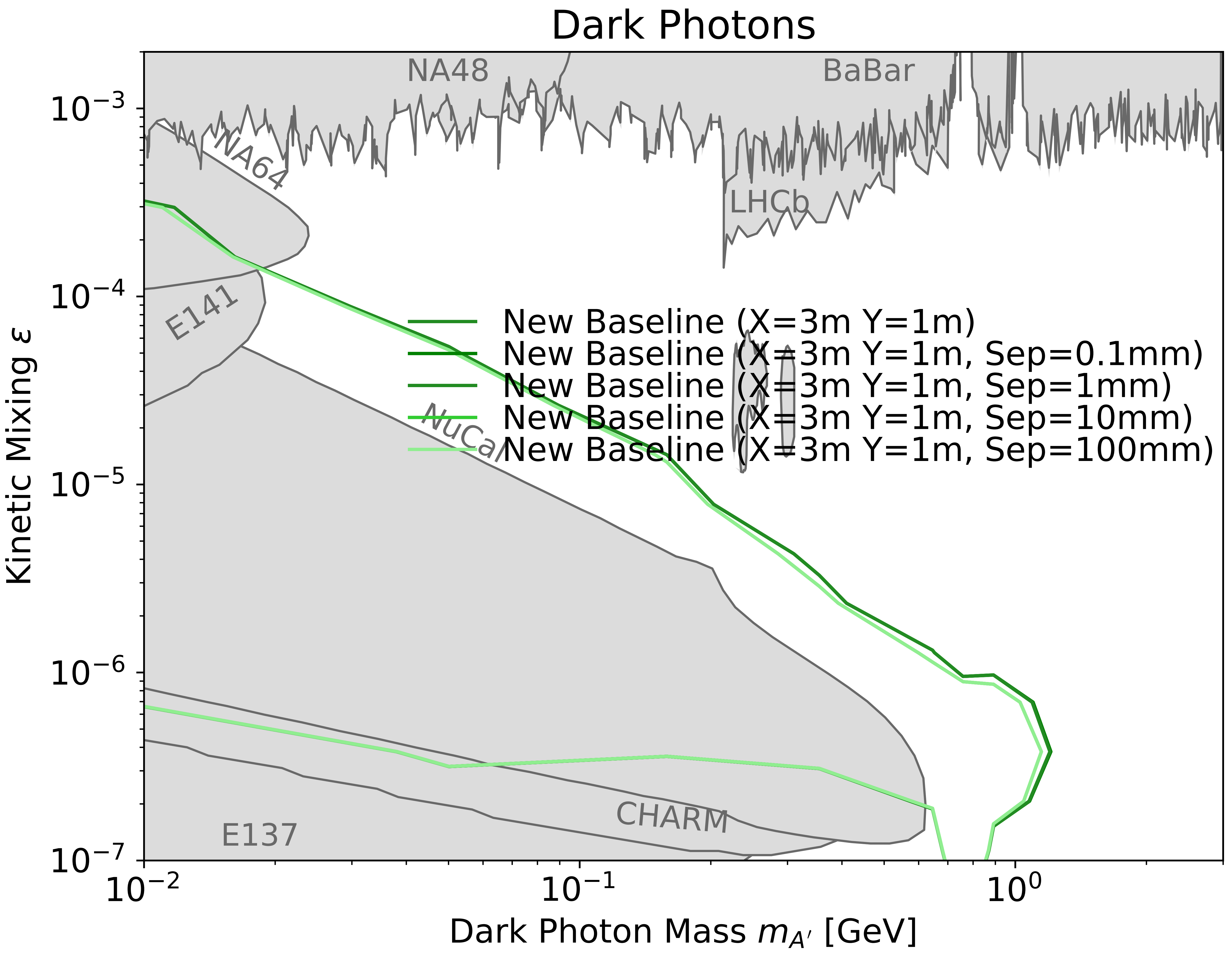
Original FASER2 layout



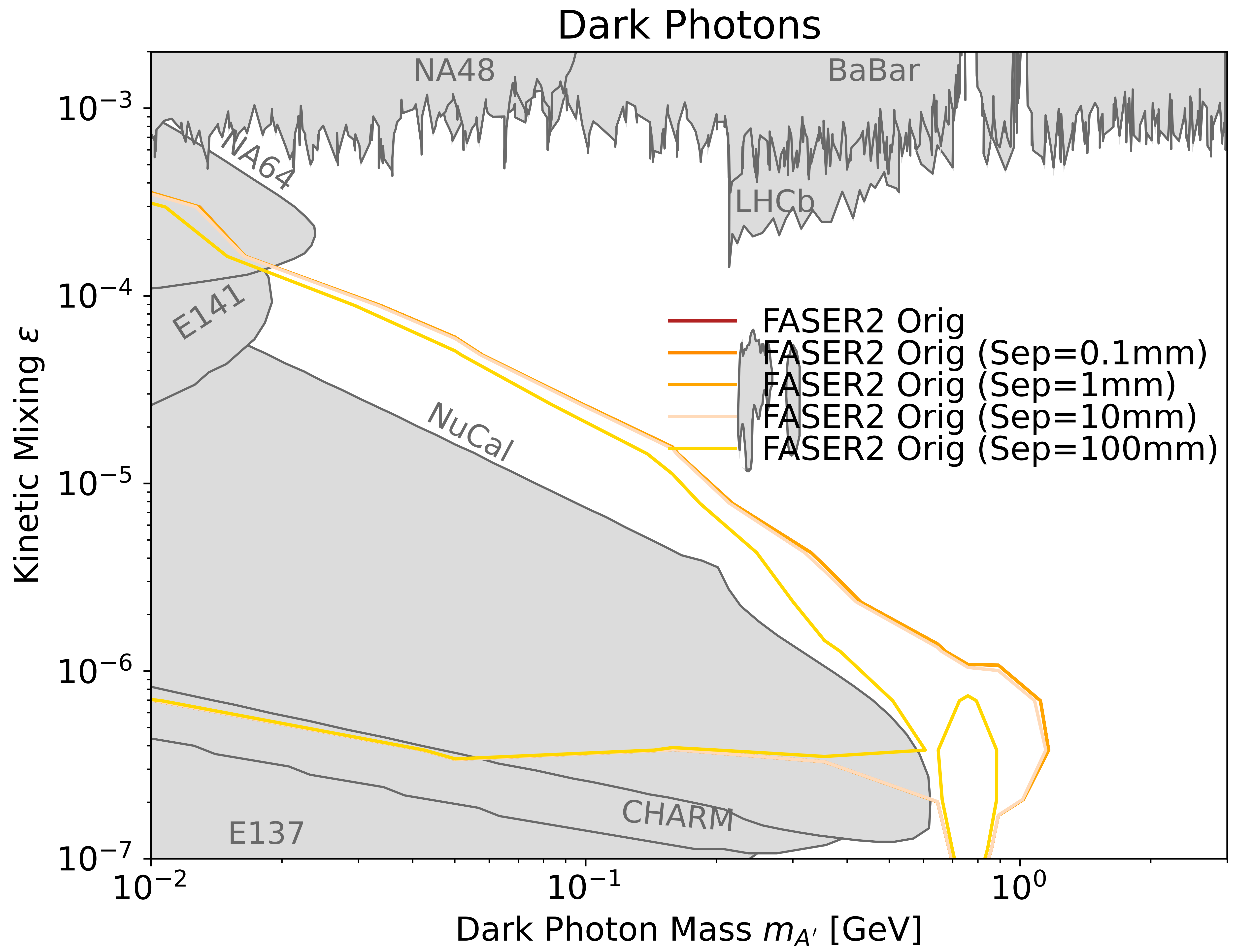
New FPF Cavern Baseline



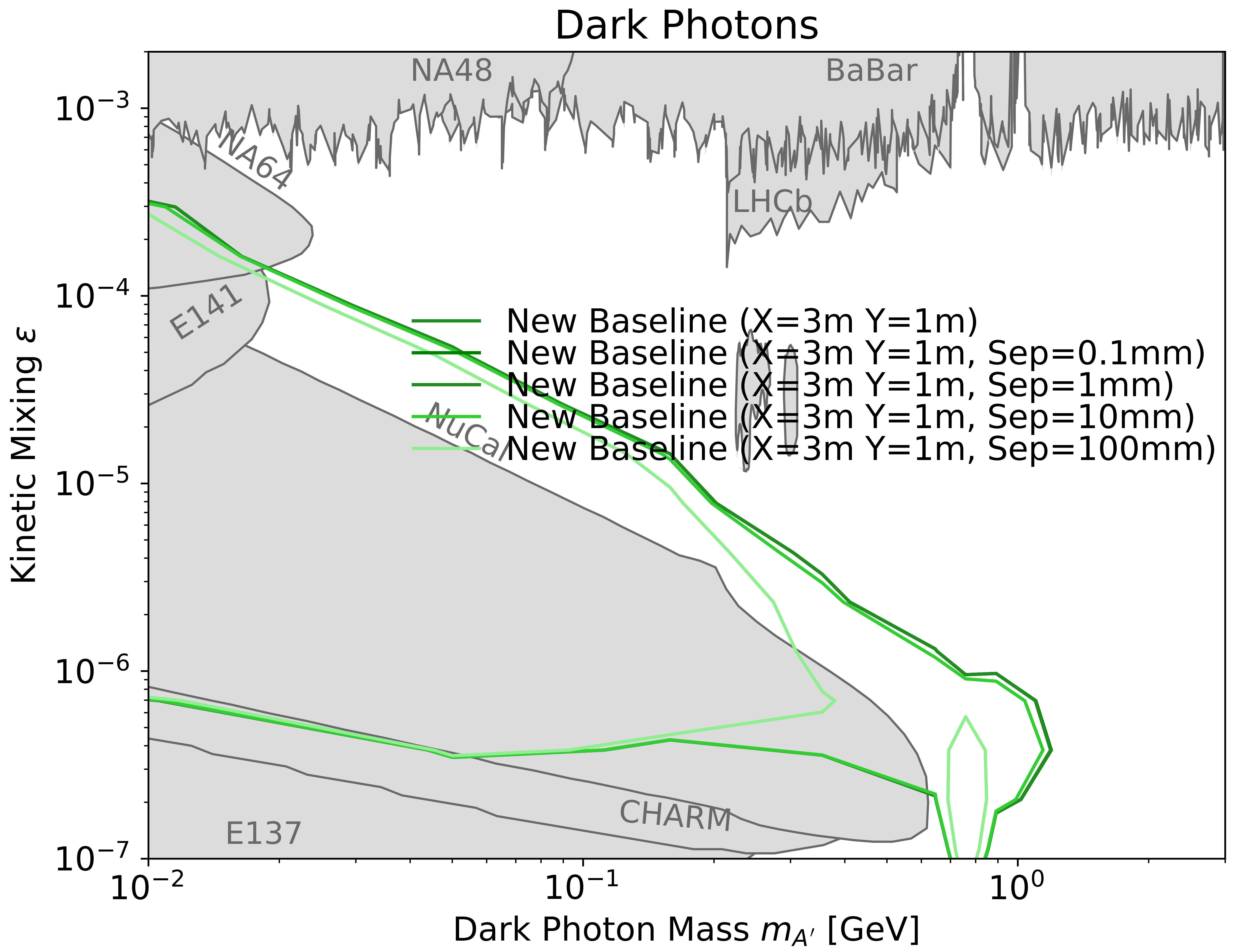
Effect on reach of separation cuts

- Separation at final tracking station/calorimeter

- **Original FASER2 layout**



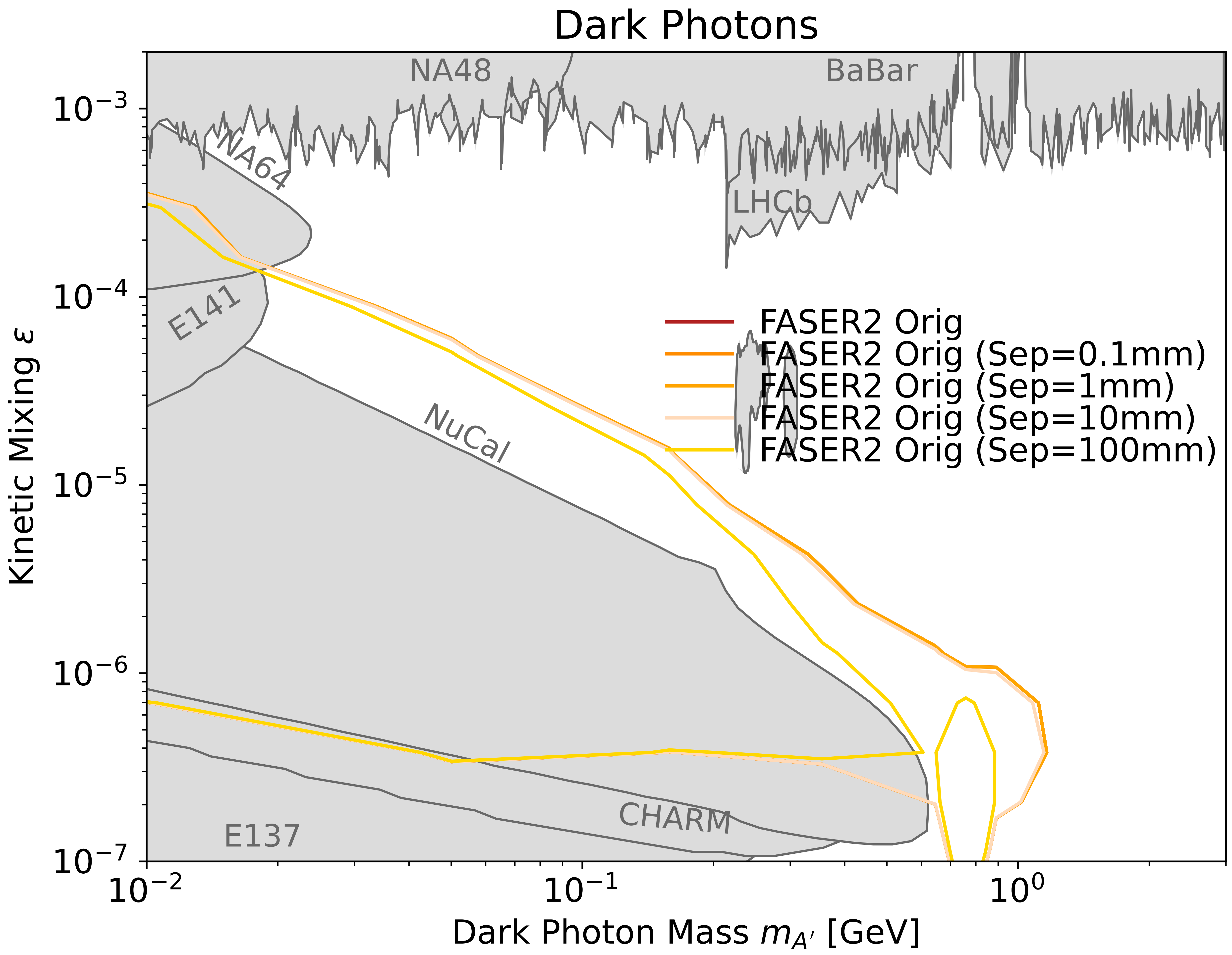
- **New baseline KEK rectangular**



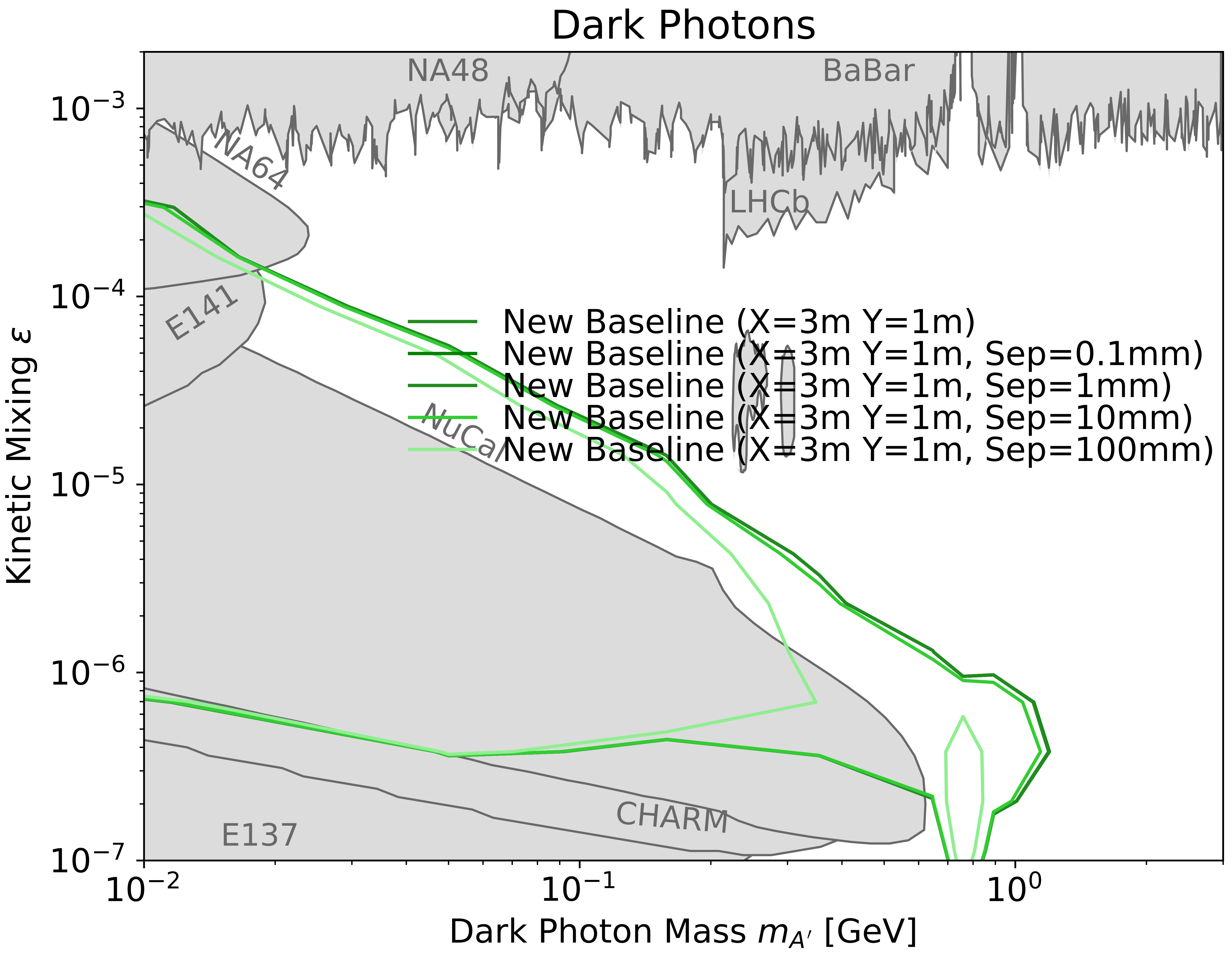
Effect on reach of separation cuts

- Separation at final tracking station/calorimeter

- **Original FASER2 layout**

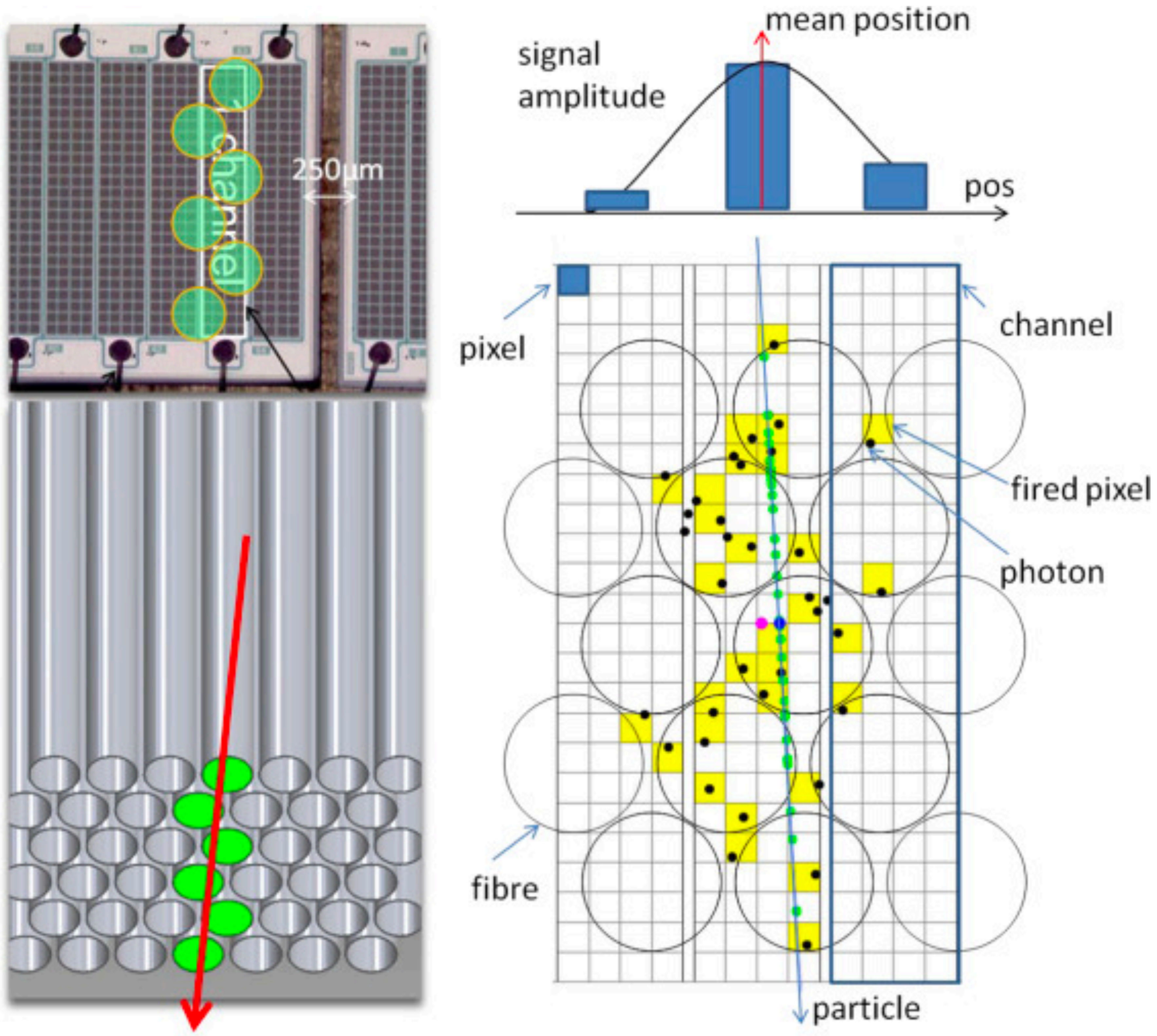


- **New baseline KEK circular**



Tracker design and costing

- Based on SciFi detector installed in LHCb in LS2.
  - SiPM+scintillating fibre design
  - Fibres 250um diamater => 80um resolution.
- Each module consists of a mat of 4 fibres, with >99% efficiency.
- Costing done by scaling LHCb detector to the FASER2 design, and includes readout.
- Cost could be reduced by re-using tooling from LHCb if relevant institutes were involved.



SciFi design and costing

The upstream tracker

6 vertical + 2 horizontal modules makes up a station.

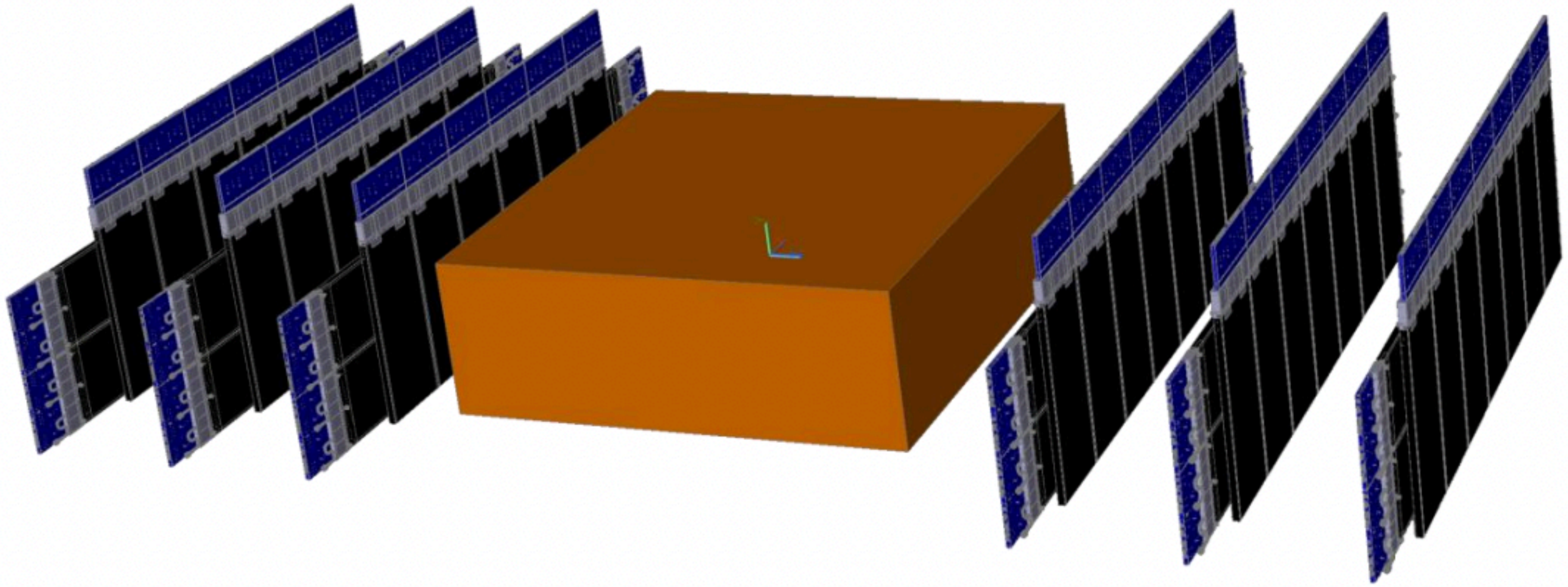
3 stations.

The downstream tracker

7 vertical + 2 horizontal modules makes up a station.

3 stations.

Sune Jakobsen



- The stations should be relatively rotated e.g. 1 degree to maximize performance for multi tracks etc.
- Cost: ~3.8M CHF

SciFi design and costing

The upstream tracker

6 vertical + 2 horizontal modules makes up a station.

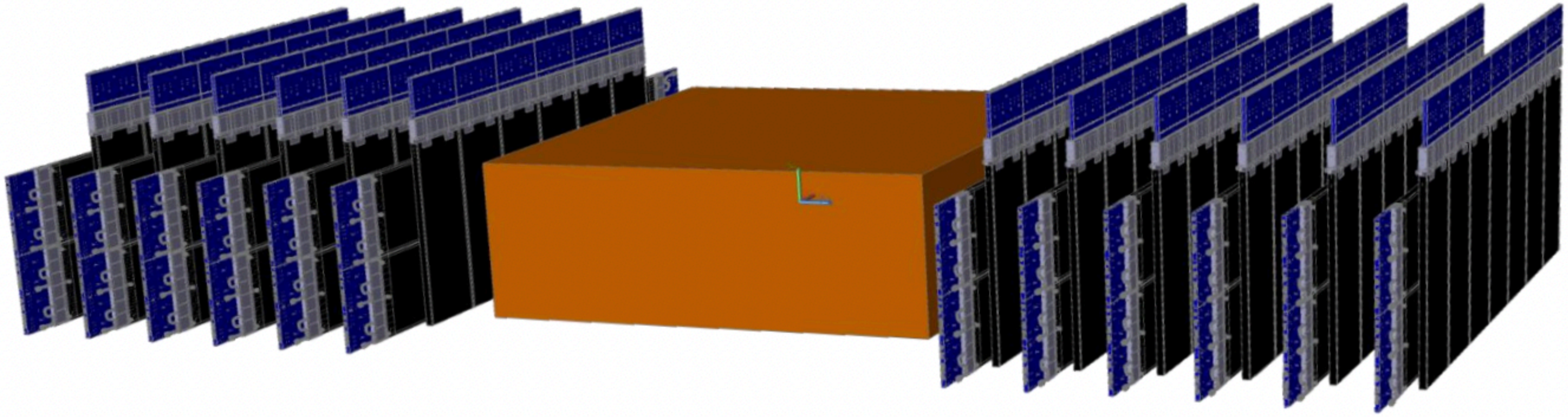
6 stations.

The downstream tracker

7 vertical + 2 horizontal modules makes up a station.

6 stations.

Sune Jakobsen



- The stations should be relatively rotated e.g. 1 degree to maximize performance for multi tracks etc.
- Cost: ~6.7M CHF

SciFi design and costing

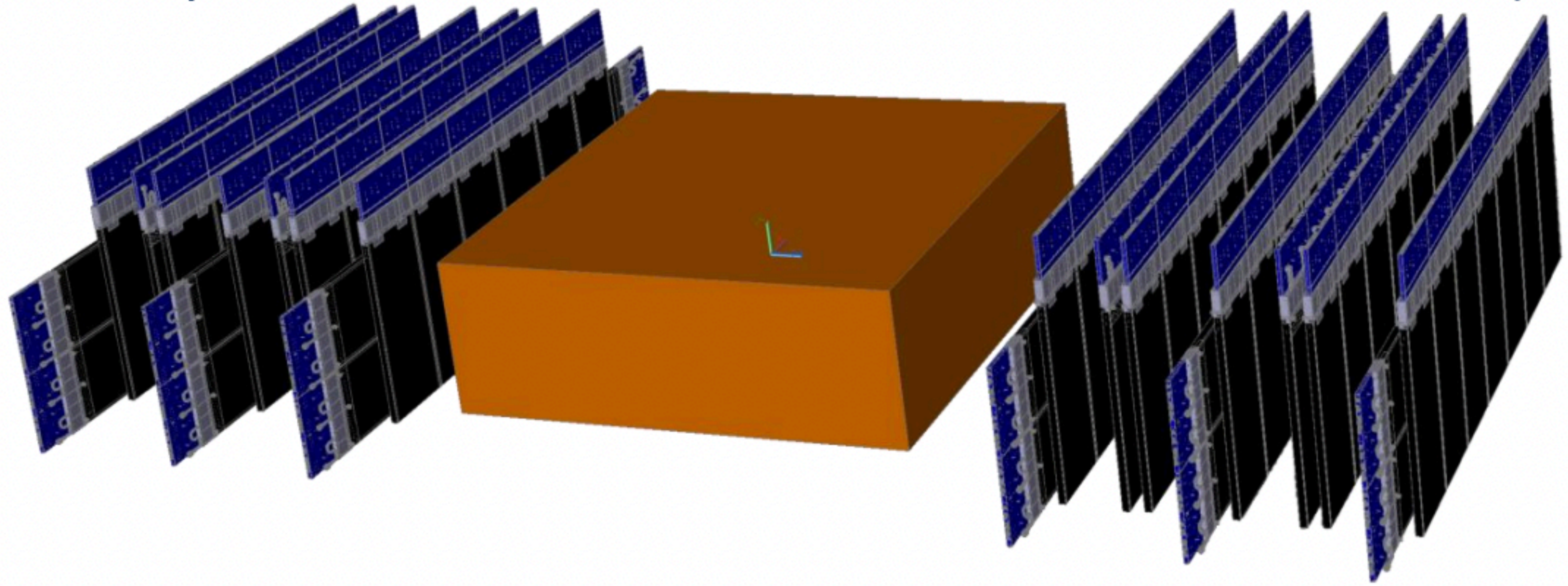
The upstream tracker

6 vertical + 2 horizontal modules makes up a station.
3 stations.
2 extra station with only vertical modules.

The downstream tracker

7 vertical + 2 horizontal modules makes up a station.
3 stations, Aperture covered: 3.5 m x 1 m.
2 extra station with only vertical modules.

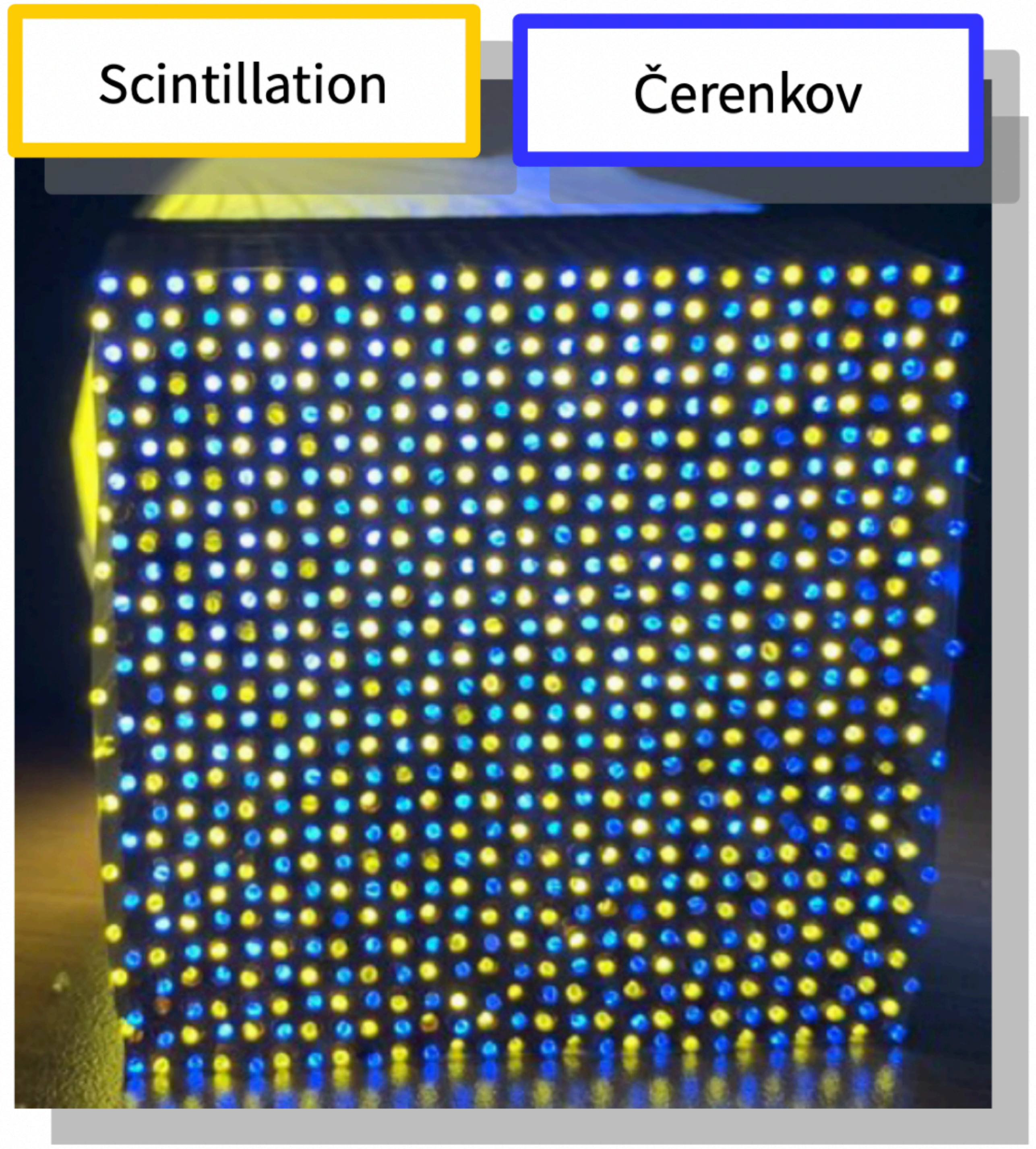
Sune Jakobsen



- The stations should be relatively rotated e.g. 1 degree to maximize performance for multi tracks etc.
- Cost: ~6.3M CHF

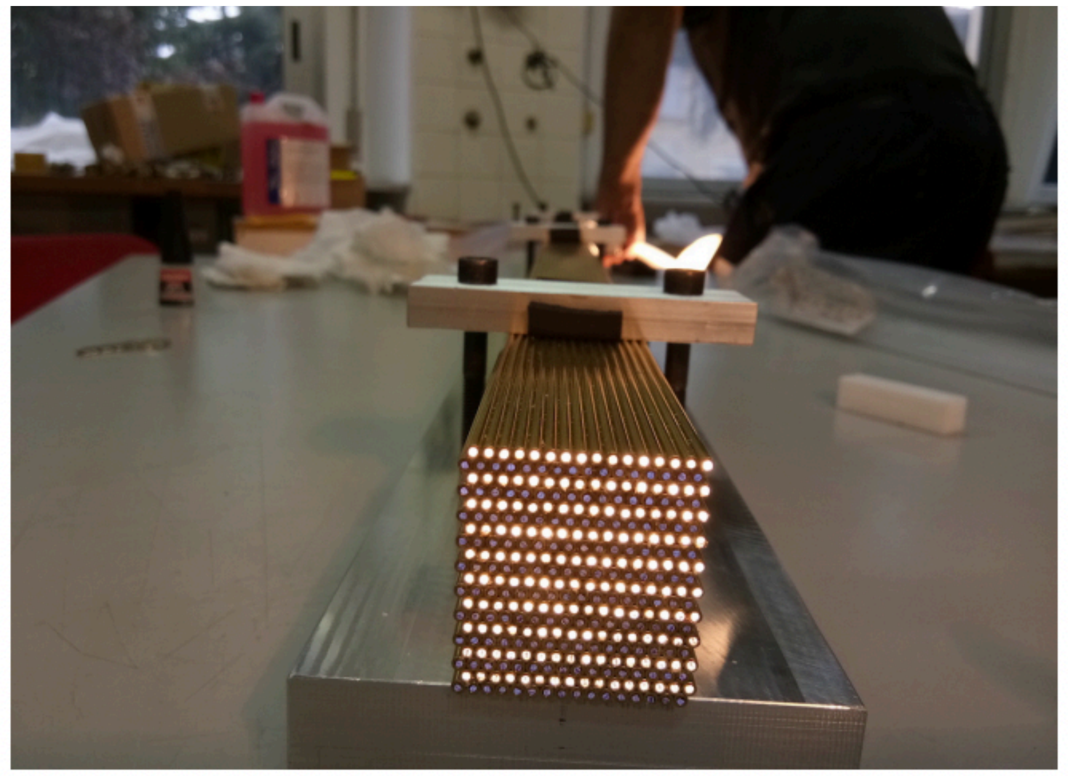
Calorimeter | Dual-readout

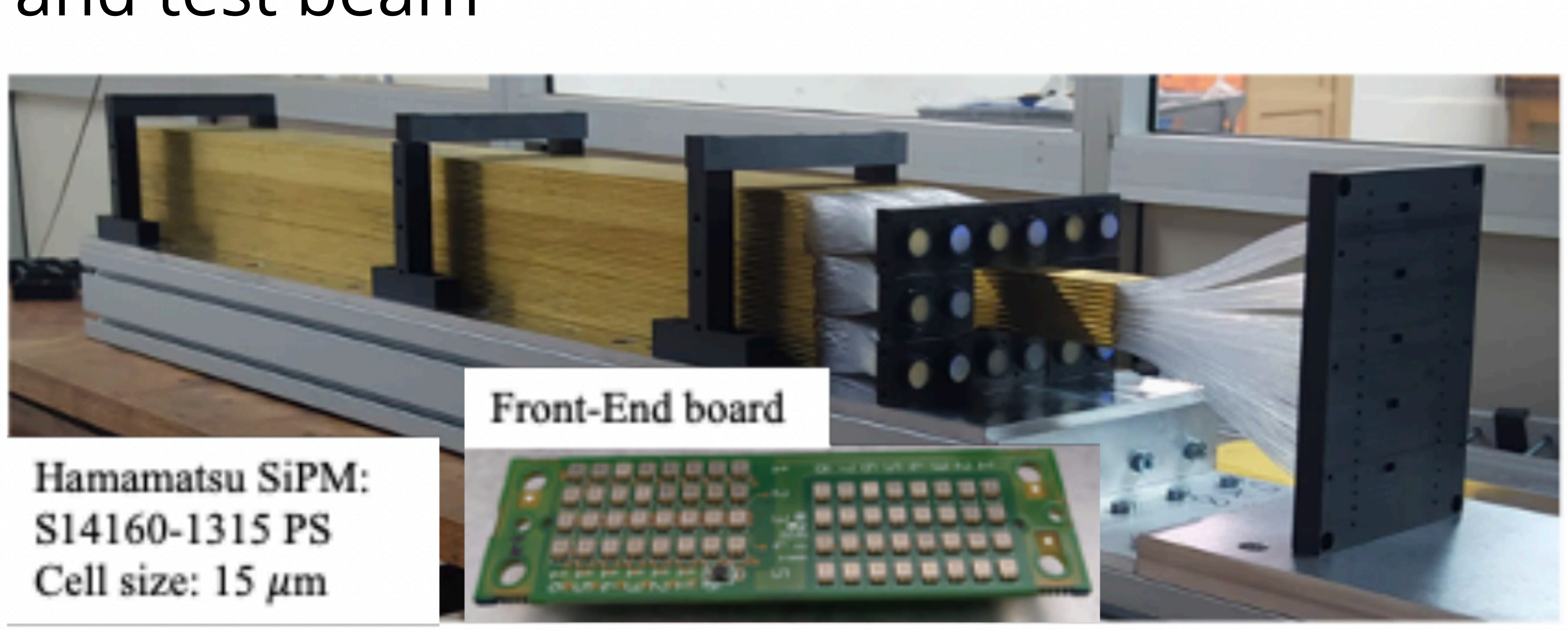
- Design based on Dual Readout calorimeter design
  - Being studied in context of e+e- Higgs factories
- Spacial Resolution:
  - Tested with fibre diameter of 1mm. 2mm brass collar.
  - So ~5 mm resolution possible.
- EM Energy resolution: 15/√E + ~1% constant term
- Particle ID
  - EM vs Hadronic vs MIP PID possible - best performance would need longitudinal information.

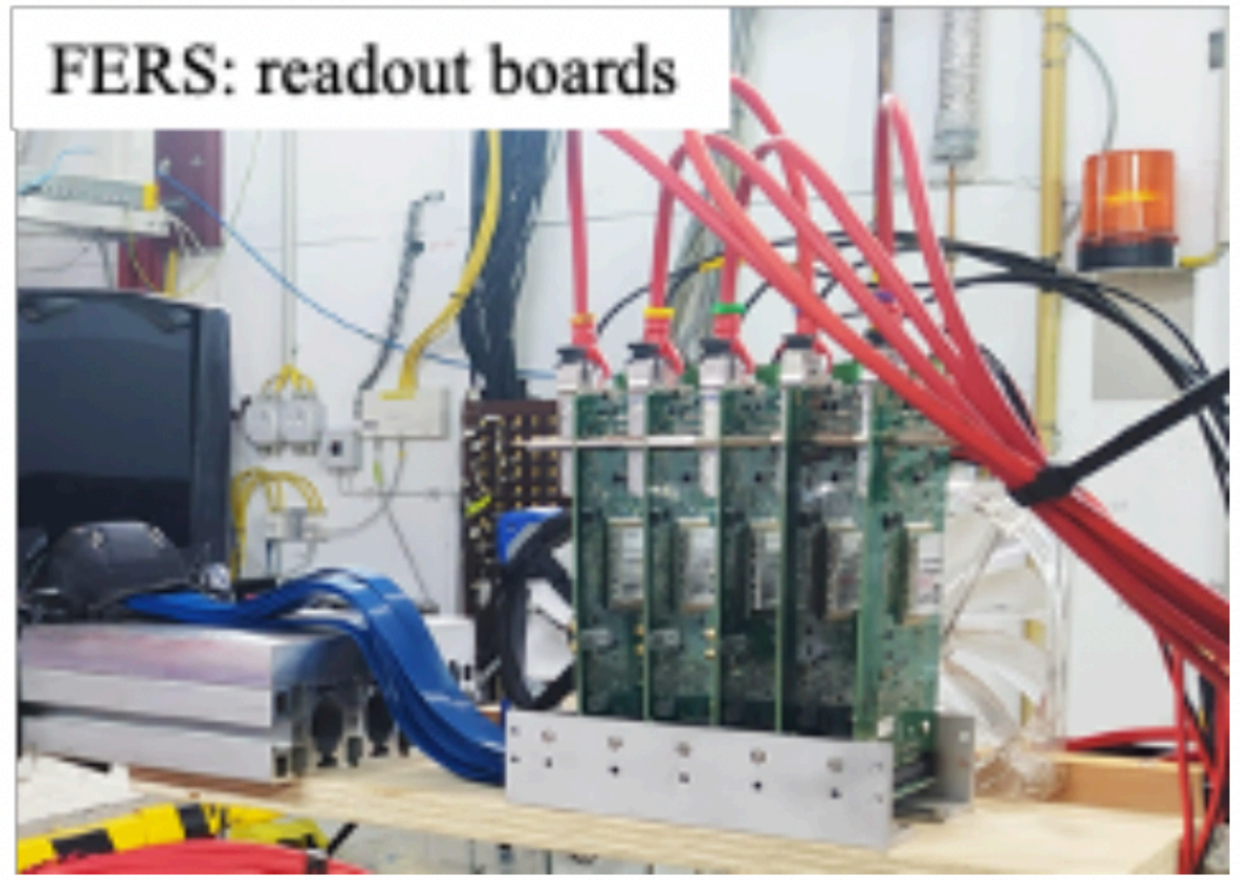


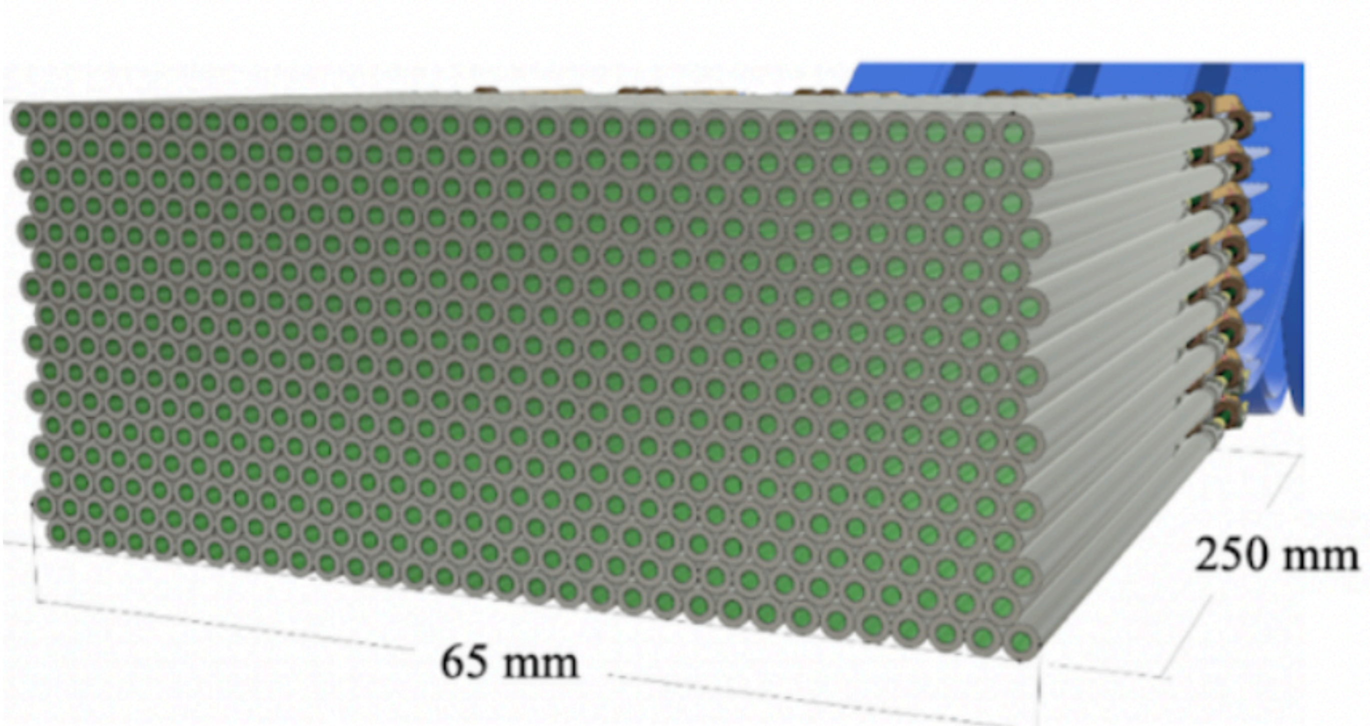
Calorimeter design

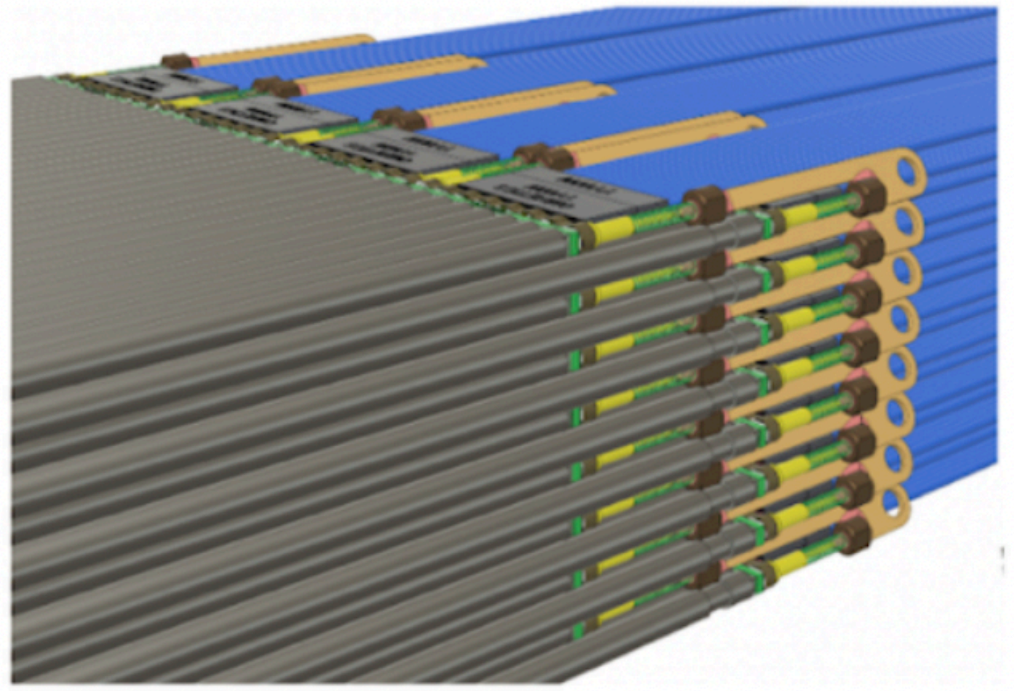
- Costing from existing prototypes
  - EM prototype exists, construction of hadronic-size prototype ongoing
    - Costing based on HiDRa “hadronic size” prototype - INFN
      - 65x65x250 cm (presentation)
      - Aiming for 2023 construction and test beam







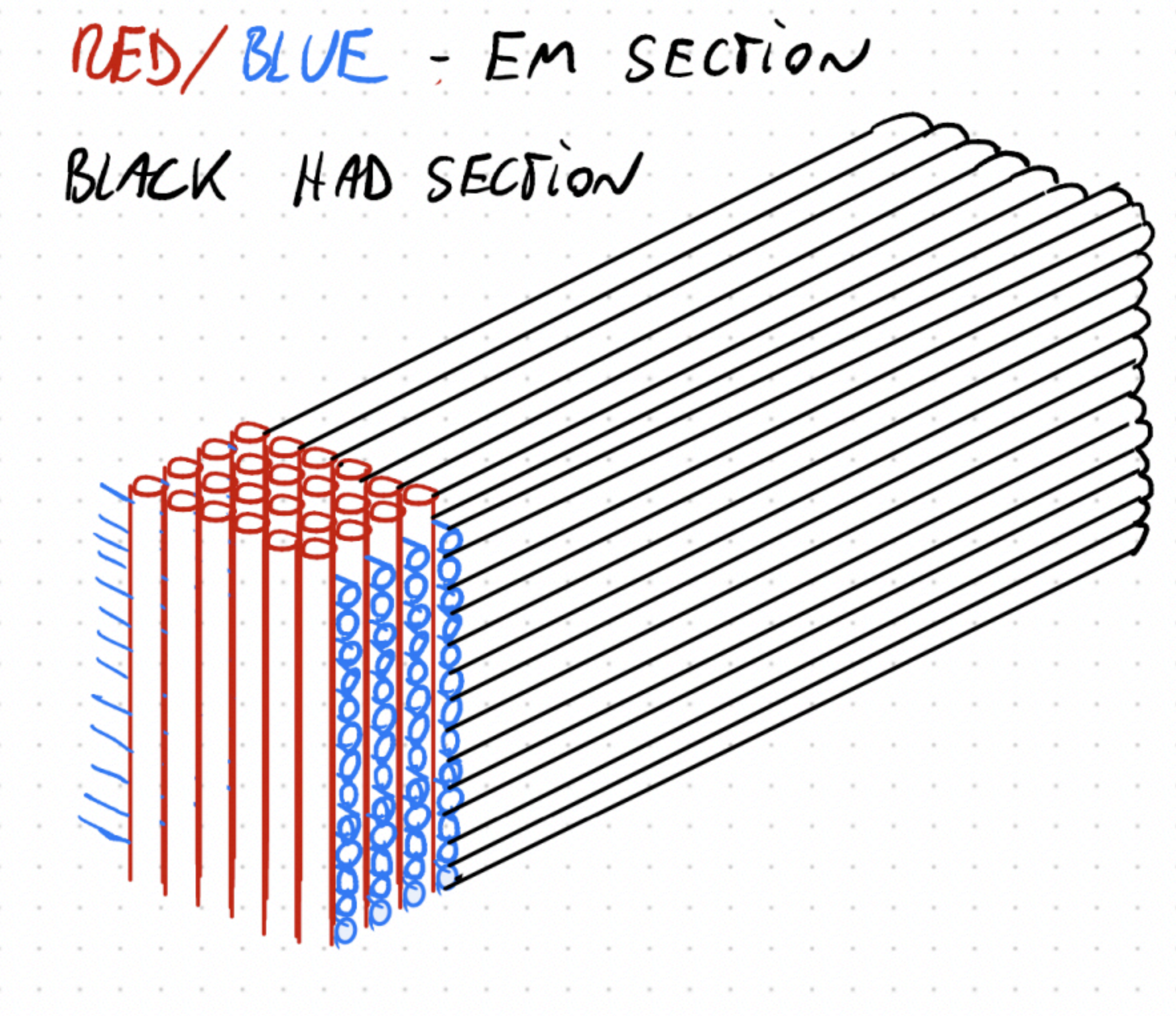




Iacopo Vivarelli

Calorimeter design and costing

- Fully segmented design
  - Perpendicular crossing of EM layers
  - Don't need dual readout - no Cherenkov fibres
  - Very preliminary costing for 2m and 1.5m diameter aperture



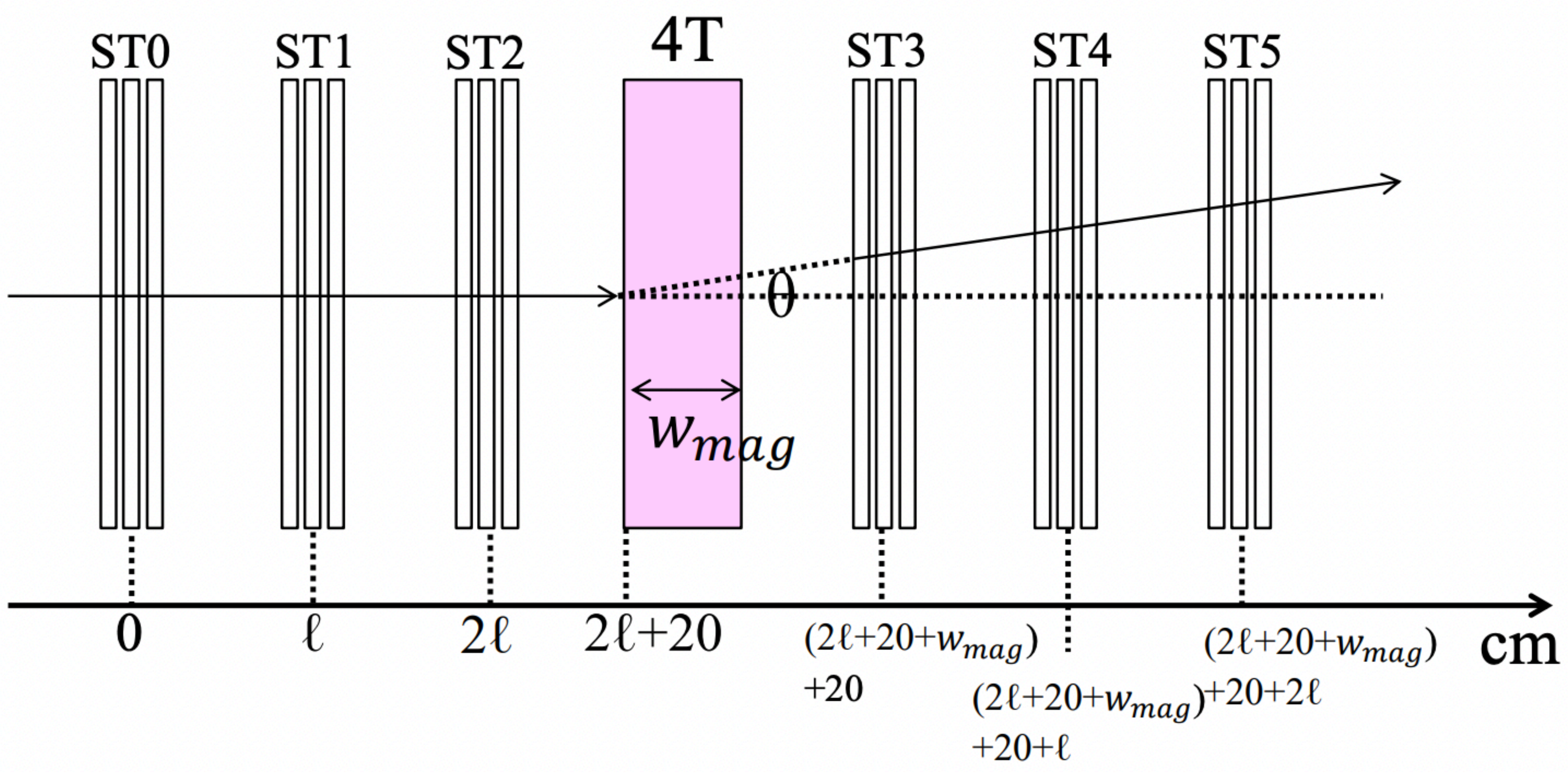
- Costing Option 1:
  - EM section 2 m x 2 m x 37 cm (15 X0) (1.85e5 2 m elements)
  - HAD section 2 m x 2 m x 2.5 m (1e6 elements)
  - Total (excluding EM FE and HAD readout): ~4.8 M euros

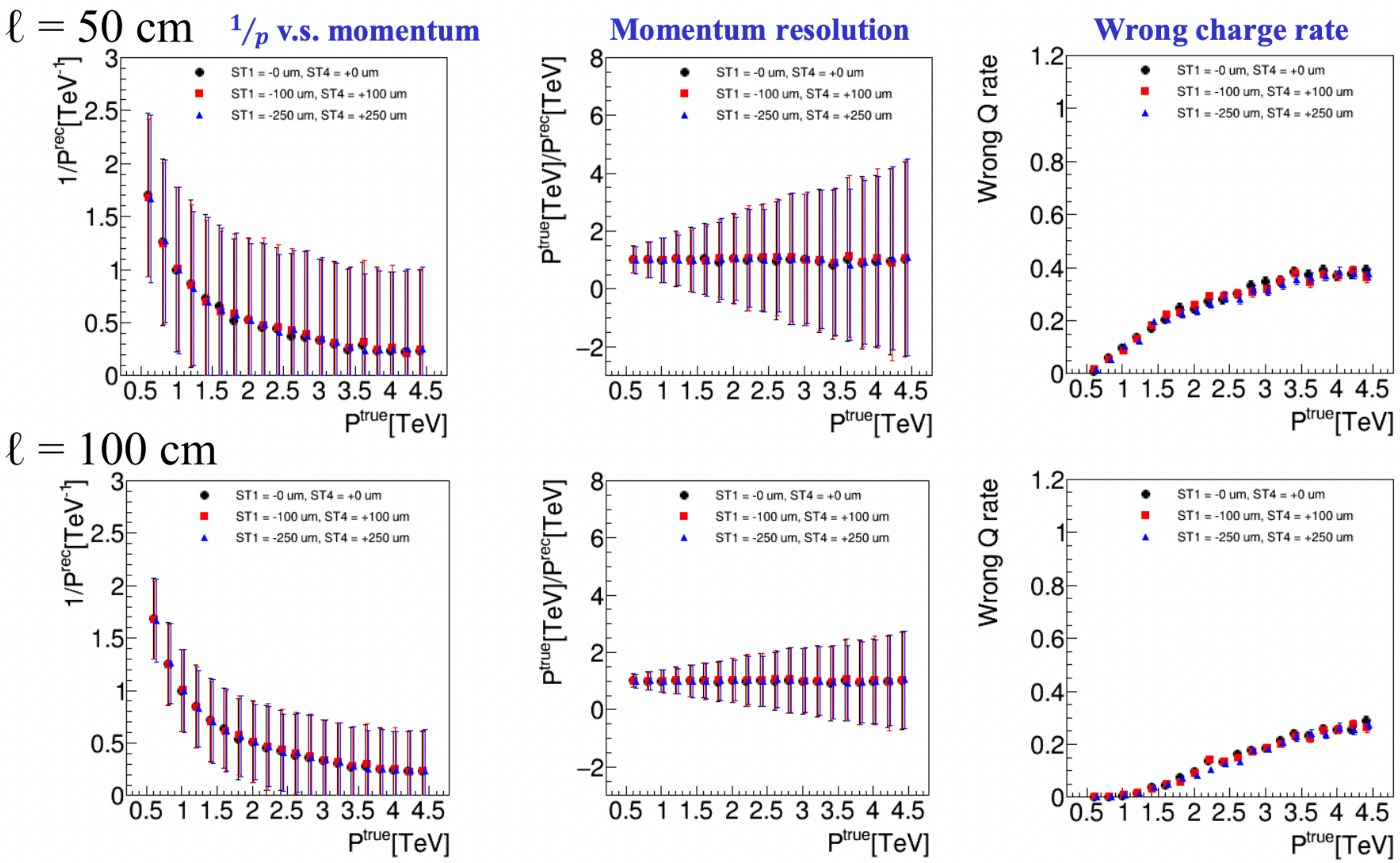
- Costing Option 2:
  - EM section 1.5 m x 1.5 m x 37 cm (15 X0) (1.39e5 1.5 m elements):
  - HAD section 1.5 m x 1.5 m x 2.5 m (5.6e5 elements)
  - Total (excluding EM FE and HAD readout): ~3.0 M euros

Iacopo Vivarelli

Track momentum resolution

- Studying track momentum resolution and charge misconstruction rate
- Based on sampling assuming 100um resolution using analytic calculation for particle propagation in field
  - Early studies encouraging
    - Further studies on alignment planned



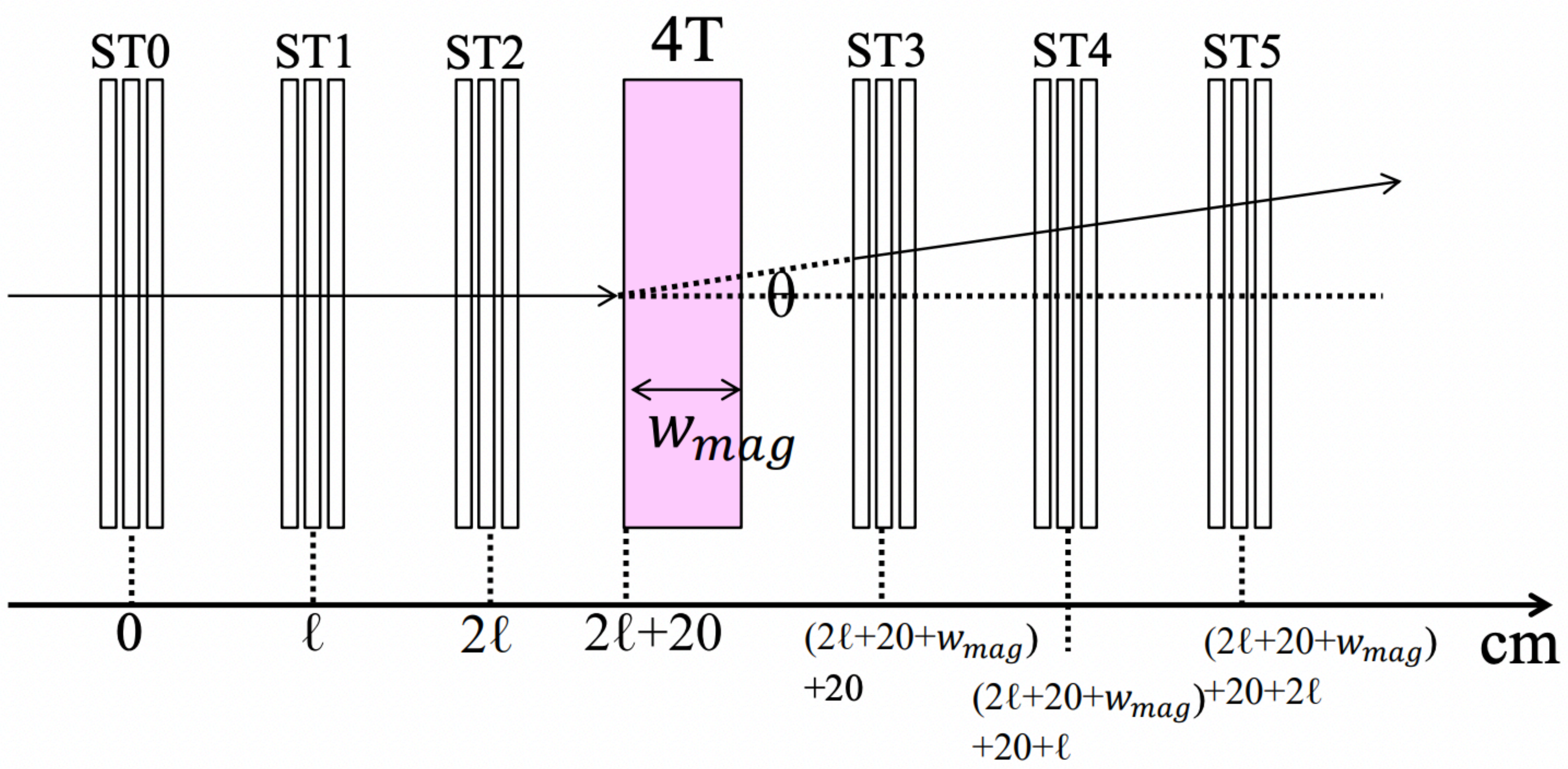


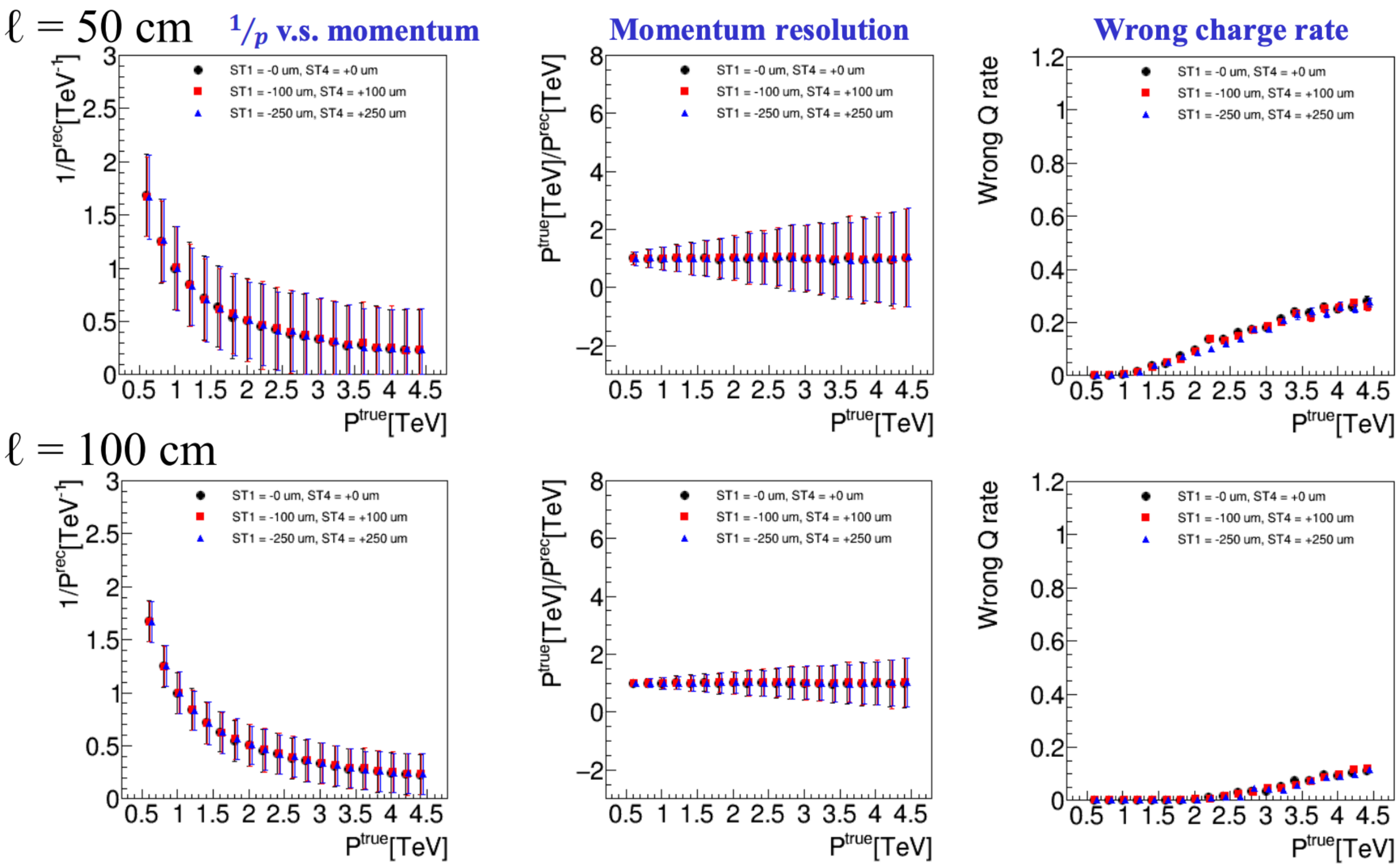
1 Tm

Yosuke Takubo

Track momentum resolution

- Studying track momentum resolution and charge misconstruction rate
- Based on sampling assuming 100um resolution using analytic calculation for particle propagation in field
  - Early studies encouraging
    - Further studies on alignment planned



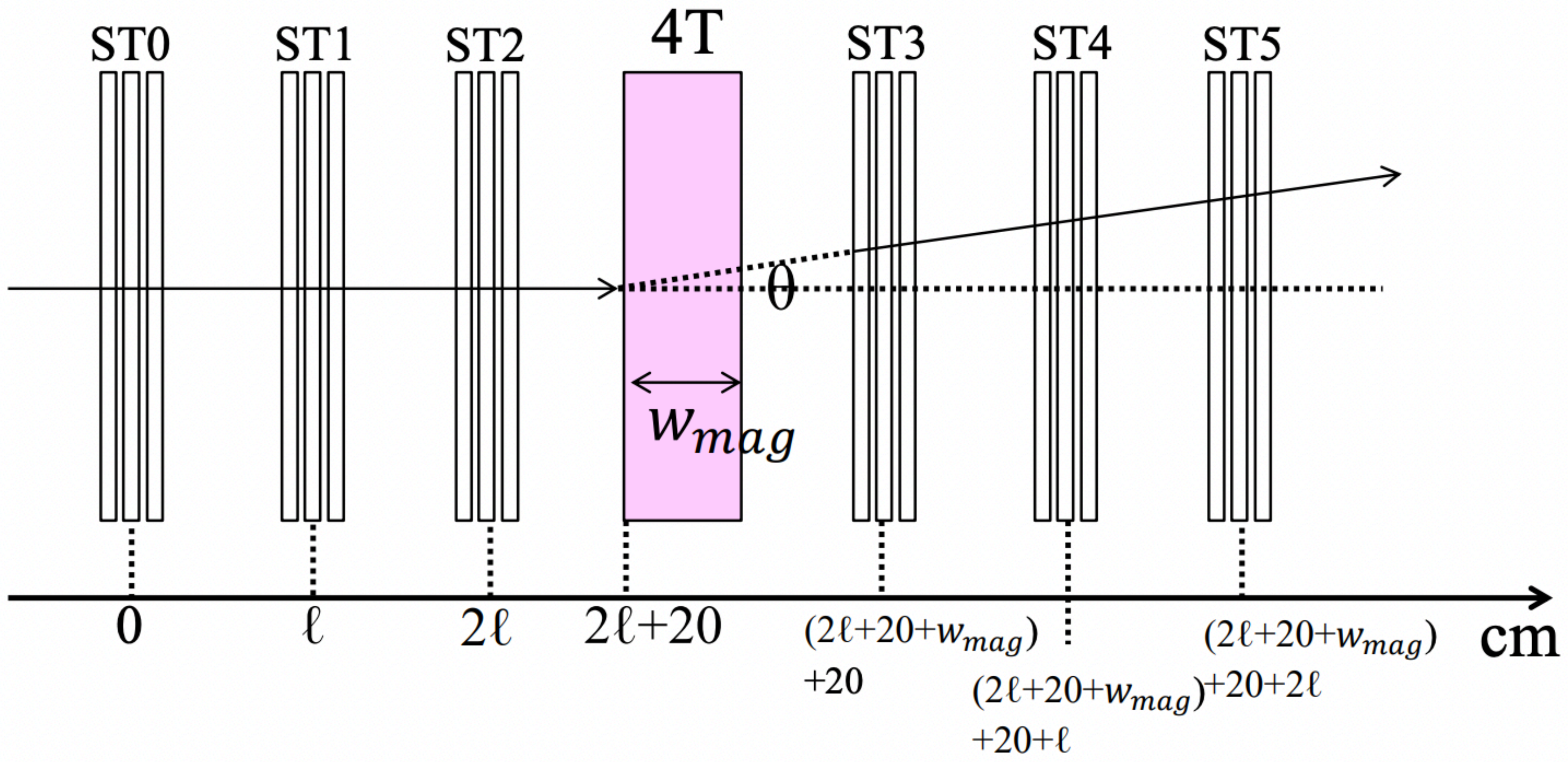


2 Tm

Yosuke Takubo

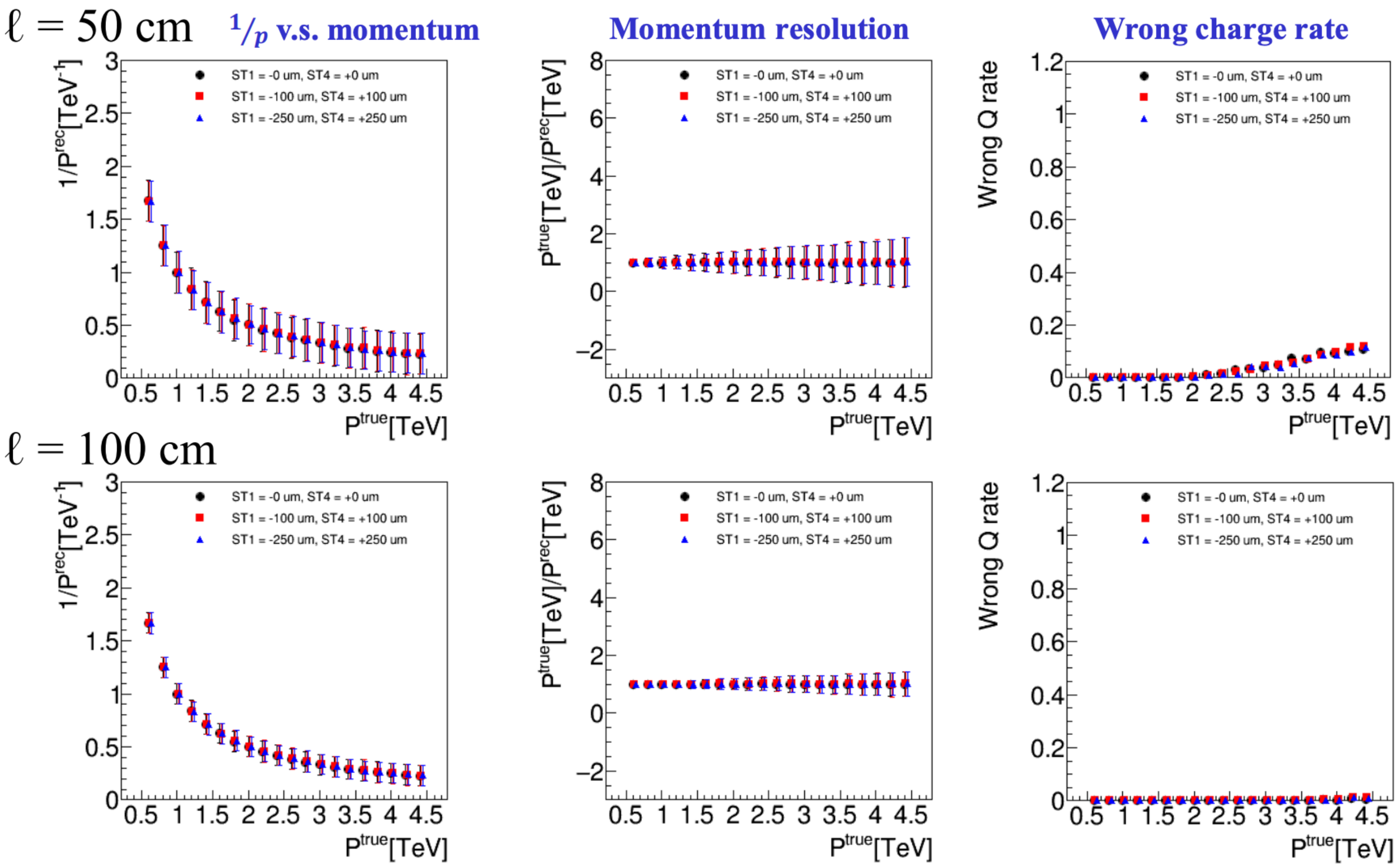
Track momentum resolution

- Studying track momentum resolution and charge misconstruction rate
- Based on sampling assuming 100um resolution using analytic calculation for particle propagation in field
  - Early studies encouraging
    - Further studies on alignment planned



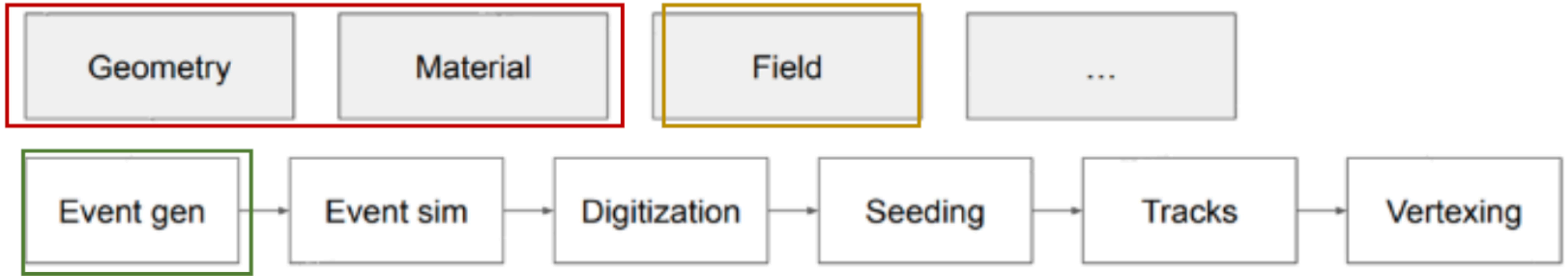
4 Tm

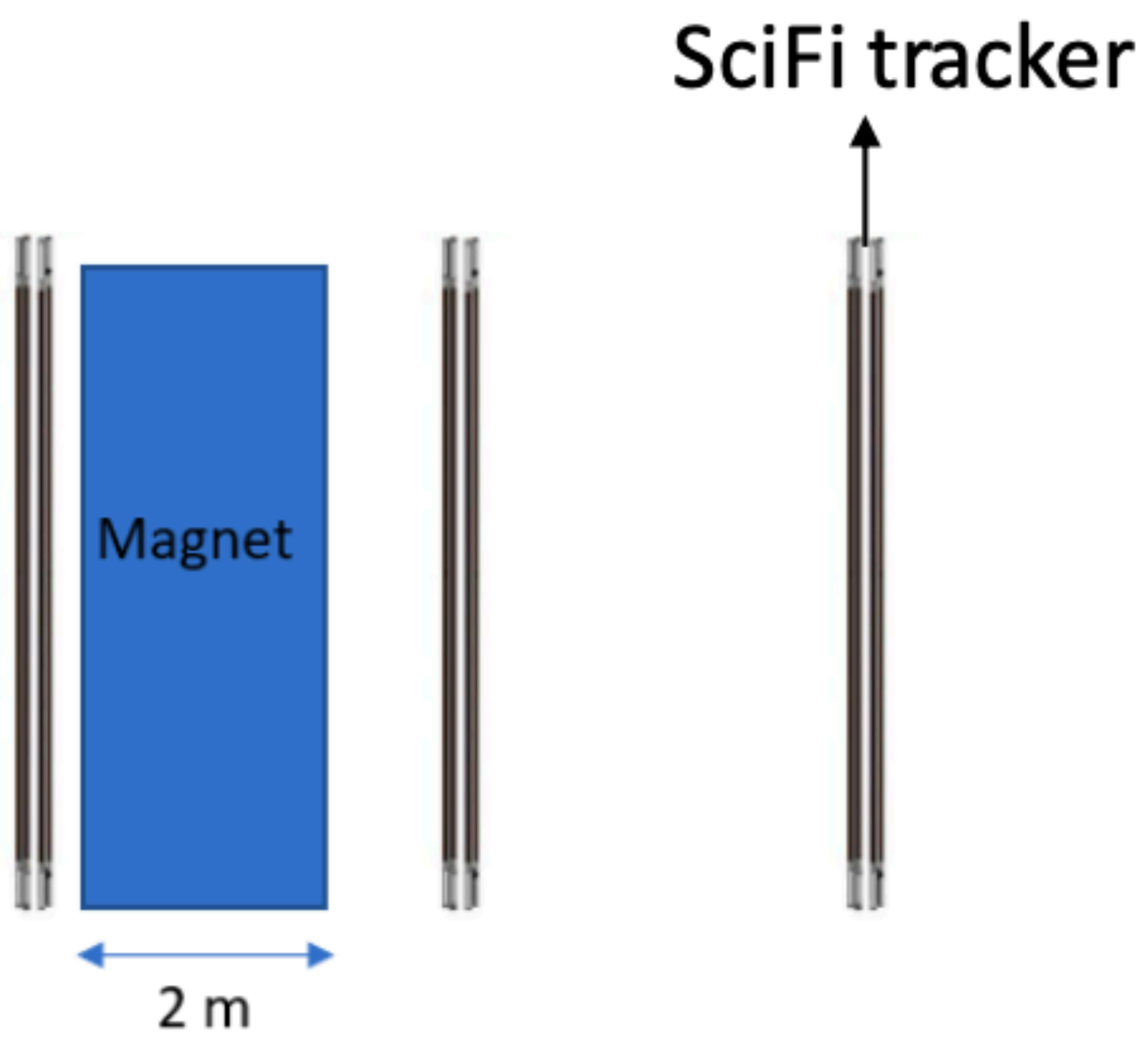
Yosuke Takubo



ACTs implementation

- Need more study on FASER2 mass and pointing reconstruction capabilities
- Starting to implement more sophisticated reconstruction framework based on ACTS
  - Used in LHC experiments including FASER, well supported.
- Working on implement SciFi tracker geometry and interfacing with FORESEE outputs



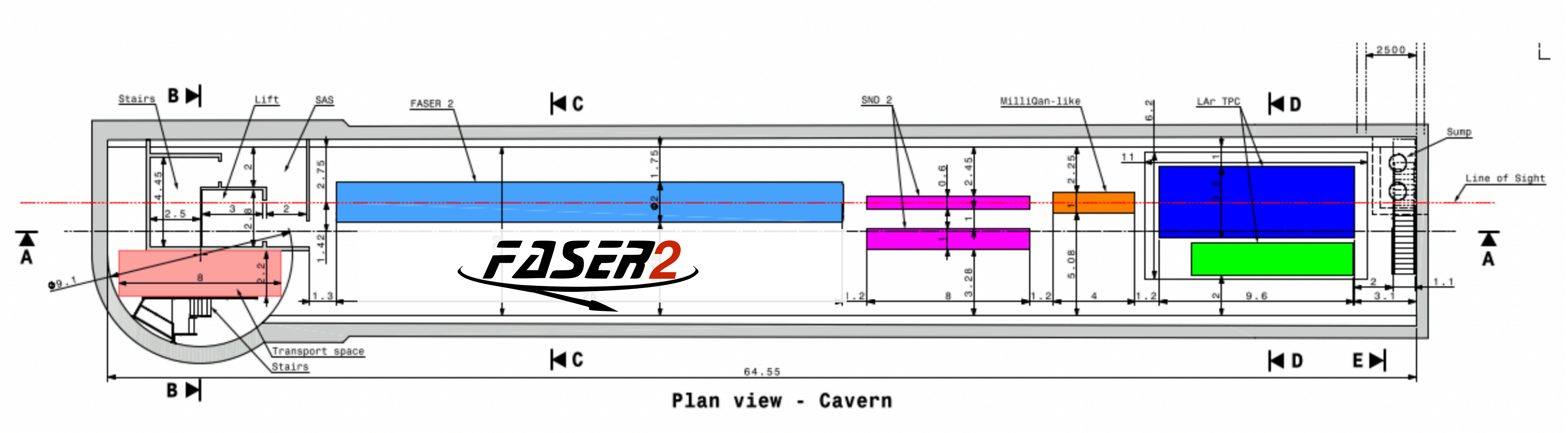


Olivier Salin

Summary of detector costings

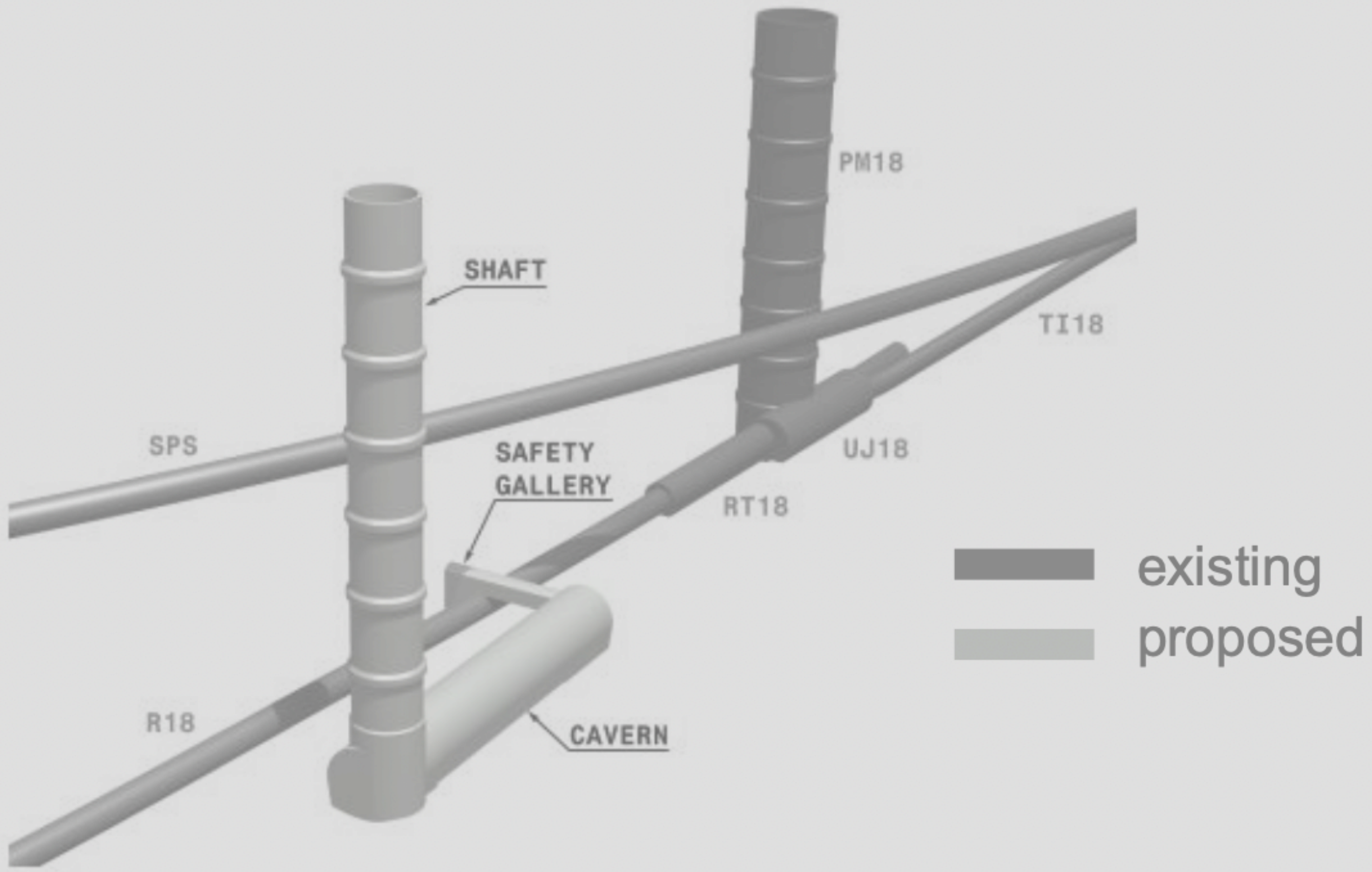
- Very preliminary overall costing of FASER2
  - Cost driven by magnet

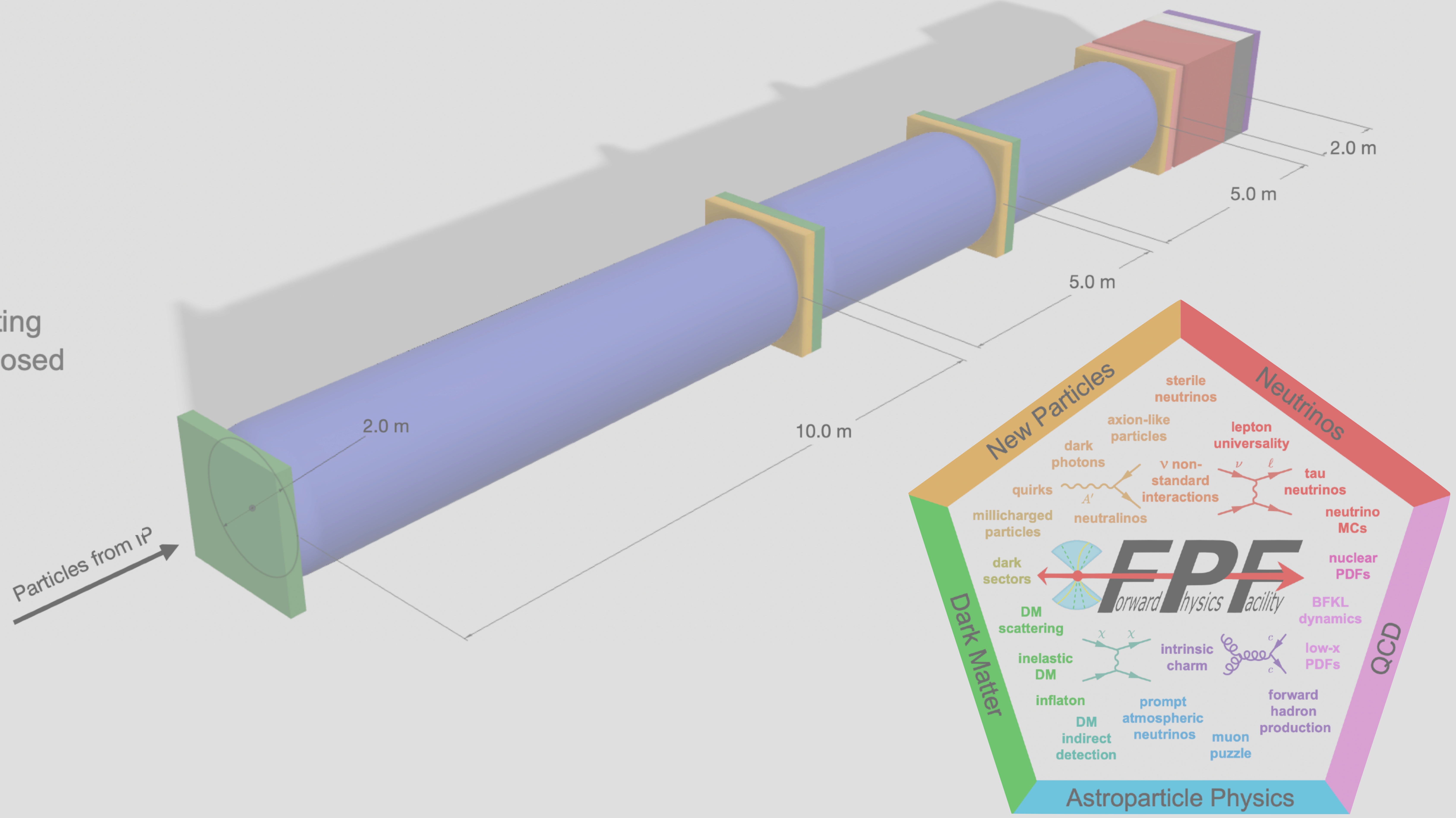
	Cost
Magnet	10 MCHF
Tracker (SciFi)	4-6 MCHF
Calorimeter	3-5 MCHF
Total	**~20 MCHF**



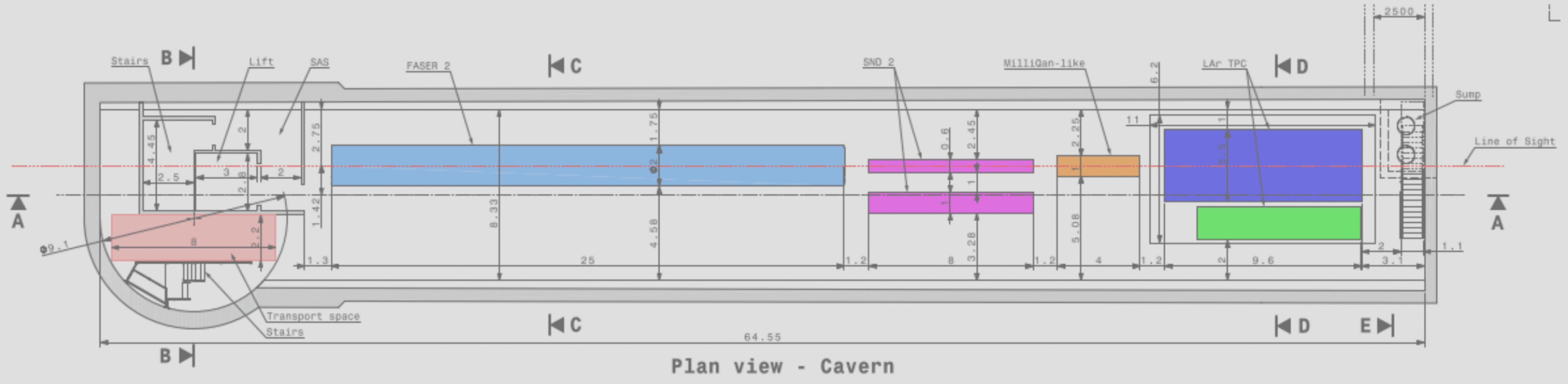
Summary

- Available/affordable magnet technology has changed since original baseline detector studies
- Lots of progress made since to identify a new baseline
  - Very comparable sensitivity achievable with new baseline
- Studies on detector/magnet technology ramping up
  - Simulation of possible magnet
  - Tracker design and costing advancing building on experience from SciFi
  - Calorimeter design developing also with costing
  - More sophisticated analysis tools being developed
- All of the work moving towards preparing CDR for Q1 2023
  - Challenging timescale, but significant increase in effort in recent months!


PM18
SHAFT
TI18
SPS
SAFETY GALLERY
UJ18
RT18
R18
CAVERN
existing
proposed

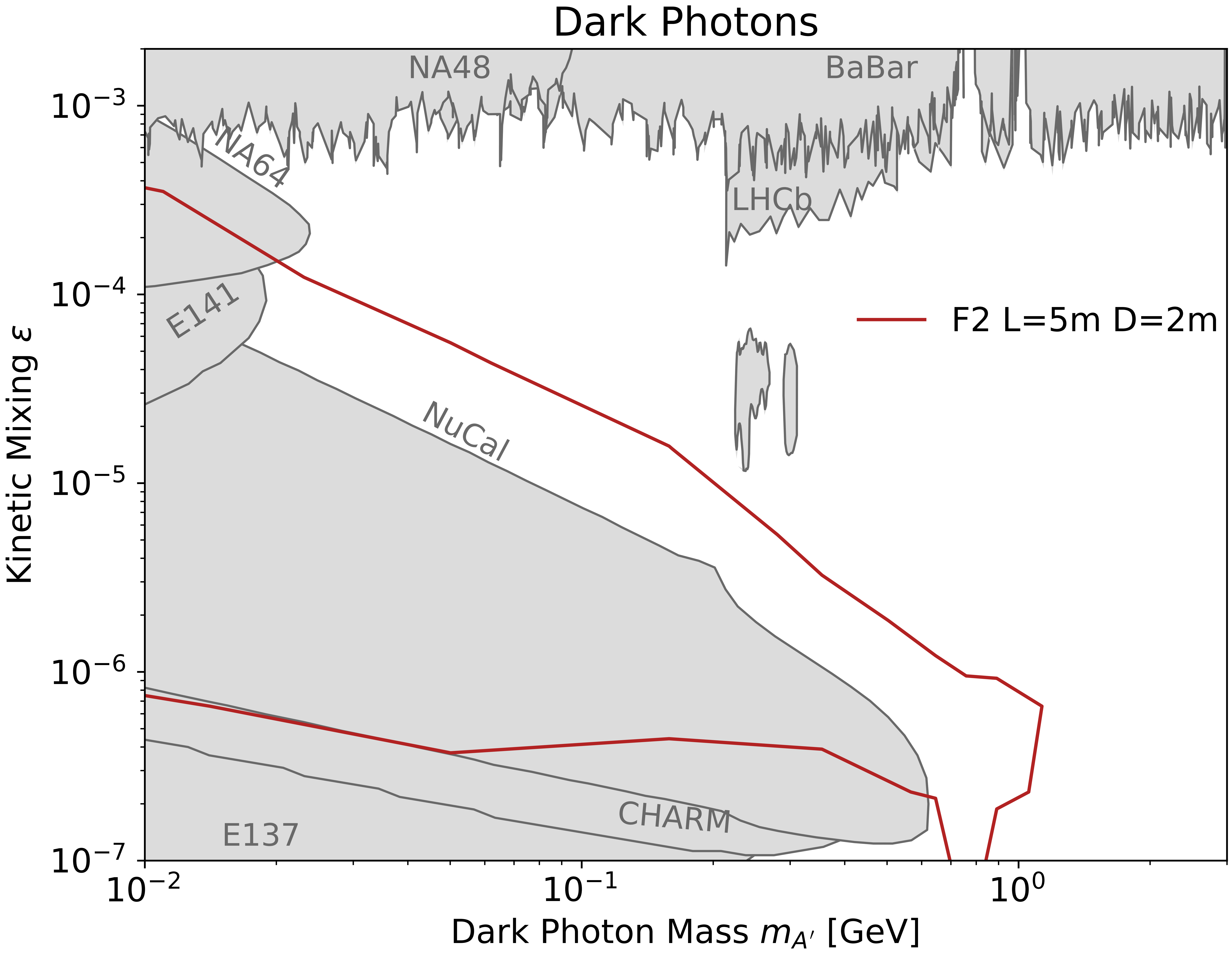

2.0 m
5.0 m
5.0 m
10.0 m
2.0 m
Particles from IP
New Particles
Neutrinos
QCD
Astroparticle Physics
Dark Matter
sterile neutrinos
axion-like particles
lepton universality
dark photons
ν non-standard interactions
tau neutrinos
quirks
millicharged particles
neutralinos
neutrino MCs
dark sectors
nuclear PDFs
Forward Physics Facility
BFKL dynamics
DM scattering
inelastic DM
intrinsic charm
low-x PDFs
inflaton
prompt atmospheric neutrinos
forward hadron production
DM indirect detection
muon puzzle

Back-ups


Stairs
Lift
SAS
FASER 2
SND 2
MilliQan-like
LAr TPC
Sump
Line of Sight
Transport space
Stairs
64.55
Plan view - Cavern

Aside - Move to FASER FORESEE setup

- Moving to use FASER's FORESEE setup
  - generate_foresee_events.py
    - Thanks to Carl!
- Good to be consistent
- Can cross-check agains their HepMC files
- Validation looks good
- Need to add Dark Higgs model



Calorimeter design and costing

Material	brass
External diameter	2 mm
Internal diameter	1 mm
Cost of fibre per meter	1 euros
Cost of brass per meter	0.30 euros
Cost of SiPM (relevant only for EM section)	7 euros
FERS cost	5000 euro/unit
FERS readout	512 SiPM

- Calorimeter parameters:
  - Effective radiation length (brass + fiber + air): 2.47 cm.
  - Effective Moliere radius: 1.97 cm.
- EM section readout: 1 channel per fiber
  - Spacial resolution o(1x1x1 mm^3)
- Had section: granularity less important. Can bundle many fibres in one traditional PMT.
- At this point, cost extrapolated based on assumed length width/height/depth of EM and HAD sections
  - Assuming same width/height for EM and HAD section.

Calorimeter design and costing

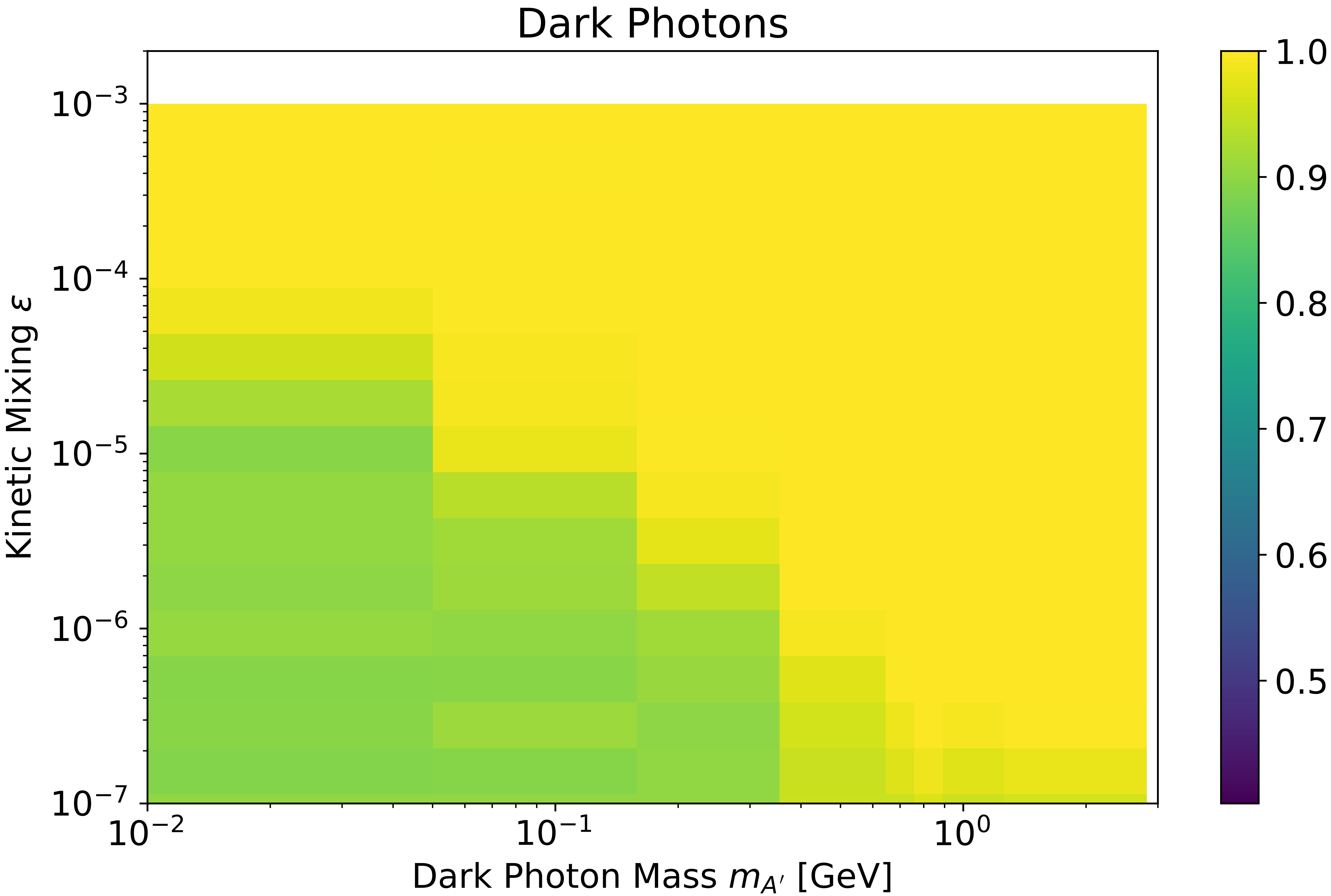
- Costing Option 1
  - EM section 2 m x 2 m x 37 cm (15 X0) (1.85e5 2 m elements)
    - Cost of brass + fibers: 380 k euros
    - Cost of SiPM (1 per element): 1.3 M euros
    - (Cost of FERS: 12.7 M - will need optimisation)
  - HAD section 2 m x 2 m x 2.5 m (1e6 elements)
    - Cost of brass + fibers: 3.2 M euros
    - (Readout cost small w.r.t. EM section)
  - Total (excluding EM FE and HAD readout): ~4.8 M euros

Calorimeter design and costing

- Option 2
  - EM section 1.5 m x 1.5 m x 37 cm (15 X0) (1.39e5 1.5 m elements):
    - Cost of brass + fibers: 260 k euros
    - Cost of SiPM (1 per element): 970 k euros
    - (Cost of FERS: 9 M - will need optimisation)
  - HAD section 1.5 m x 1.5 m x 2.5 m (5.6e5 elements)
    - Cost of brass + fibers: 1.8 M euros
    - (Readout cost small w.r.t. EM section)
  - Total (excluding EM FE and HAD readout): ~3.0 M euros

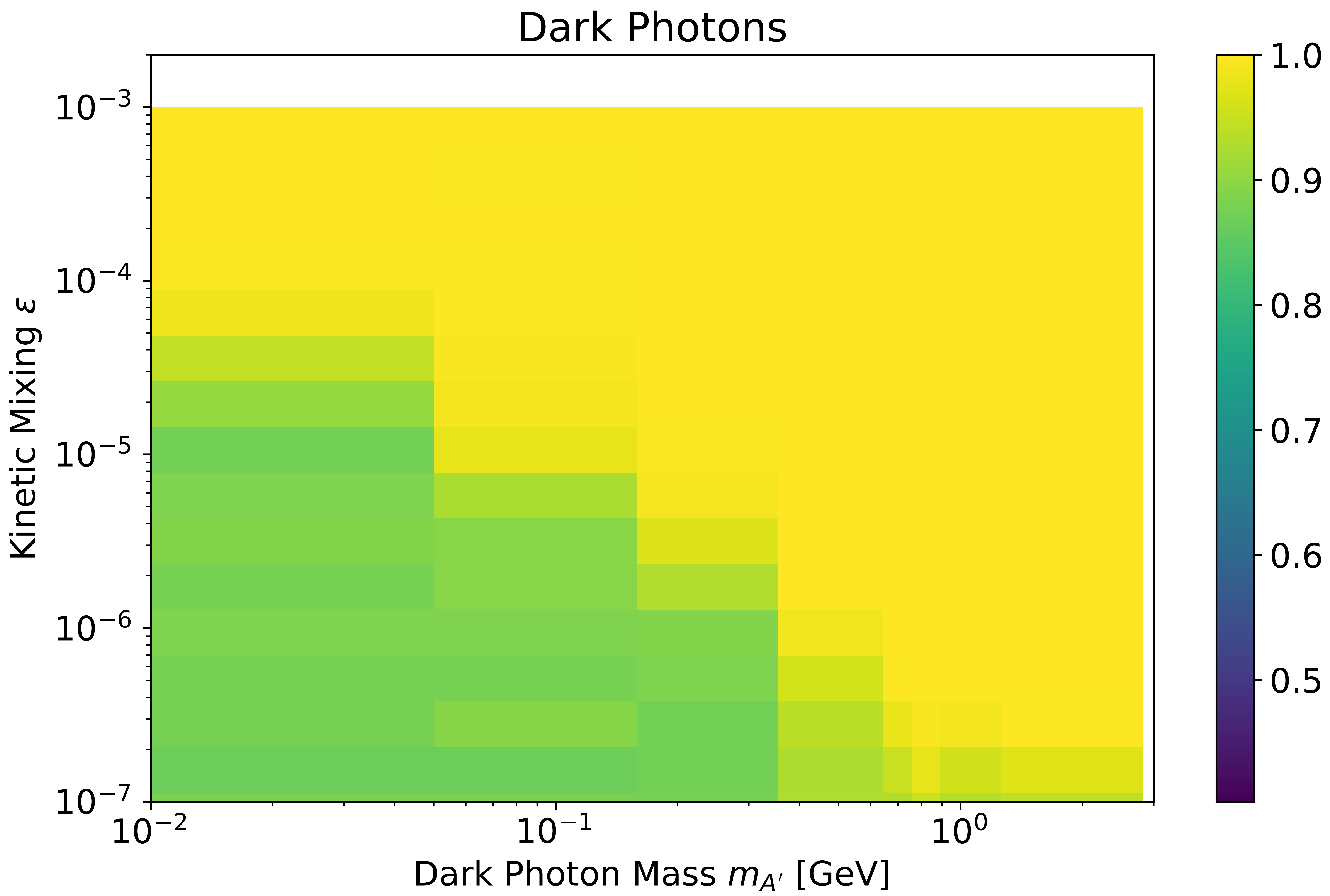
Envelope efficiency

- Env=DV



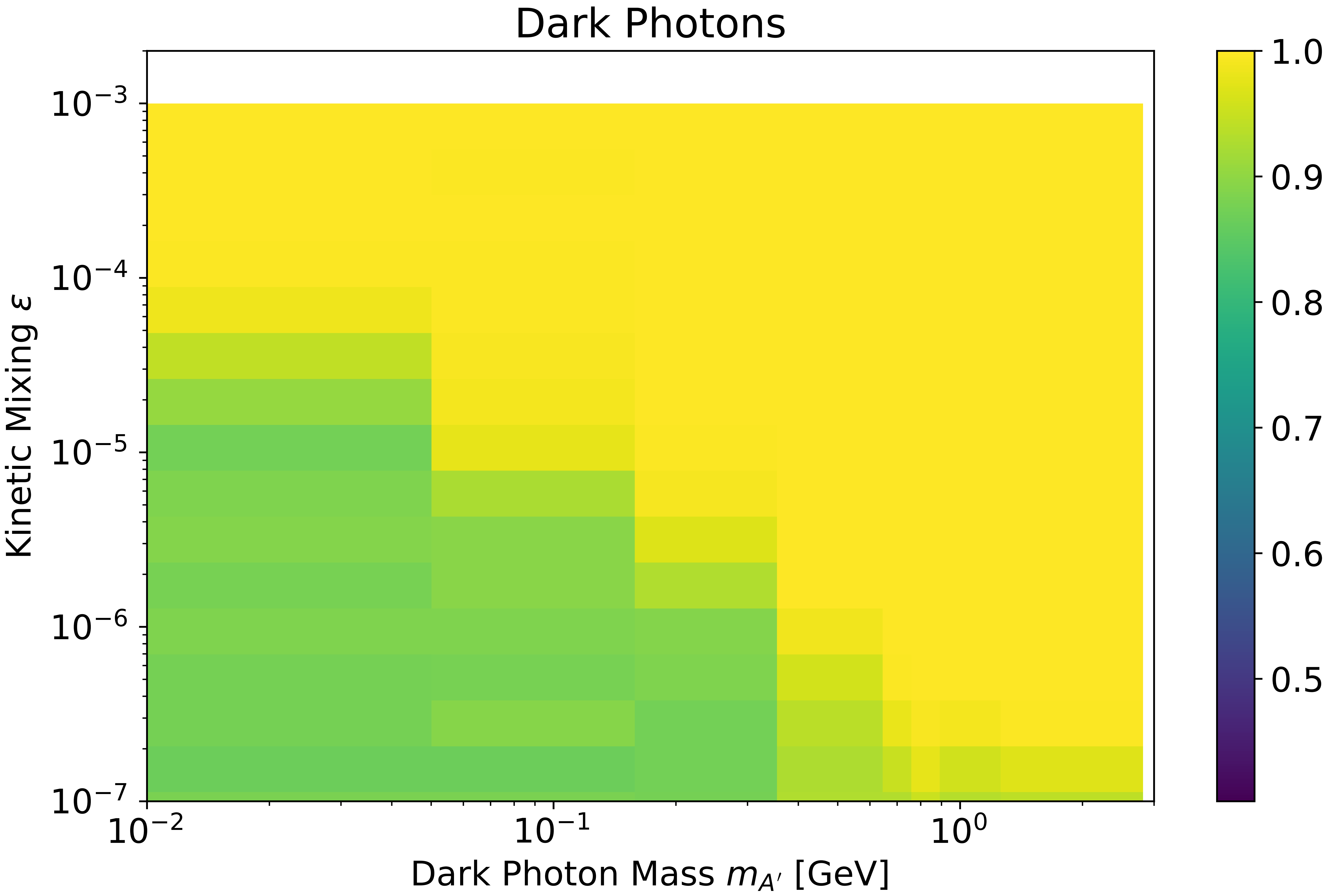
Envelope efficiency

- Env=DV-100mm (x-axis)



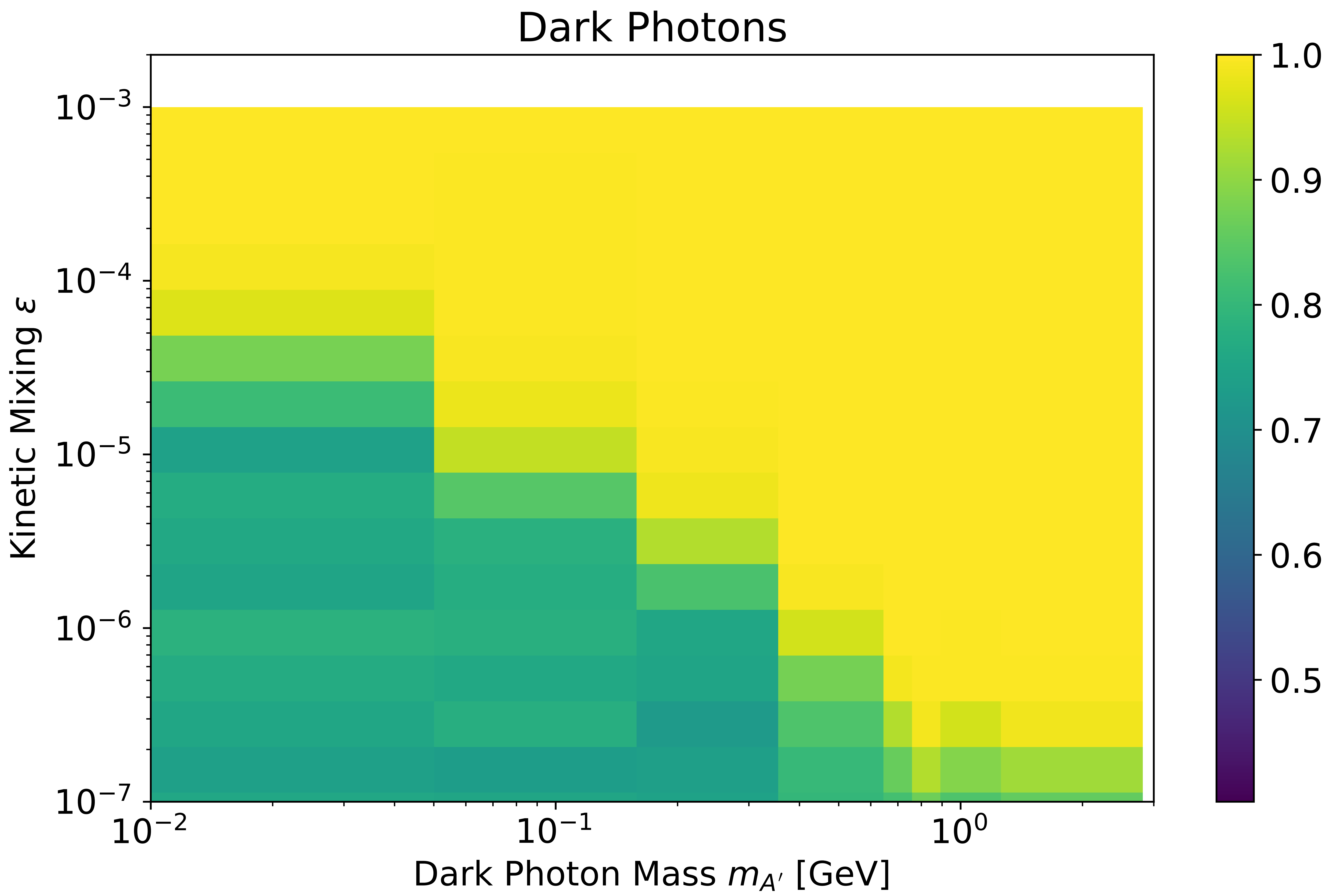
Envelope efficiency

- Env=DV-250mm (x-axis)



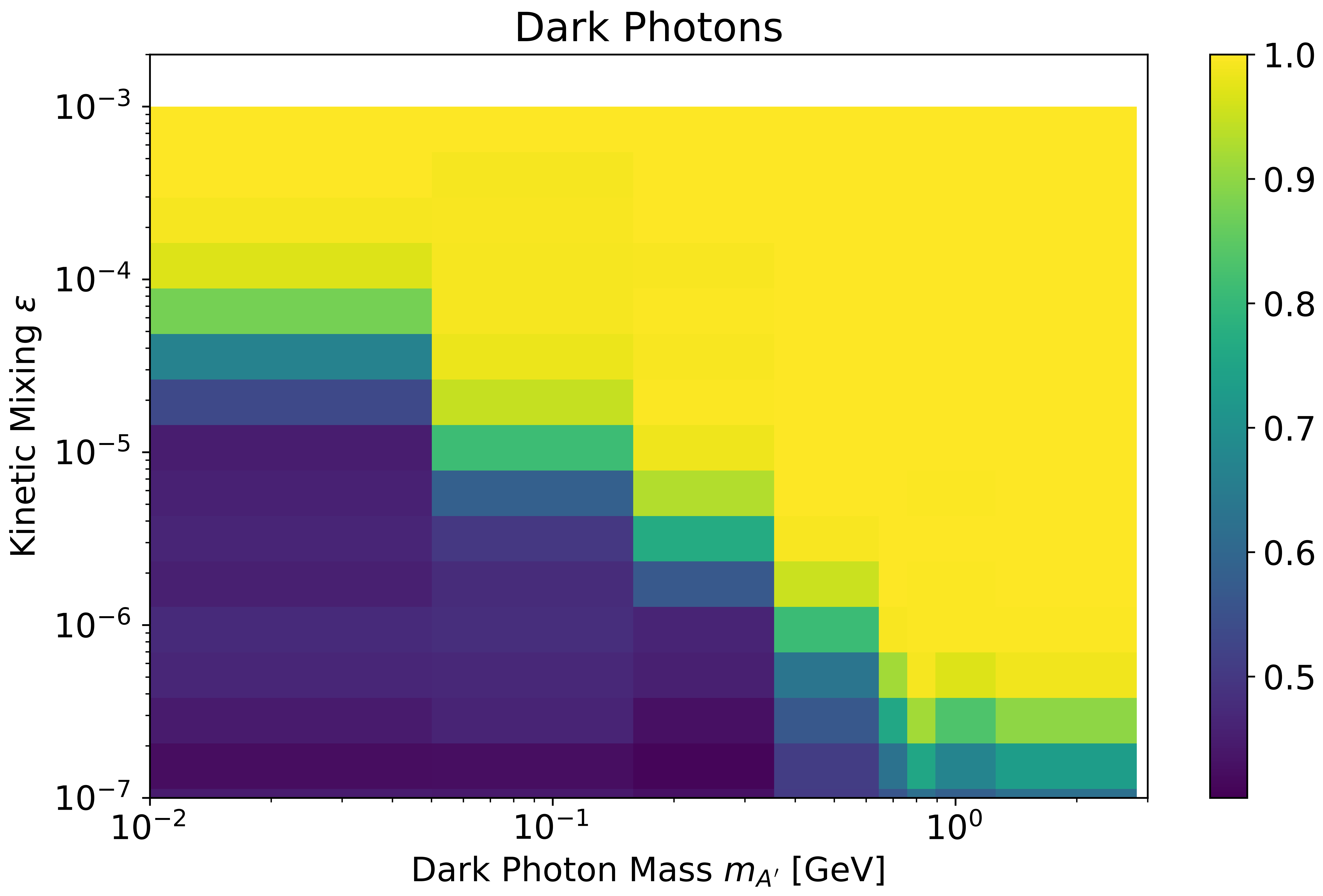
Envelope efficiency

- Env=DV-500mm (x-axis)



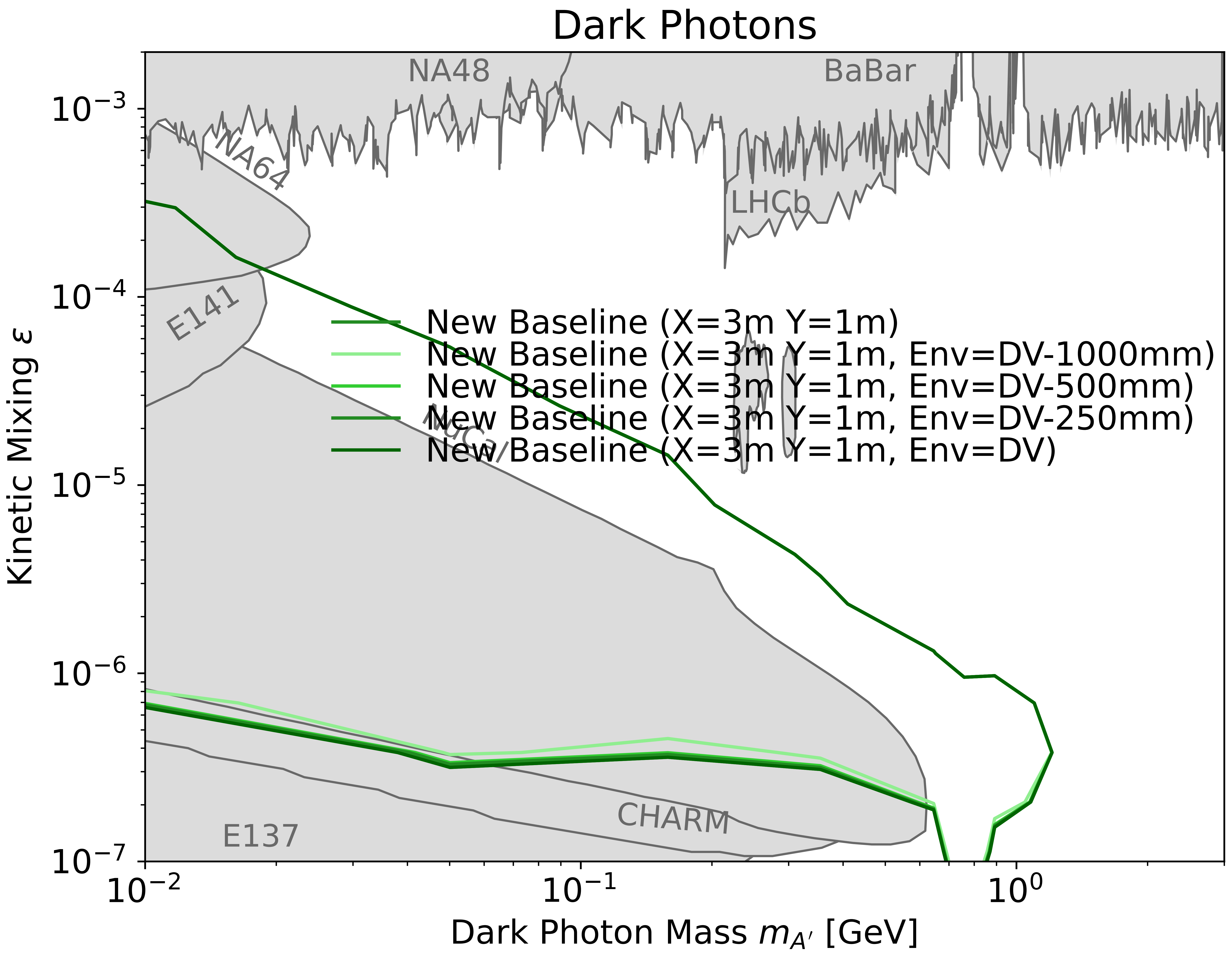
Envelope efficiency

- Env=DV-1000mm (x-axis)



Envelope efficiency

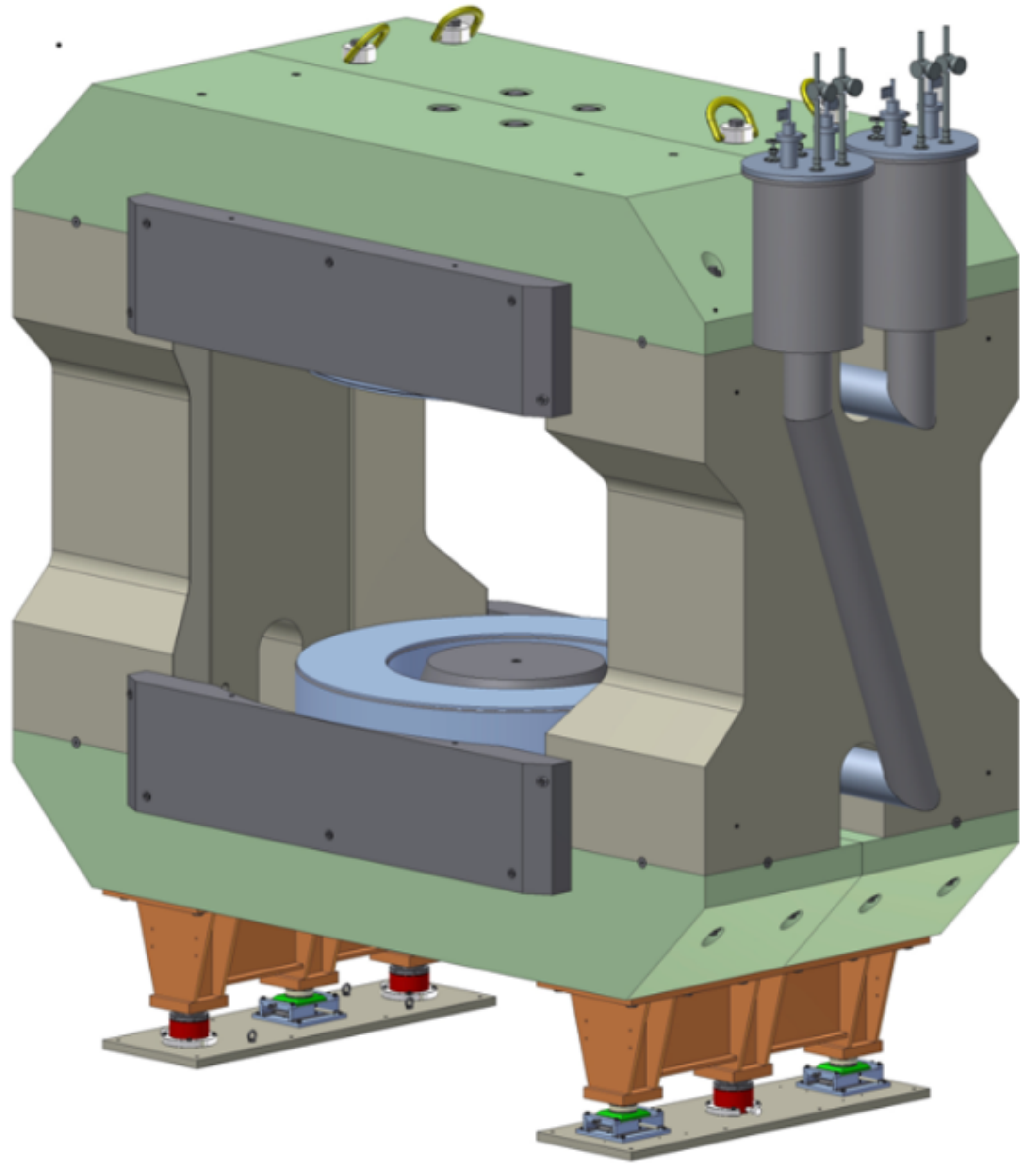
- Env=DV-1000mm (x-axis)



Magnets | Split solenoid dipole

- Split solenoid
  - Simplest design for superconducting dipole
  - Design for CMB experiment at FAIR
  - Use single strand superconductor
  - Easier thermal properties and available on market
  - 1TM bending power, aperture ~1x1x1m (TBC), stored energy 5MJ
  - Cost from industry (Bilfinger):
    - 3MCHF bare magnet, 4-4.5MCHF with PS/controls (not cryo)

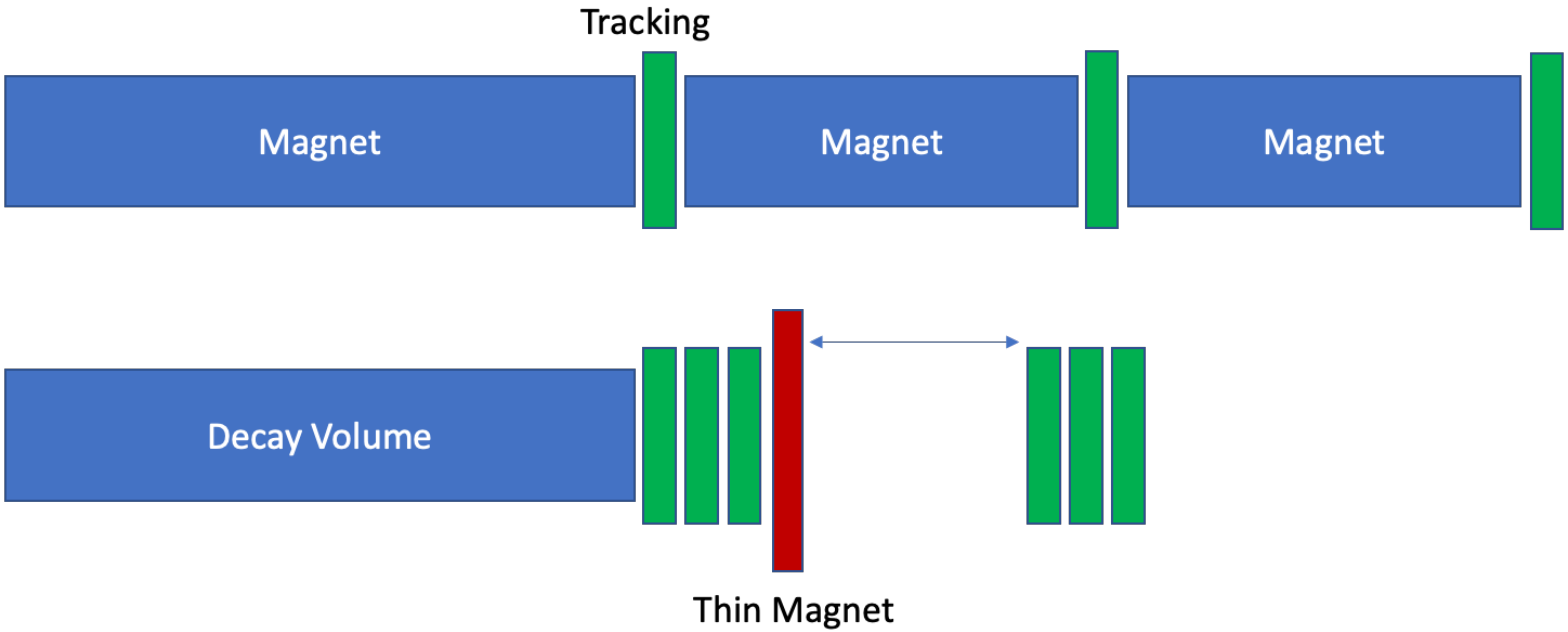
- Much more expensive for much less performance than we had been planning for



type	H-type, SC magnet
Number of turns per coil	1749
Windings of coil	Impregnated close coiling
Maximum current	686 *A*
Magnetomotive force	1.2 *MA* turns/coil
Current density,	58 A/mm^2
Maximum field at coil	3.25 *T*
Central field	1.08 *T*
Field integral	1 *Tm*
Inductance	33-19 *H*
Stored energy	5.15 *MJ*
Coil cross section (at 4K)	158.8x131.1 mm^2
Yoke (widh/depth/height)	4.4/2.0/3.7 *m*
Pole type	Tapered
Pole sizes (Rout/Rin/H)	1200/800/500 *mm*

Magnets | LHCb-like configuration

- But could be used in FASER2 in a LHCb-like configuration:

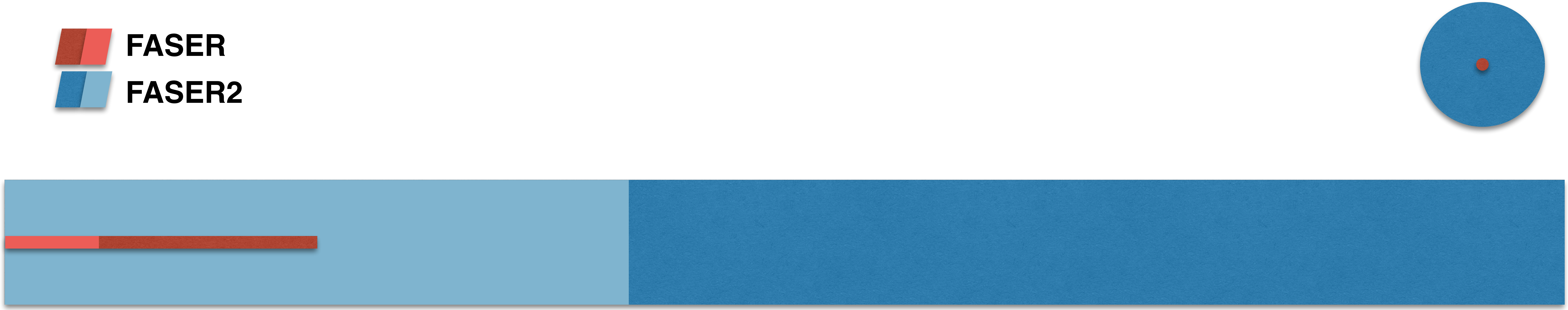


- Can imagine other comprises like reducing decay volume length for longer lever-arm for tracking
- Main take-away is that design studies essential start from scratch…

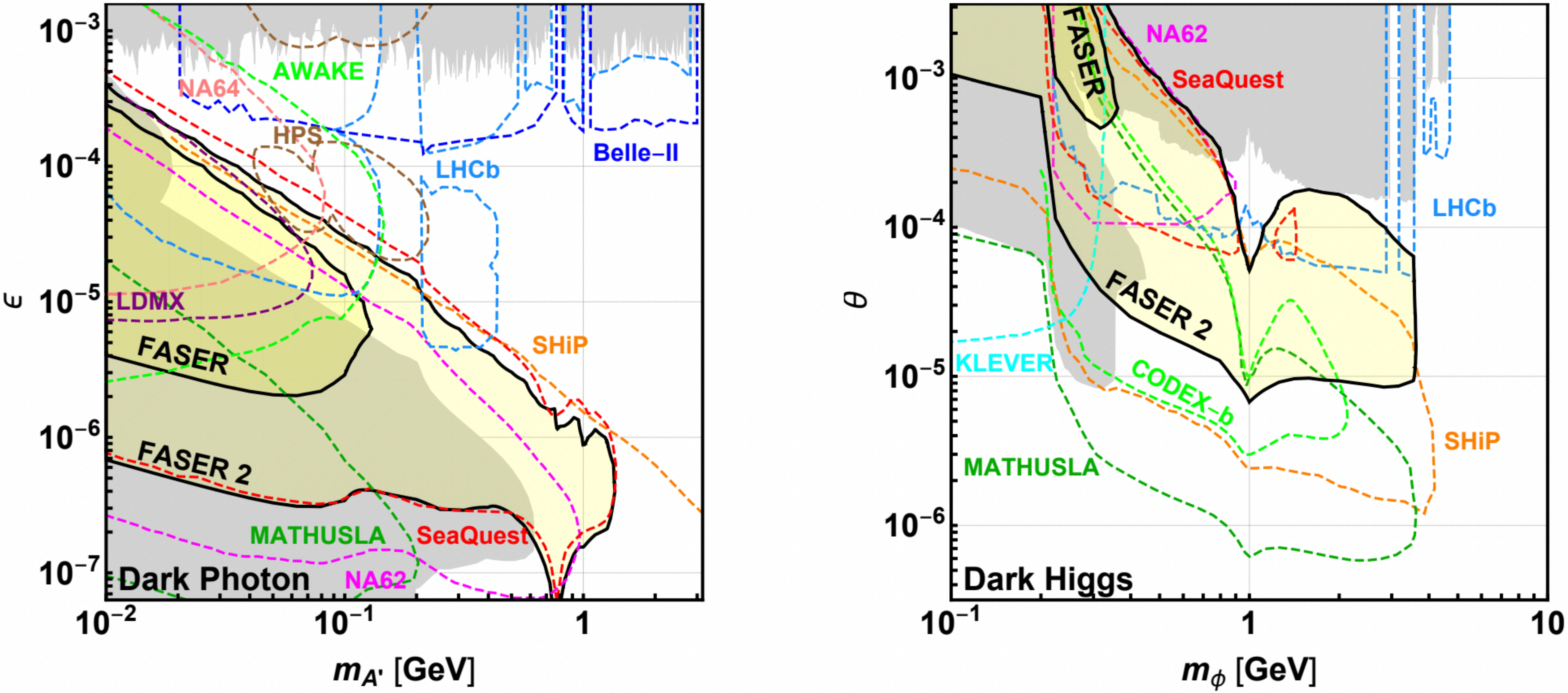
FASER vs FASER2

FASER

FASER vs FASER2

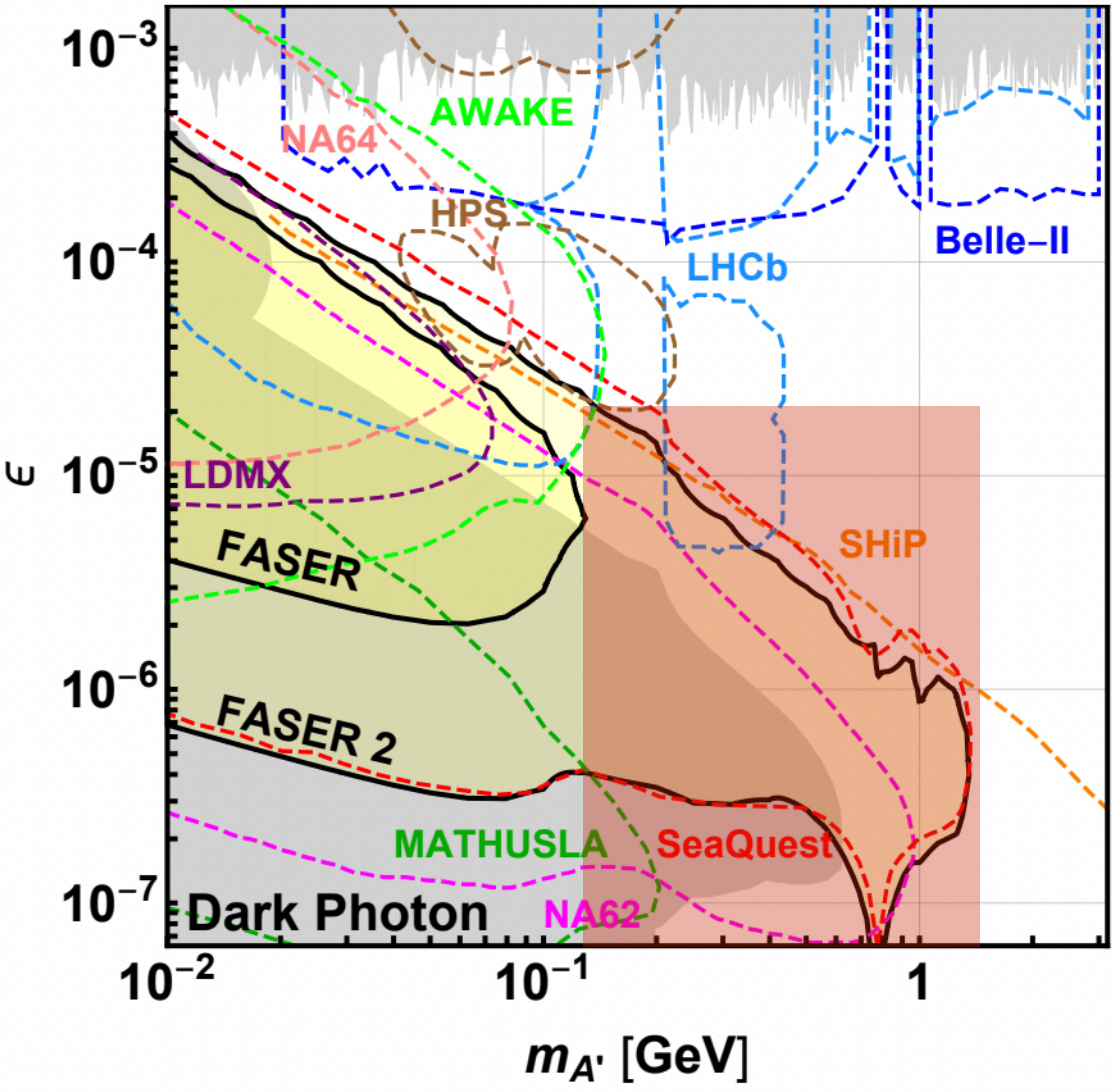


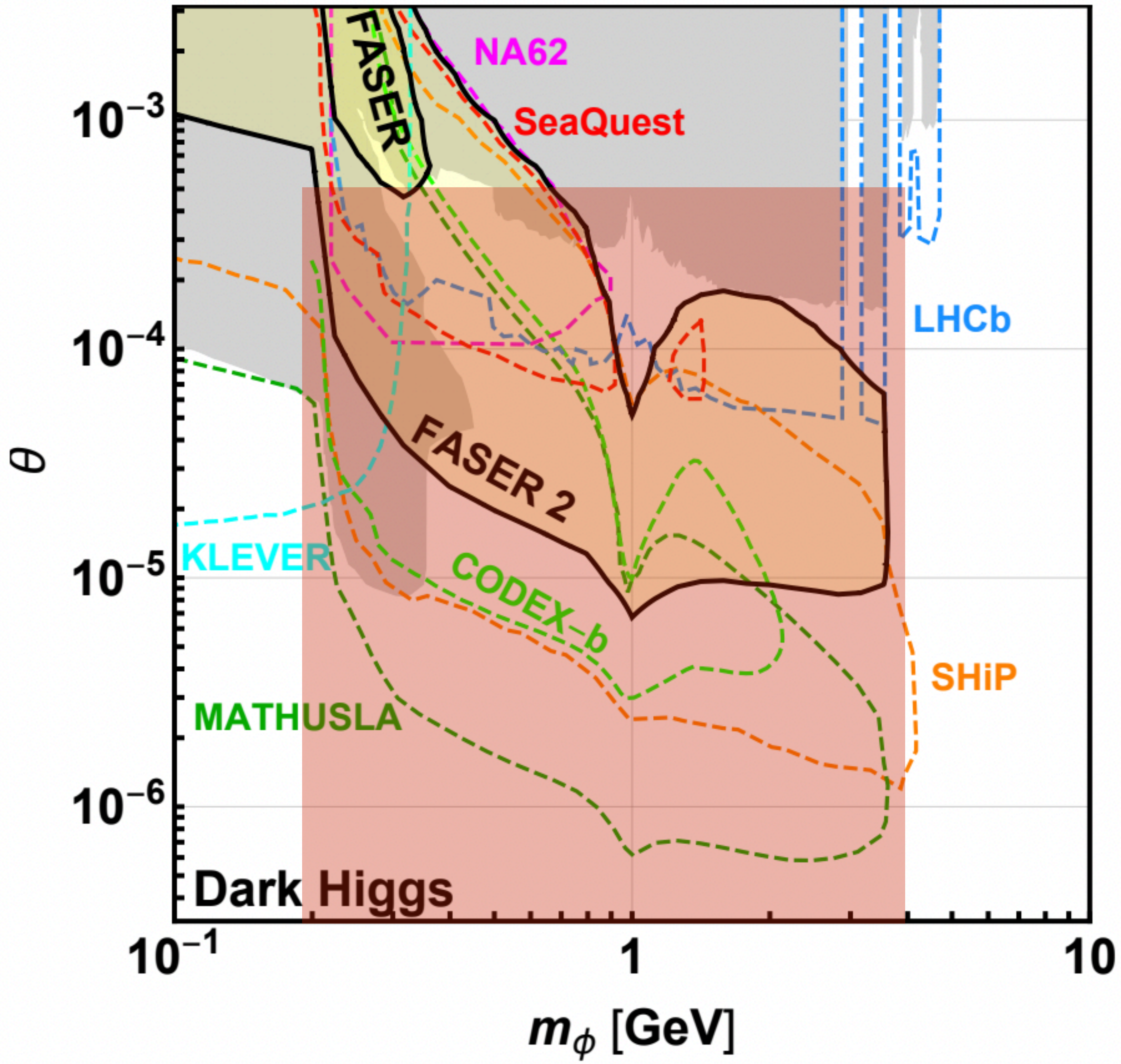
FASER2 Reach



[arXiv:1811.12522]

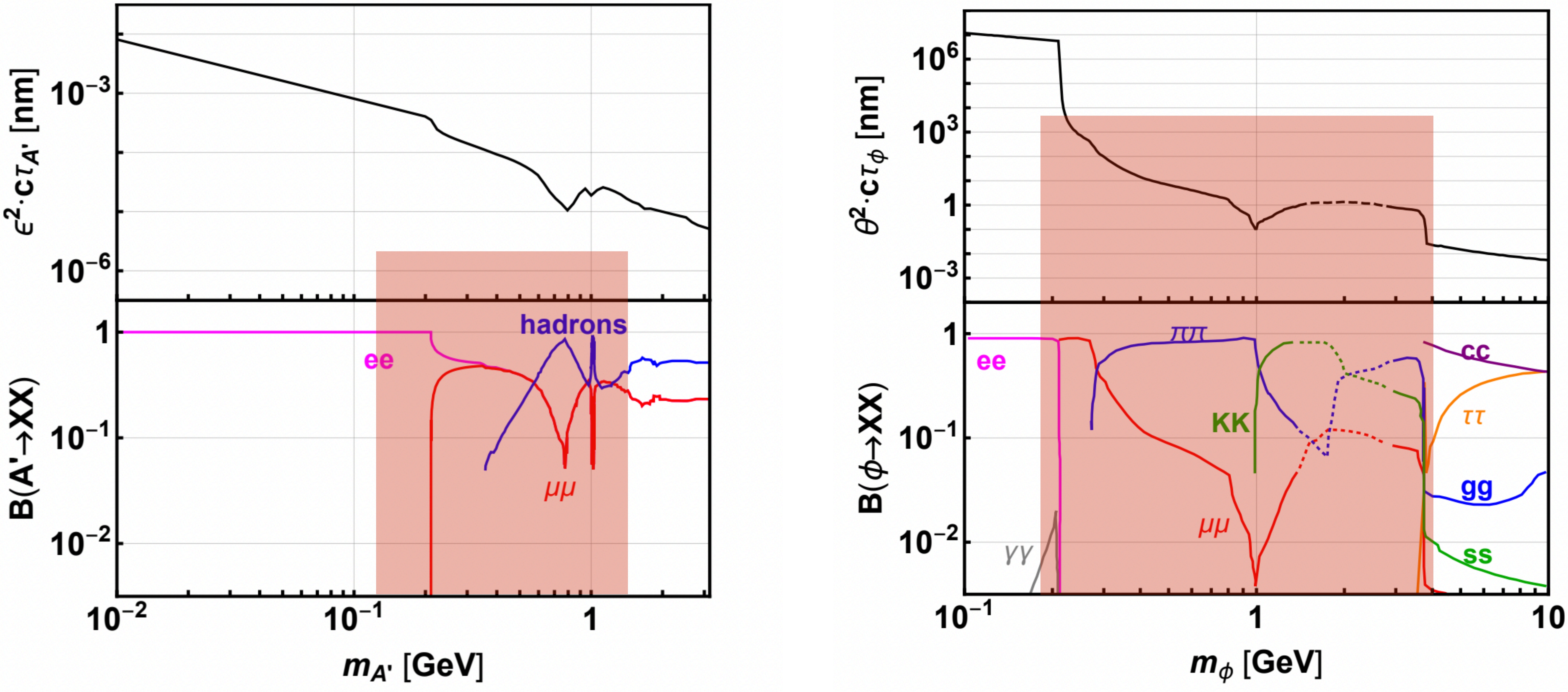
FASER2 Reach





[arXiv:1811.12522]

FASER2 Reach

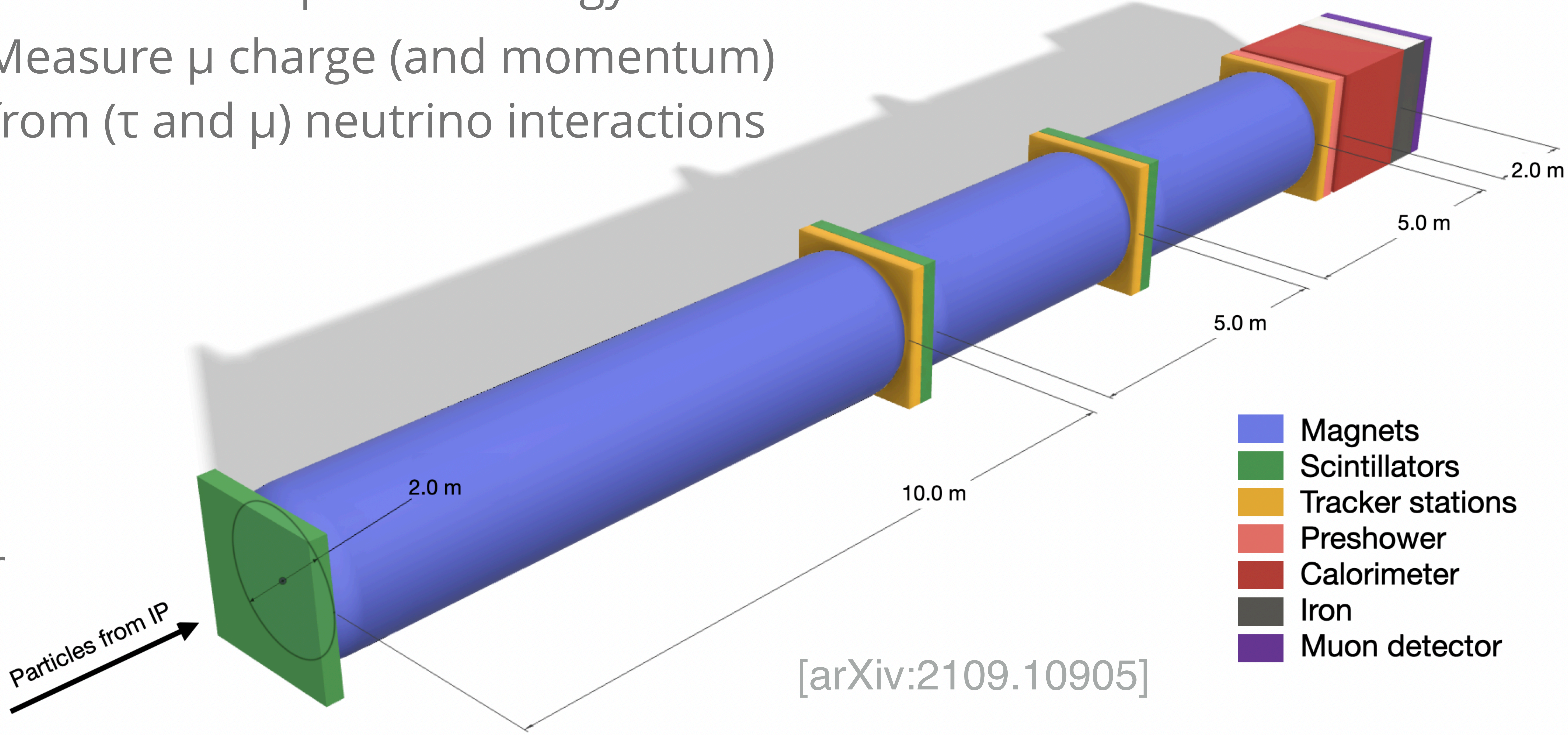


[arXiv:1811.12522]

FASER2 Design

- Design considerations for FASER2
  - Larger radius → Being on-axis less important
  - More decay channels → Need for particle ID
  - Larger detector → Larger background rate
    → Different/cheaper technology
  - Link to FASERν2 → Measure μ charge (and momentum) from (τ and μ) neutrino interactions

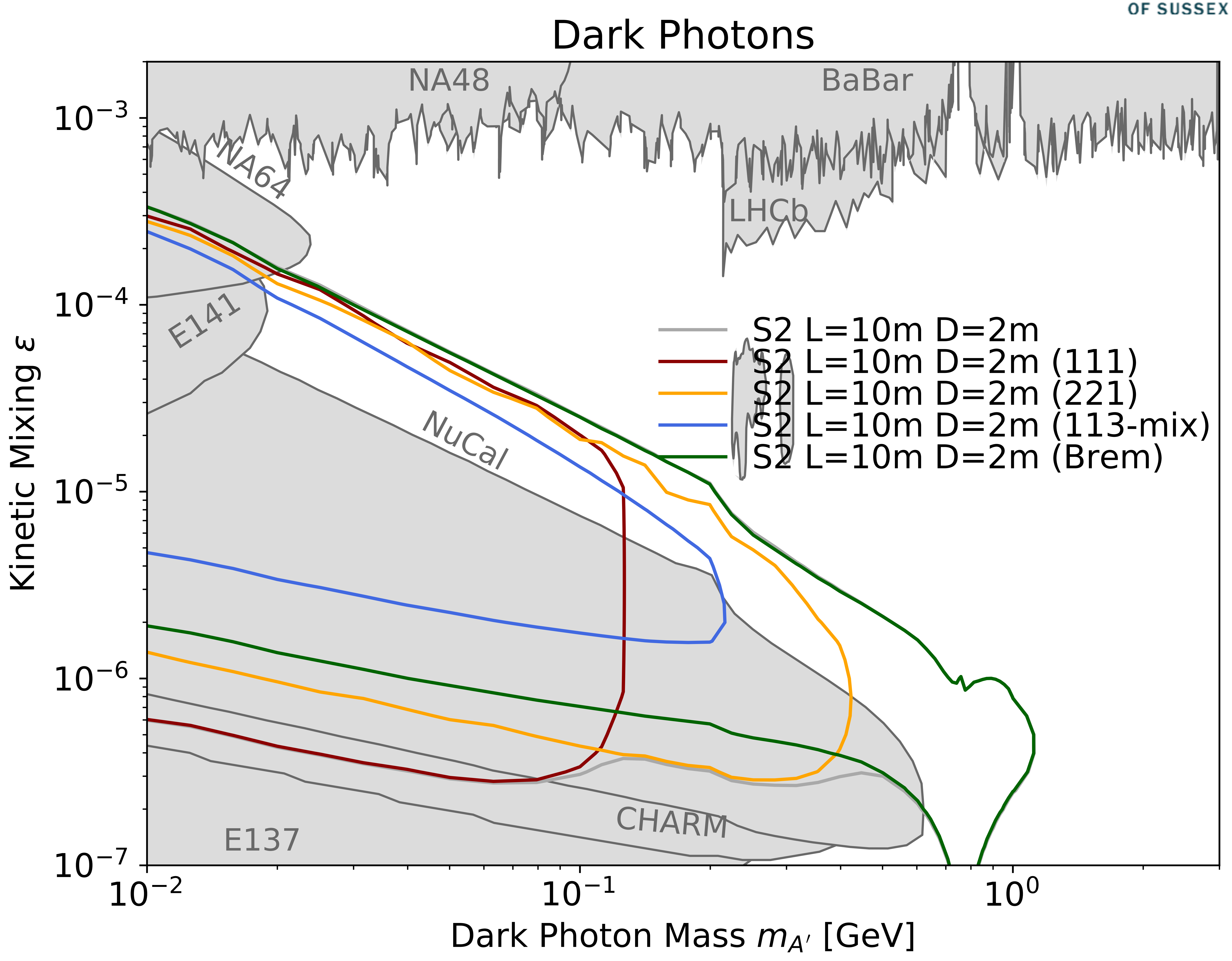
- Planned to be similar in philosophy to FASER…
  - Still much to be studied in terms of possible detector configurations and technologies.



[arXiv:2109.10905]

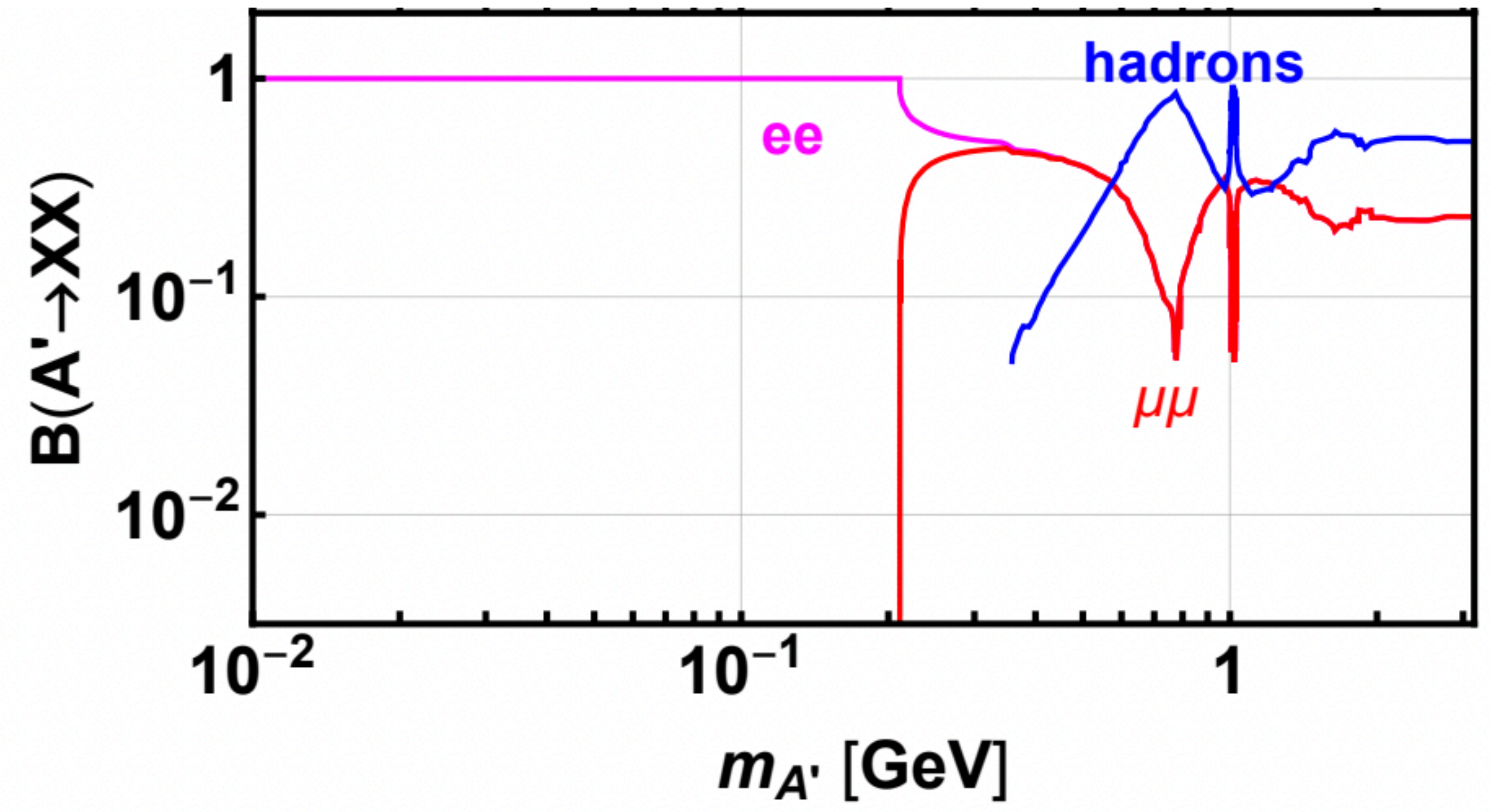
Simulation | FORESEE

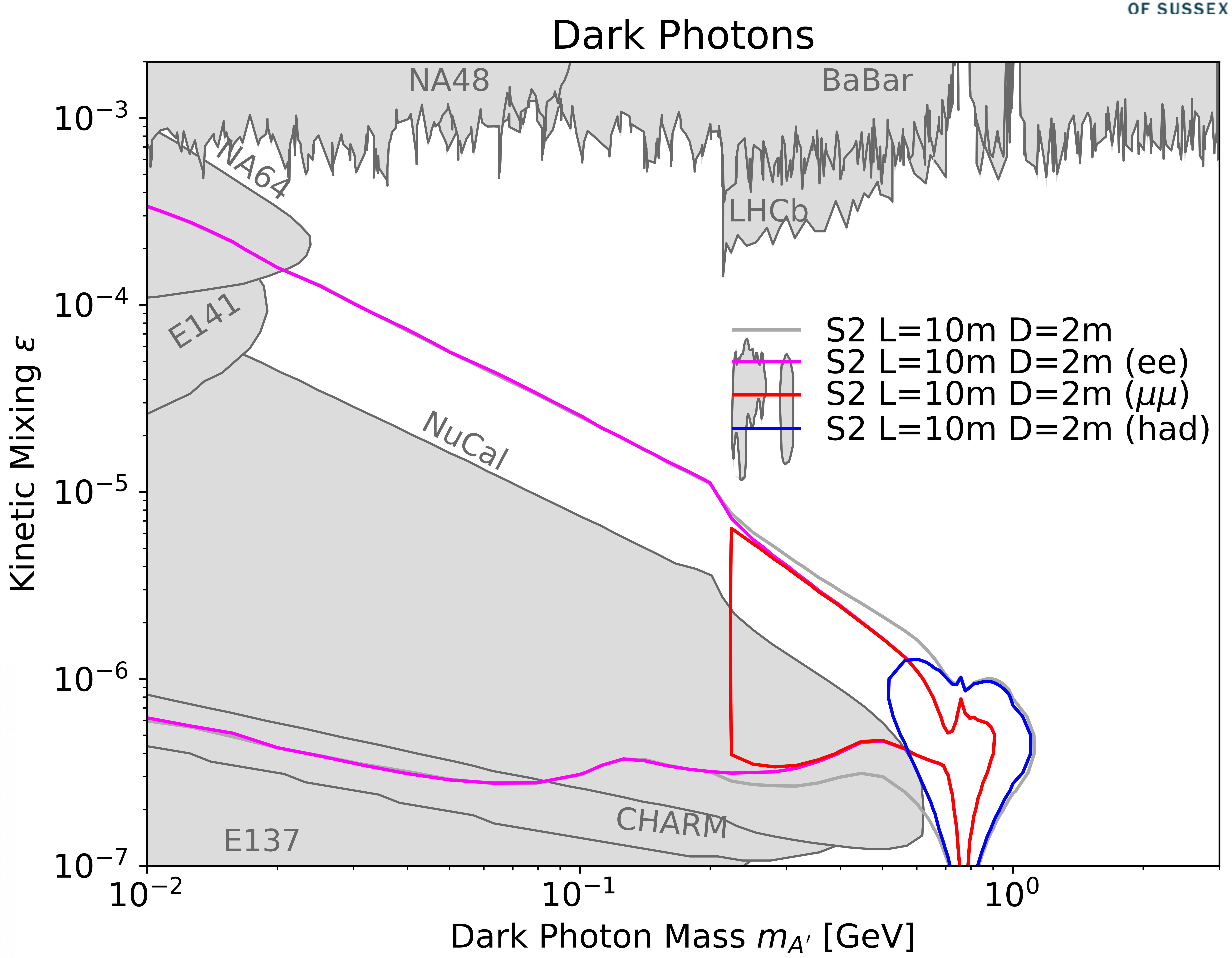
- Starting to use FORESEE and GEANT to perform simple simulations and investigate reach
  - Production modes rather different than for FASER
    - Pion decay at low mass
    - Then eta decay
    - Then Dark Bremsstrahlung



Simulation | FORESEE

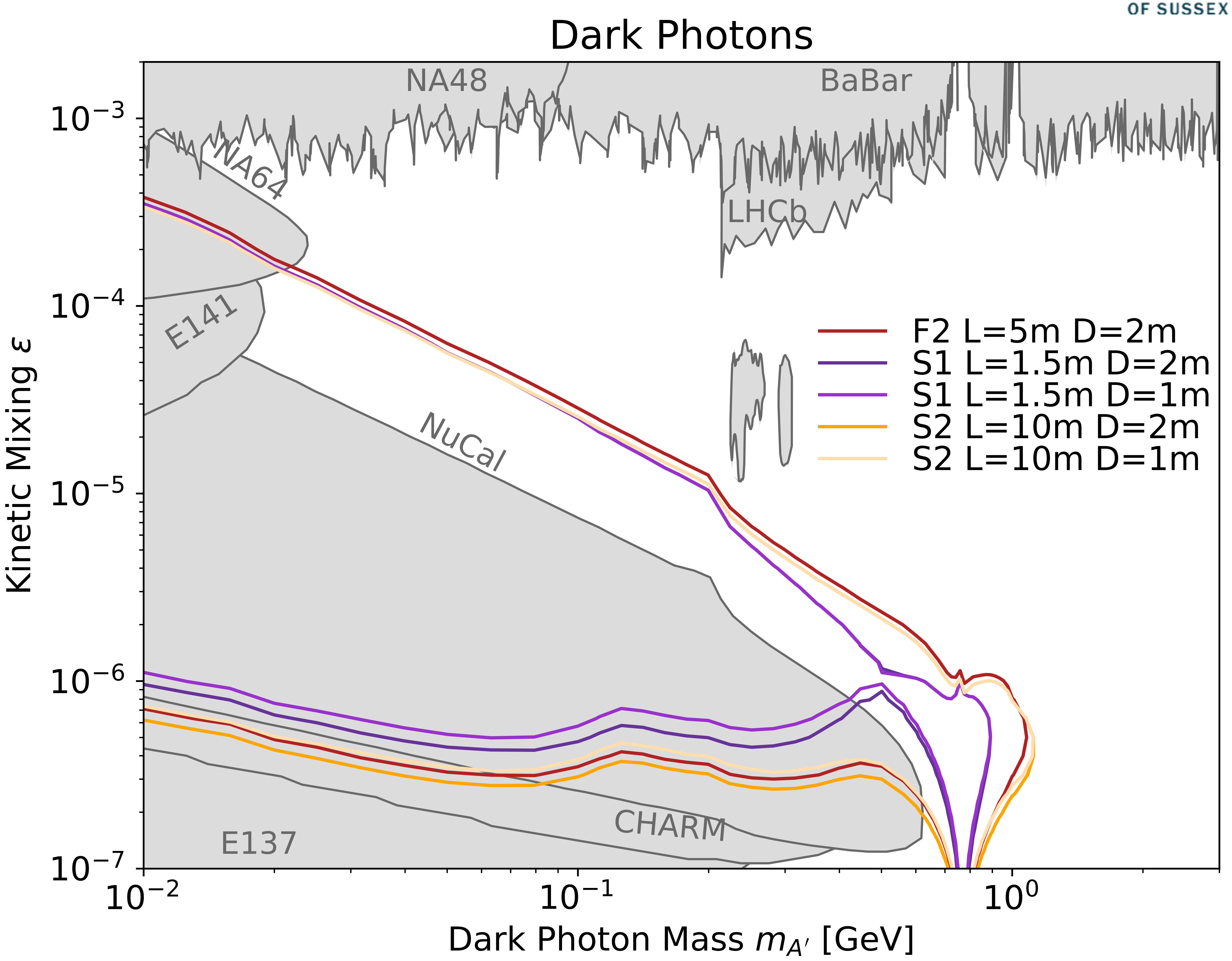
- Starting to use FORESEE and GEANT to perform simple simulations and investigate reach
  - Decay modes also very different to FASER
    - Electron decay at low mass
    - Muon decay
    - Hadrons





Simulation | FORESEE

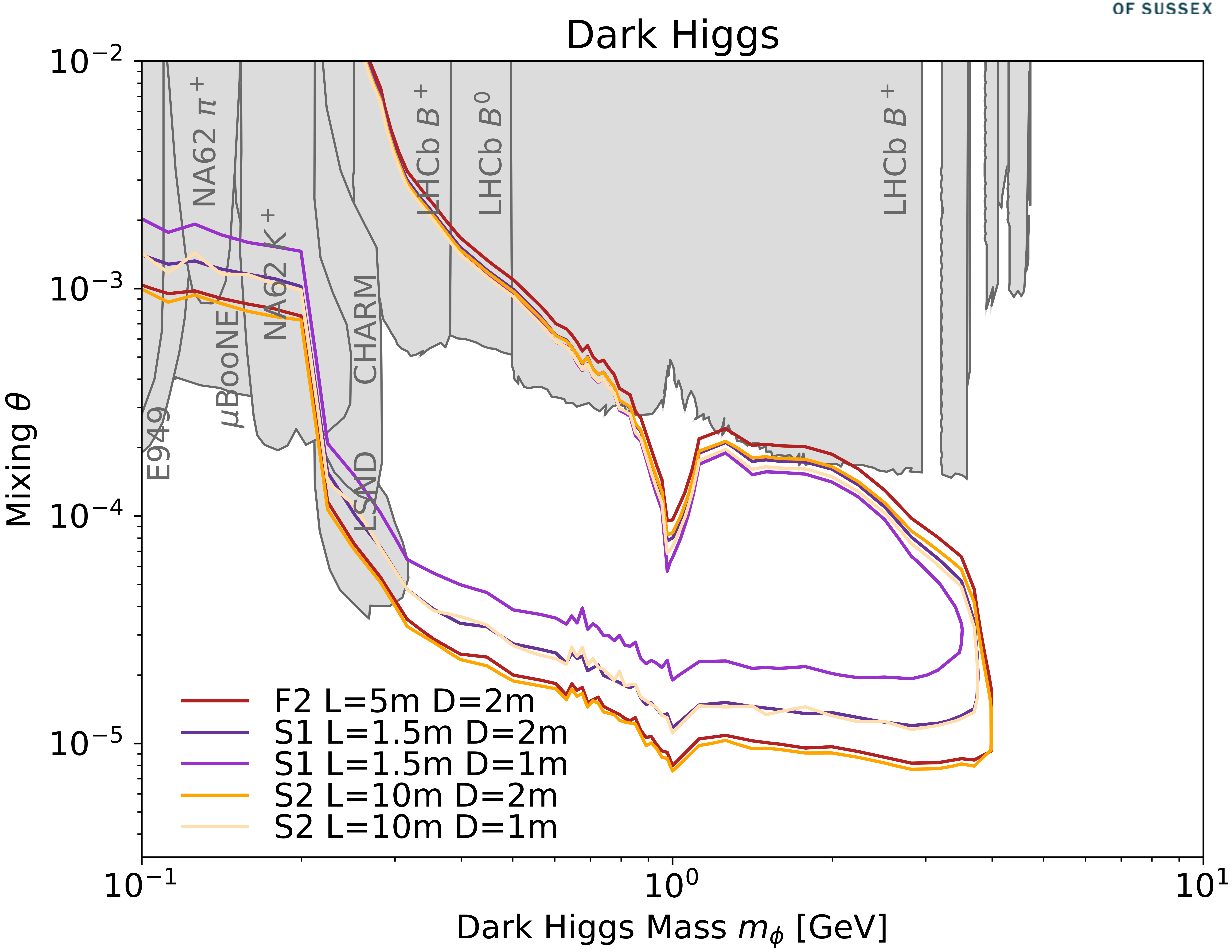
- **FASER2-default**
- **Scenario 1:**
  - Significantly degraded sensitivity due to reduced decay volume length
- **Scenario 2:**
  - Comparable sensitivity to FASER2-default, but somewhat improved due to larger decay volume length.
  - Very small degradation in diagonal due to increased distance from IP.



[arXiv:2109.10905]

Simulation | FORESEE

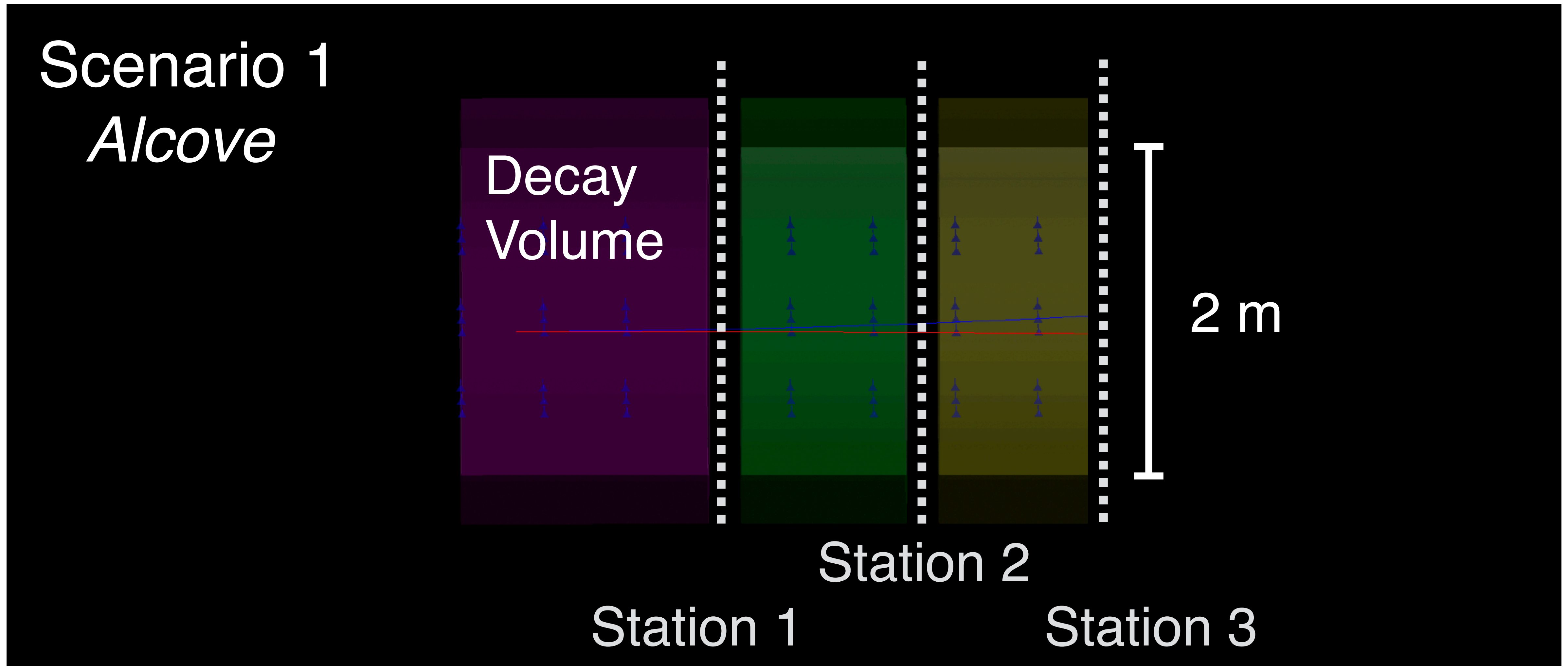
- **FASER2-default**
- **Scenario 1:**
  - Significantly degraded sensitivity due to reduced decay volume length
- **Scenario 2:**
  - Diameter of detector much more important here. Due to larger angle emission from B-hadrons of LLP.

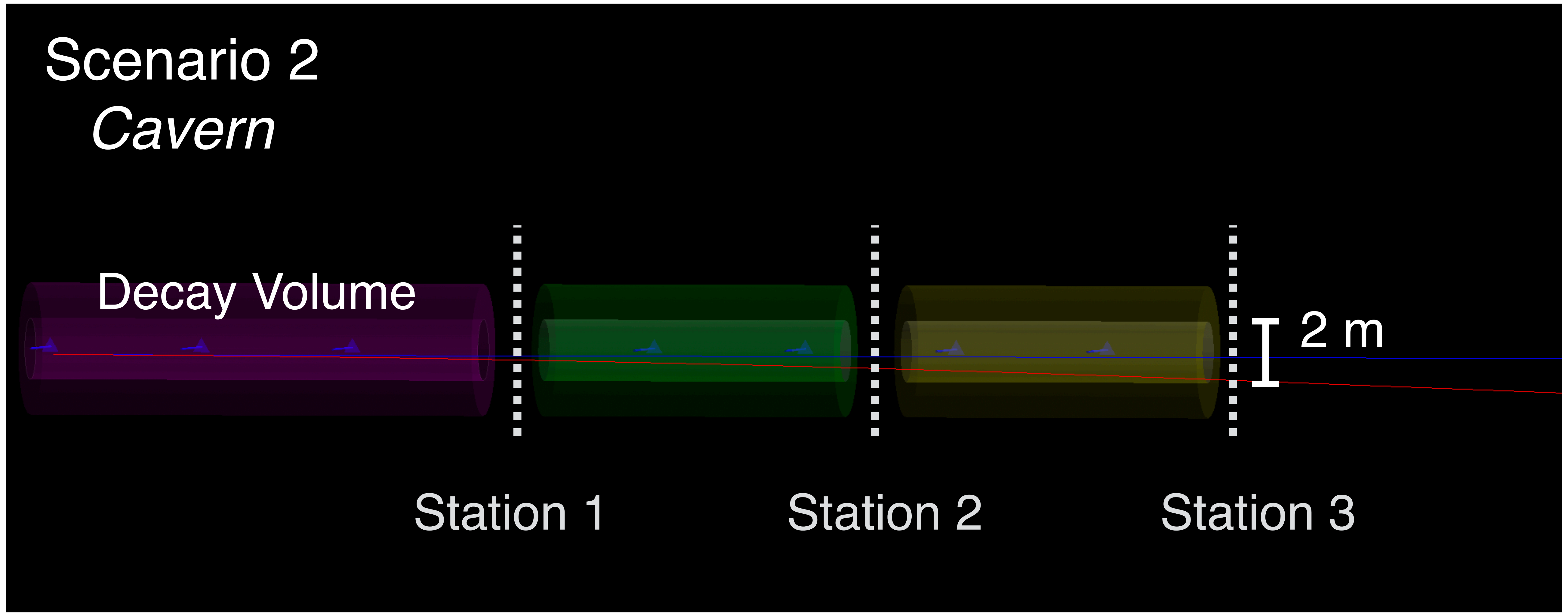


[arXiv:2109.10905]

Simulation | Geant4

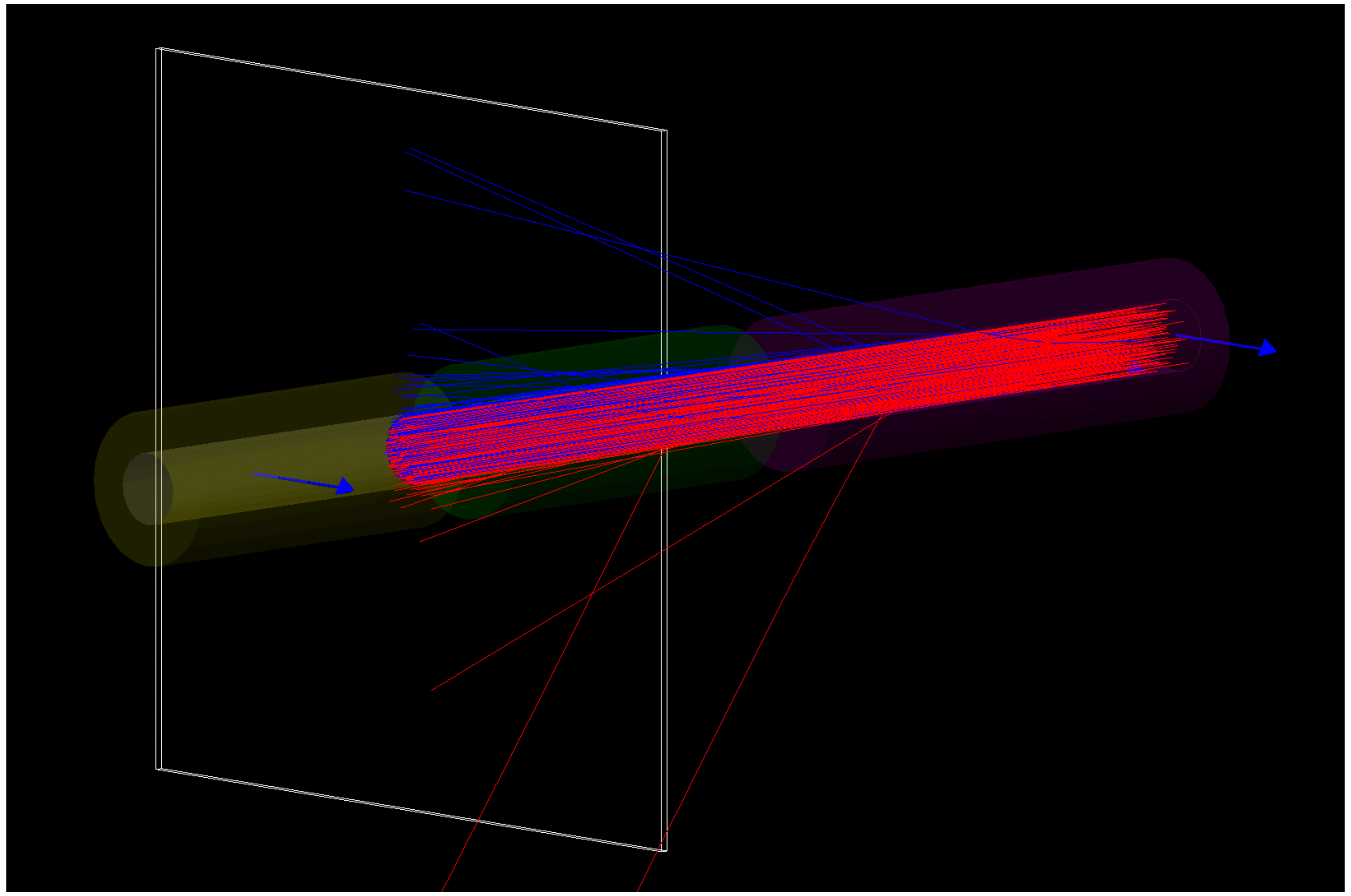
- Geant4 simulations of possible FASER2 designs
  - Focussing on magnets and particle separations
  - Impacts tracker and calorimeter design considerations
- Using events generated with FORESEE as input to G4
  - LLP spectra and decays handled by FORESEE



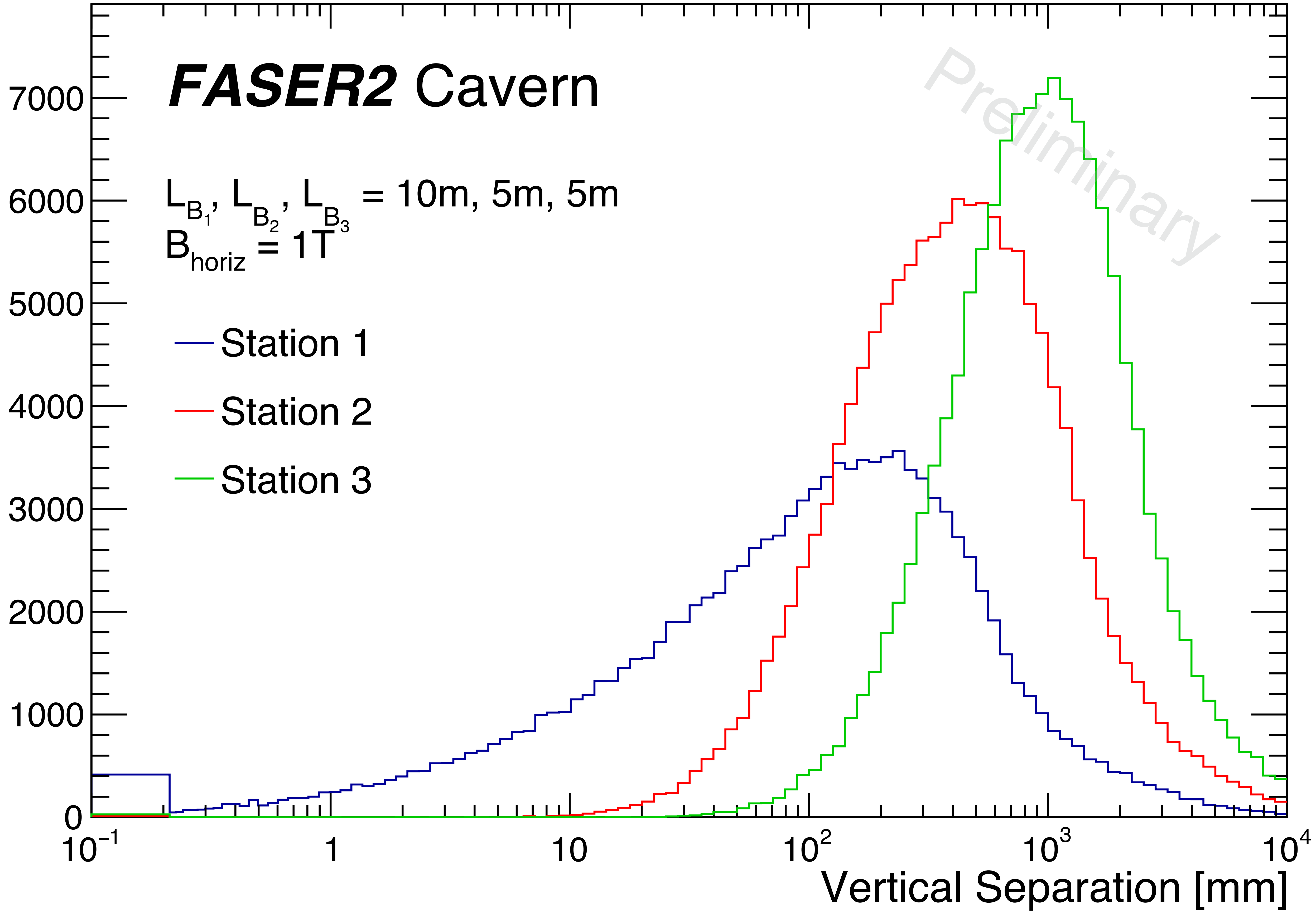


Simulation | Particle separations

- Use Geant for propagation of particles through magnetic field and measure positions at various "tracker" locations.



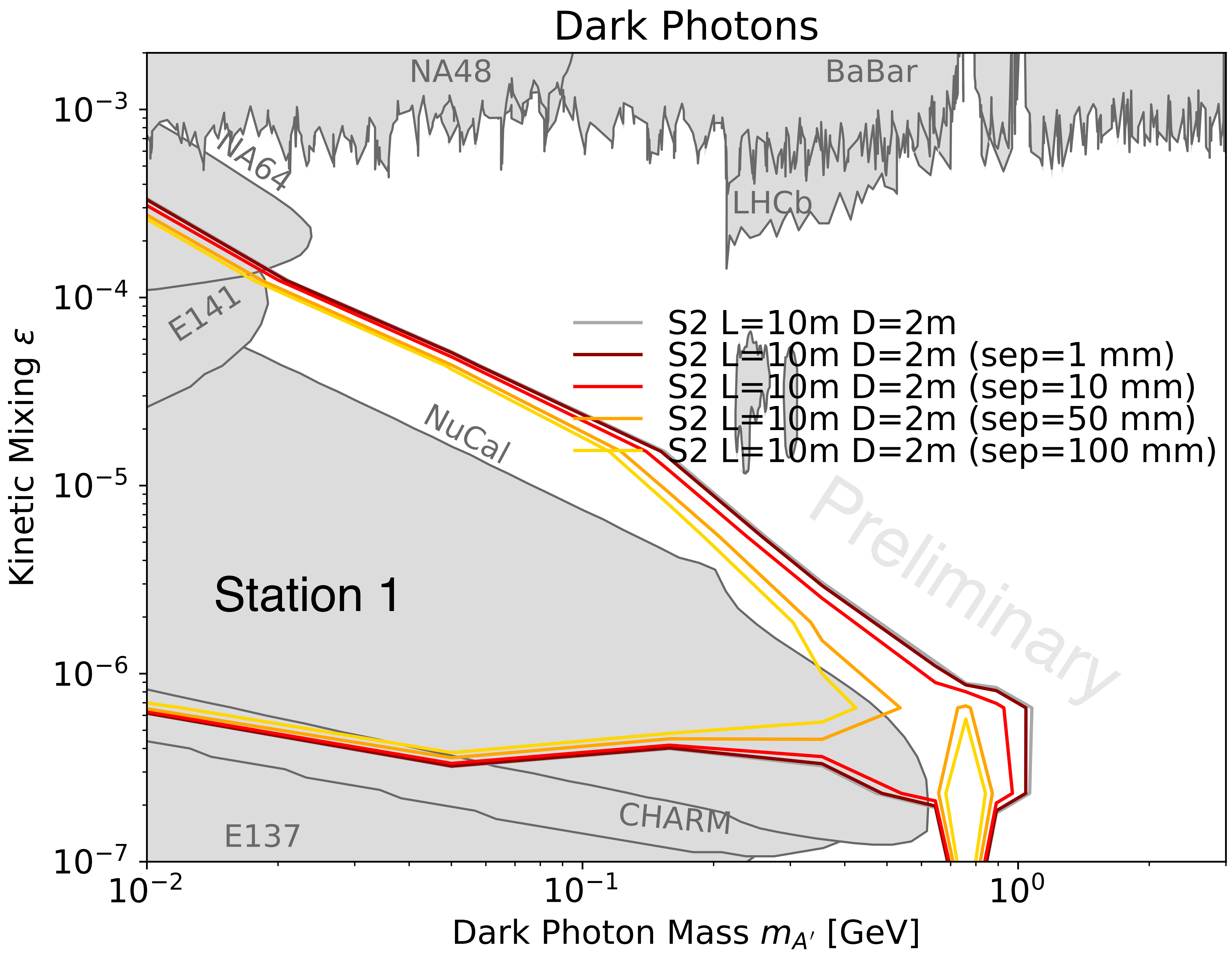
Dark Photon, $m_{A'}$ = 100 MeV

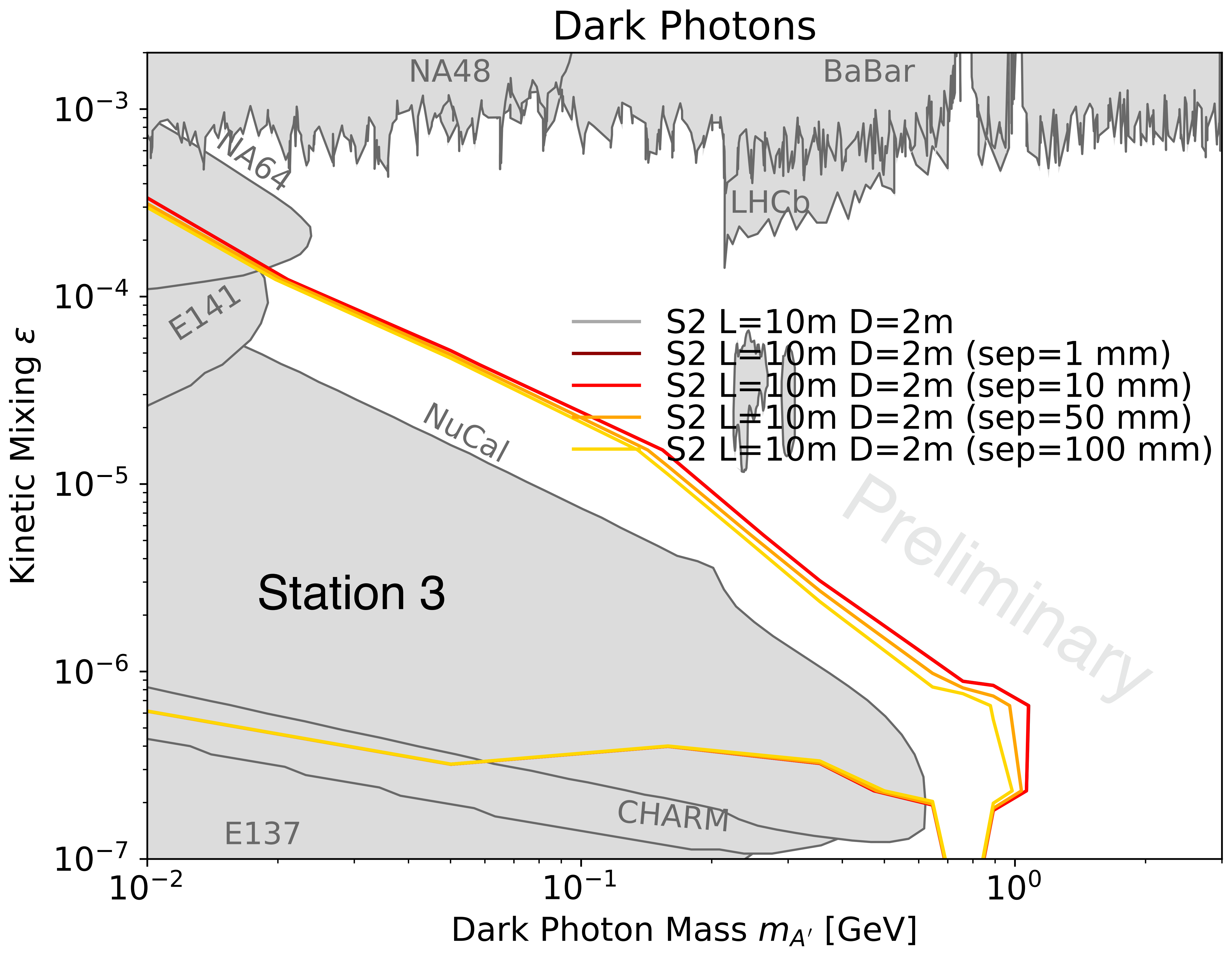


Simulation studies

UNIVERSITY OF SUSSEX

- **FPF Cavern Scenario**
  - At 1st tracker station loss of sensitivity comes between 1 and 10 mm separations.
  - At 3rd tracker station/calorimeter loss comes between 10 and 50 mm separations.

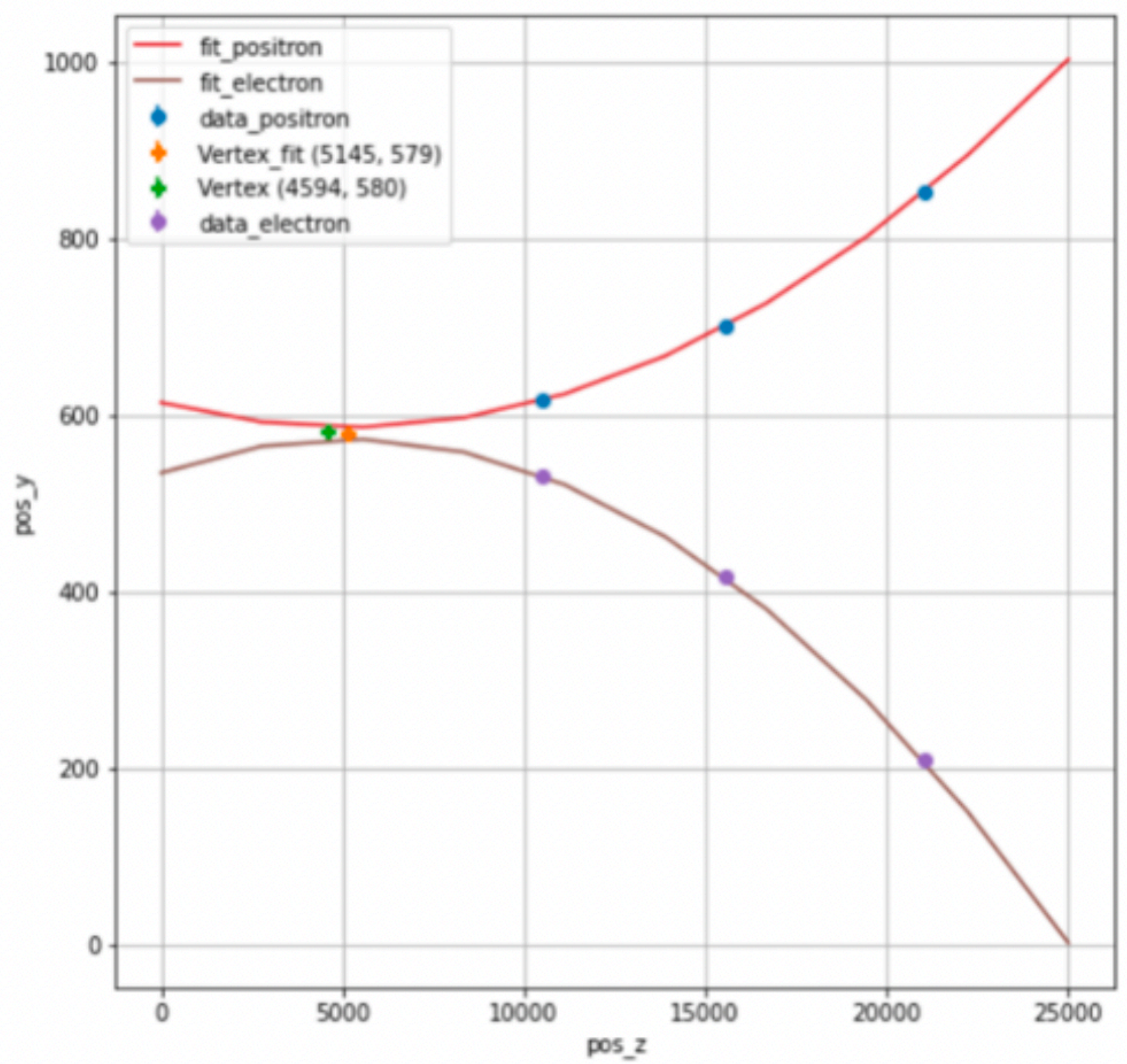




Tracking studies

- Simple tracking study with helix fit

Olivier Salin & Alan Barr (Oxford)



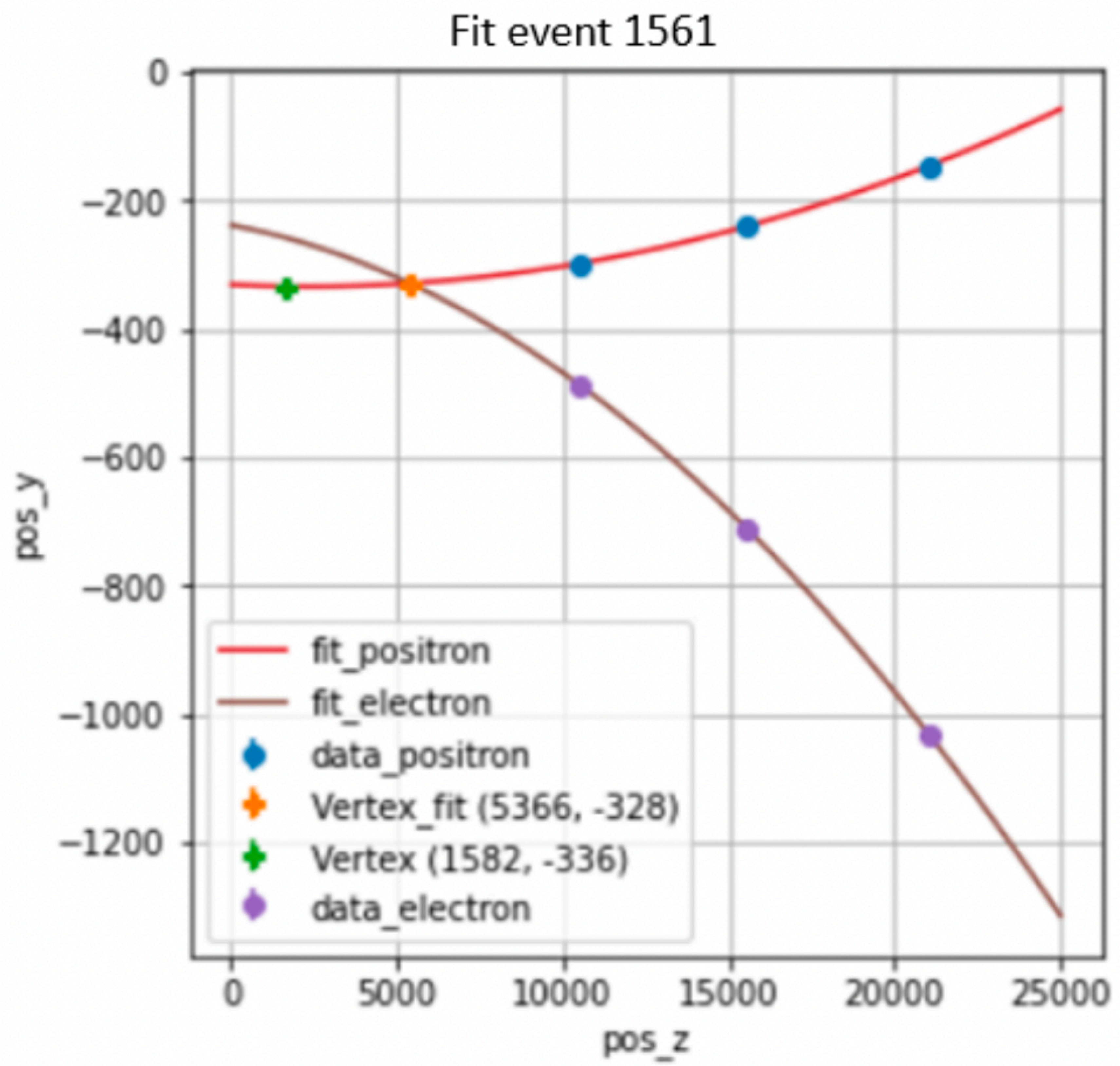
Distance between the FORESEE and the reconstructed Vertex : 550 mm

Radius e^+ : r_{fit}=472.87 m $r_{FORESEE}$ = 467.32 m

Relative error on momentum e+ : 1,18 %

Radius e^- : r_{fit}=345.36 m $r_{FORESEE}$ = 340.52 m

Relative error on momentum e- : 1,42 %



Distance between the FORESEE and the reconstructed Vertex : 3783 mm

Radius e^+ : r_{fit}=929.60 m $r_{FORESEE}$ = 898.61 m

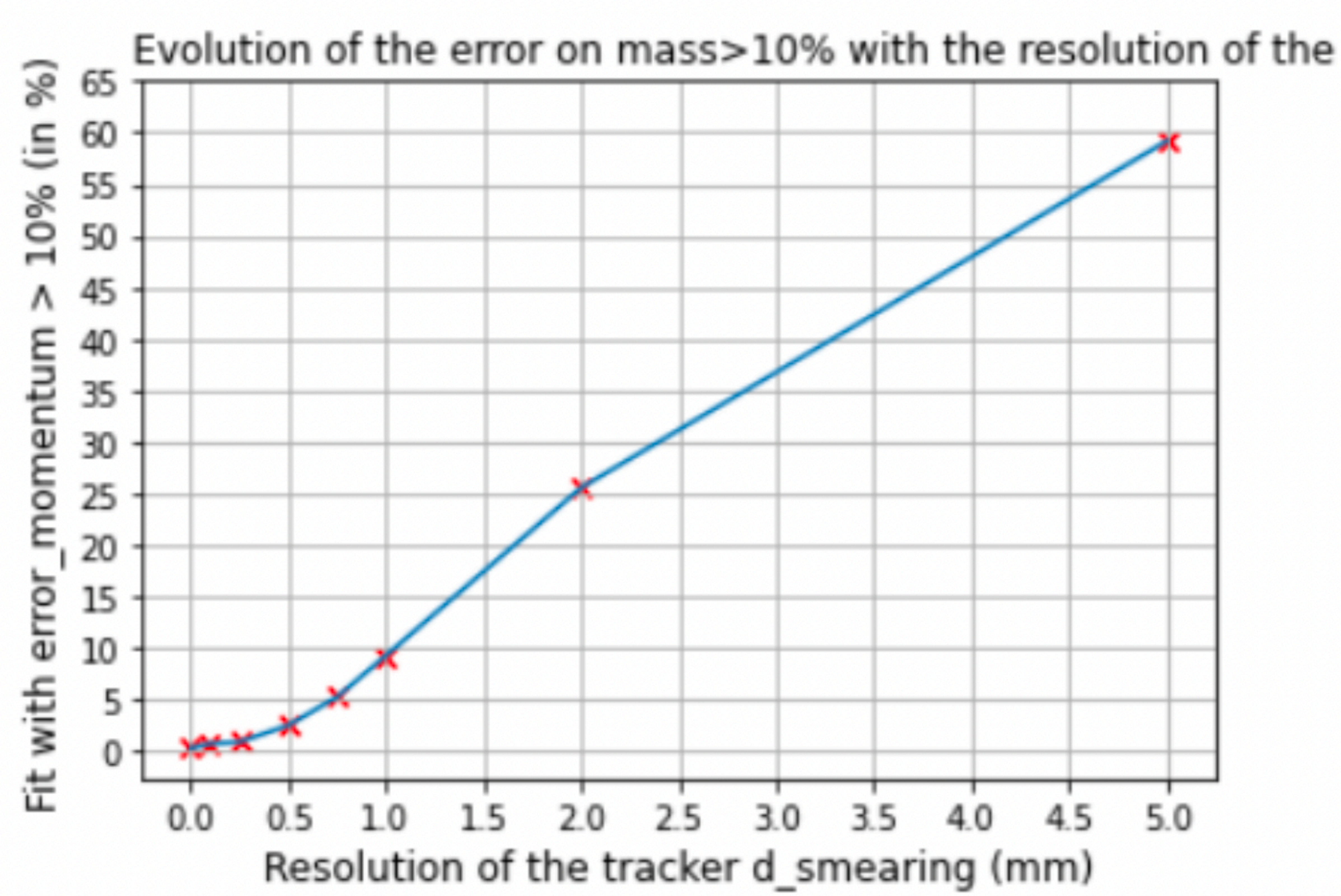
Relative error on momentum e+ : 3,44 %

Radius e^- : r_{fit}=375.67 m $r_{FORESEE}$ = 232.98 m

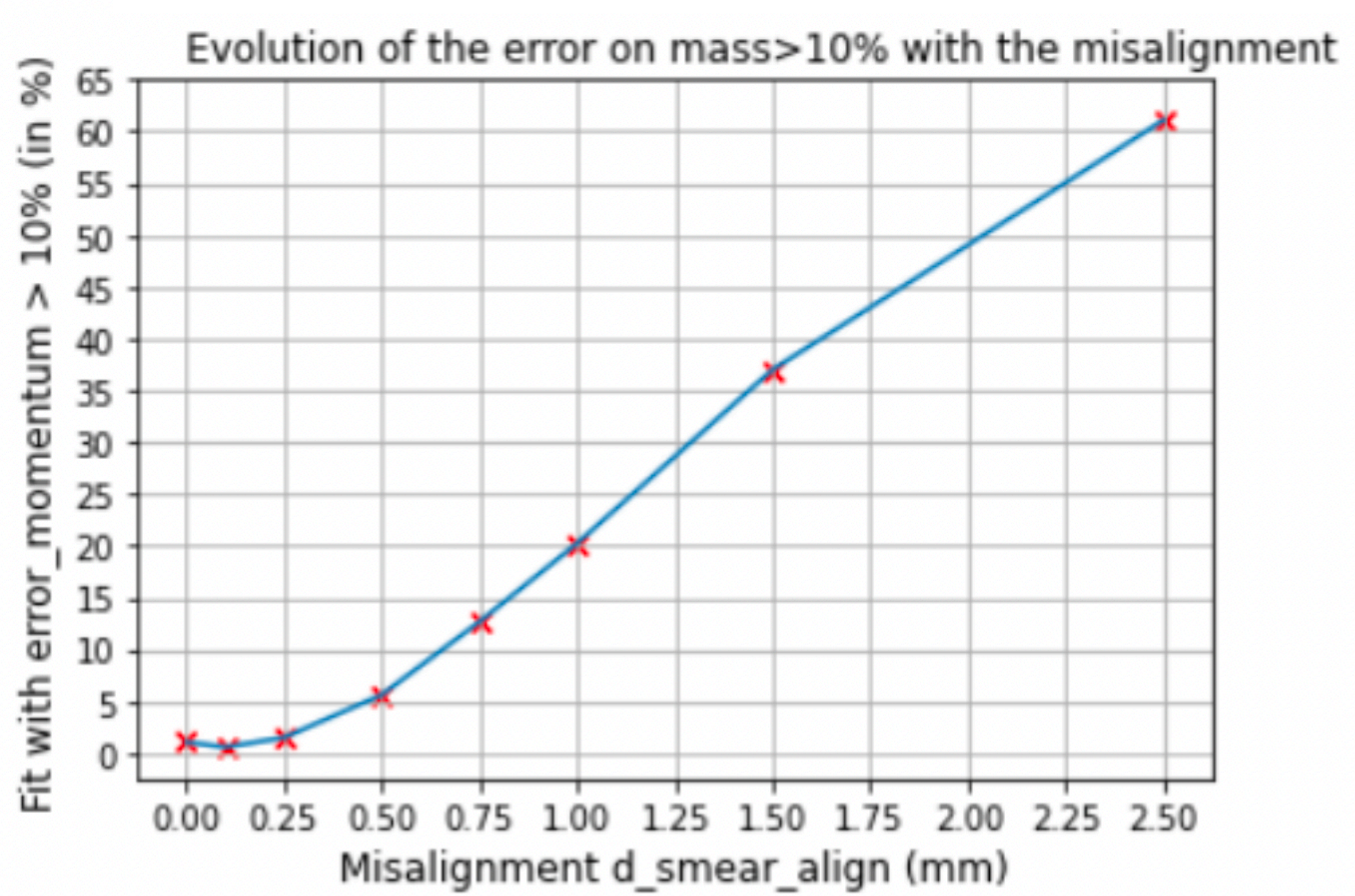
Relative error on momentum e- : 61,24 %

Tracking studies

- Momentum reco studies with detector resolution smearing & misalignment



Degradation from > ~700 μm?



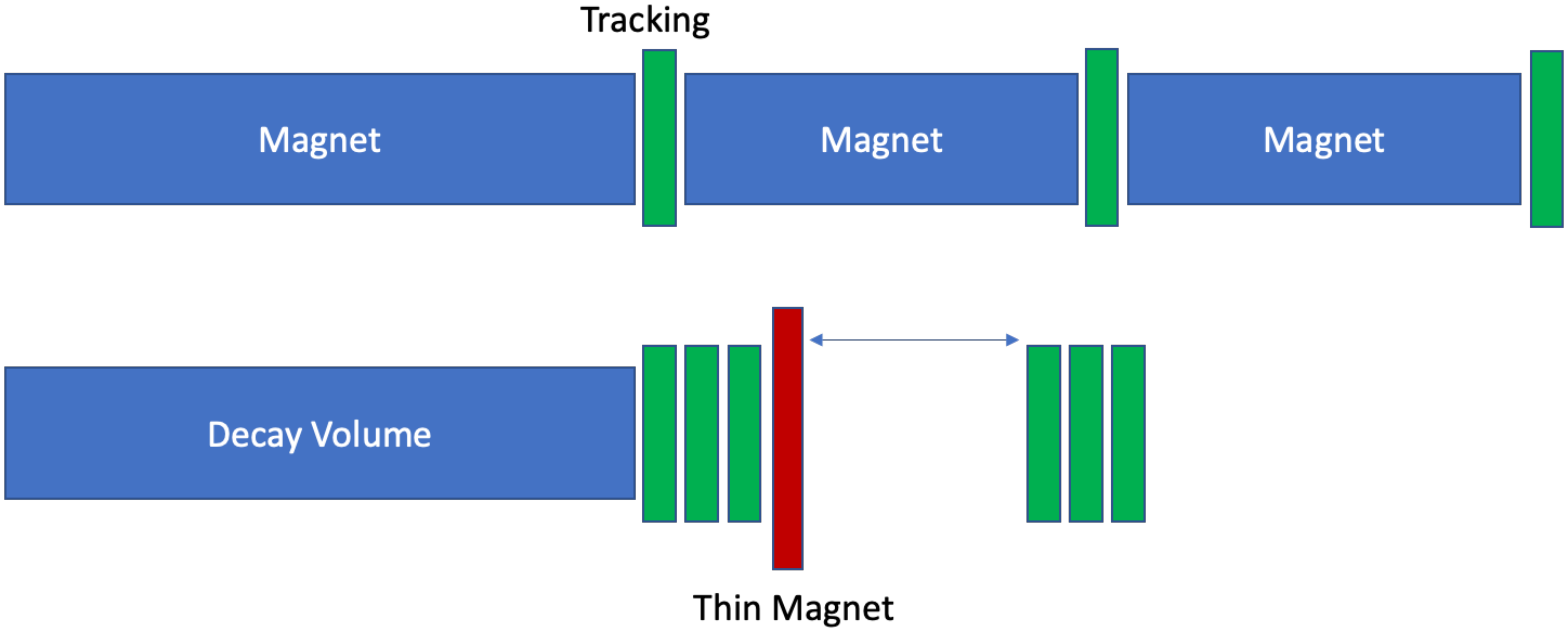
Degradation from > ~200 μm?

- Next steps:
  - Extend studies to mass and vertex position resolution

Olivier Salin & Alan Barr (Oxford)

Magnets | New detector configurations

- Given latest magnet situation need to consider other configurations
  - e.g. a la LHCb:

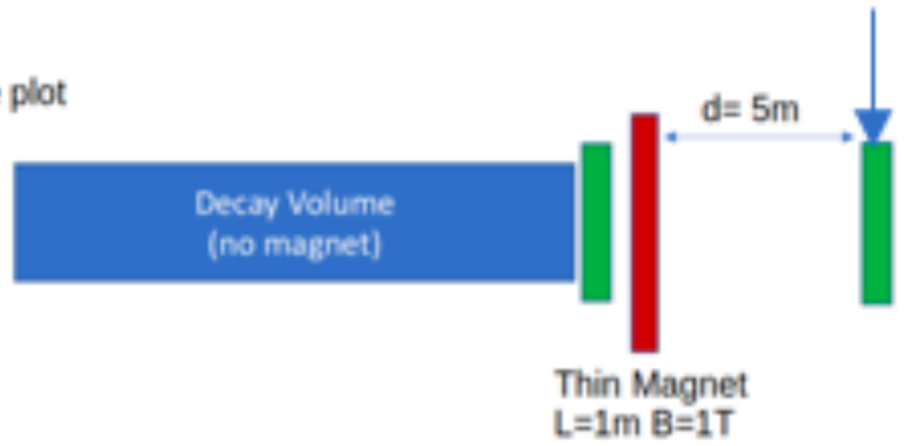


- Main take-away is that design studies essential start again from scratch…

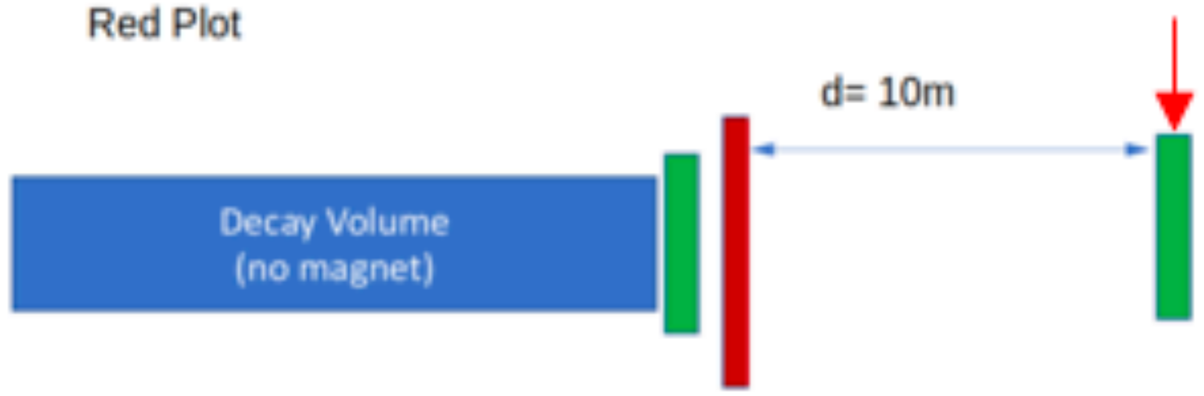
New configurations

Olivier Salin & Alan Barr (Oxford)

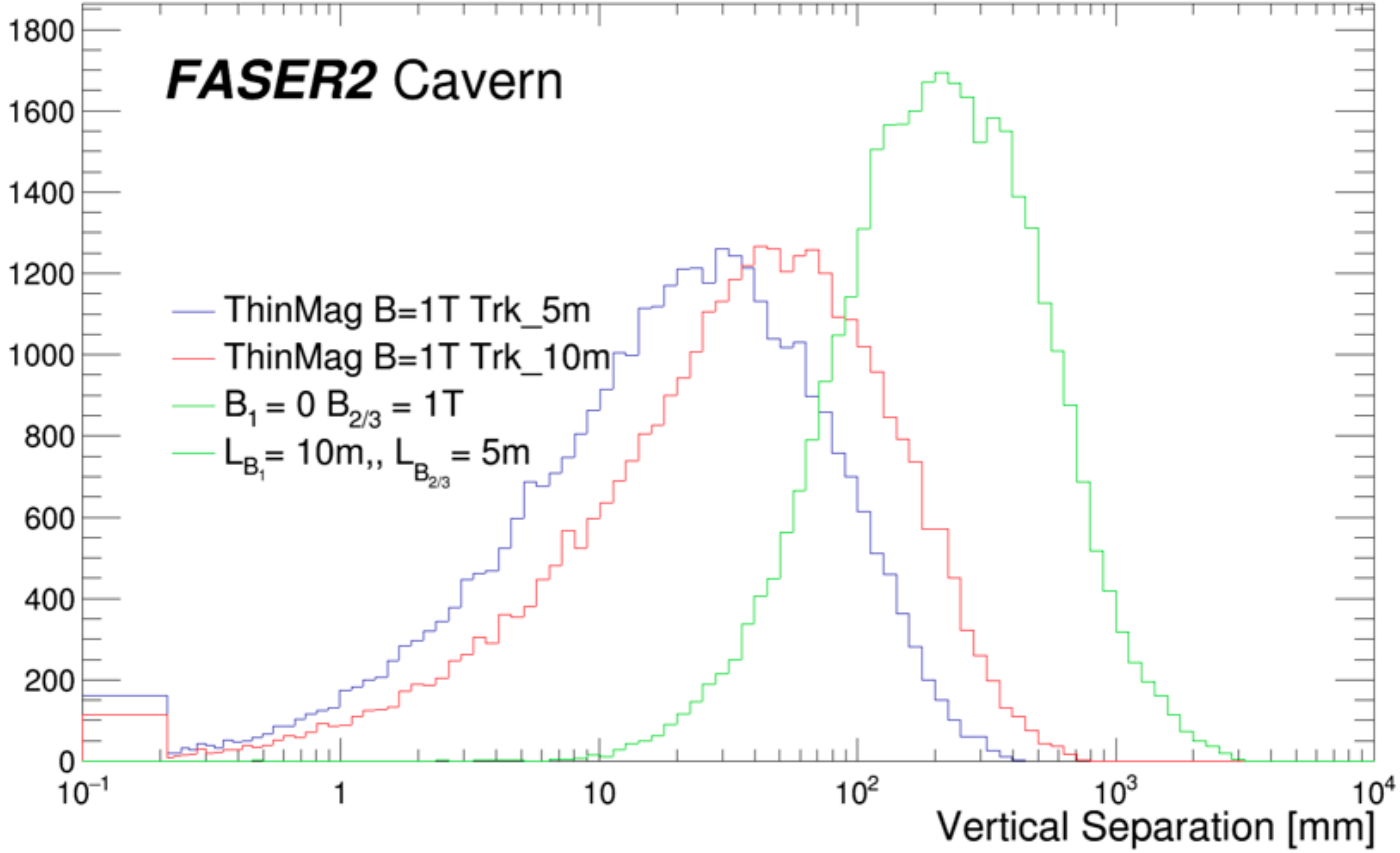
Blue plot



Red Plot



Green plot



New configurations

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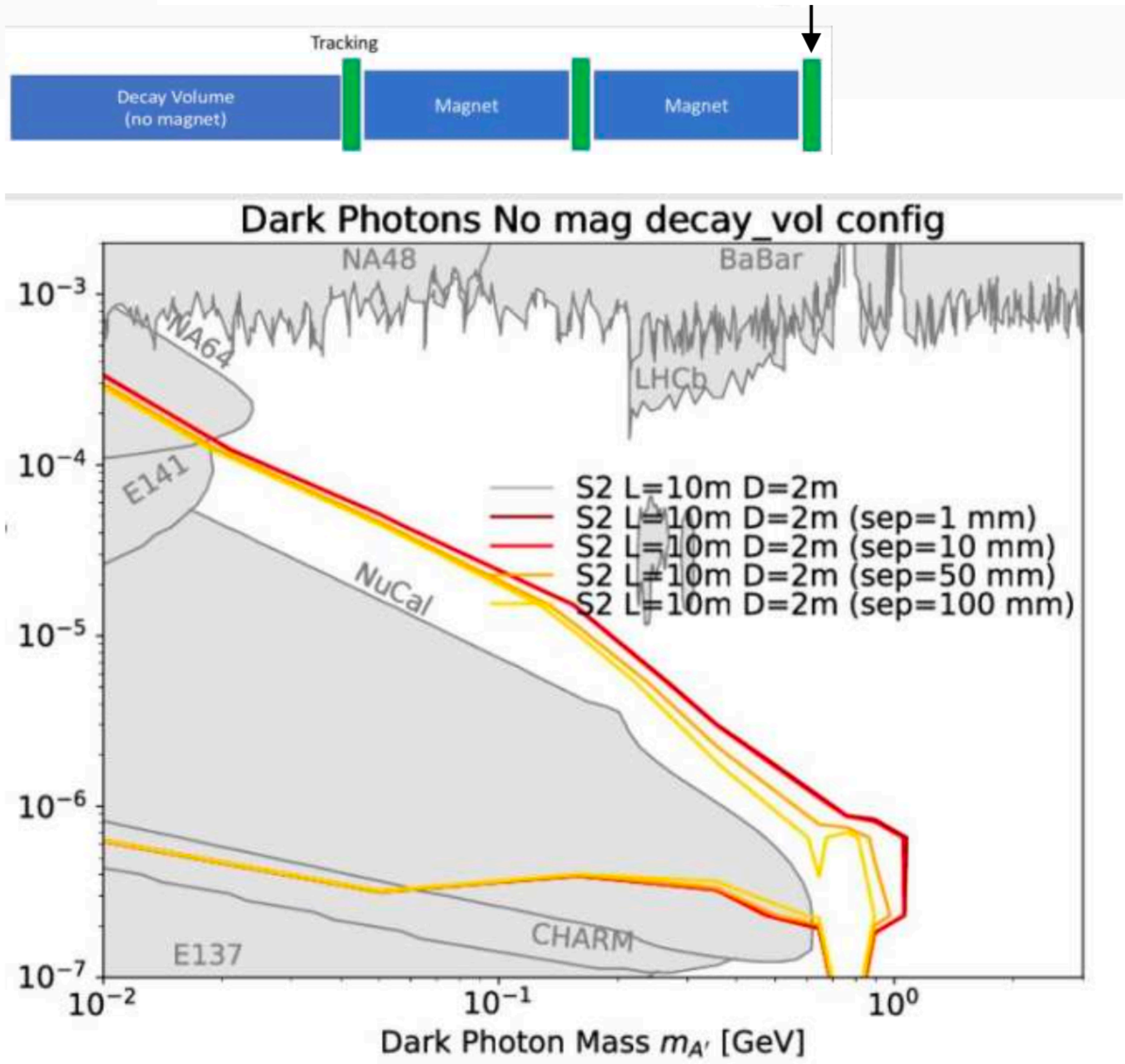
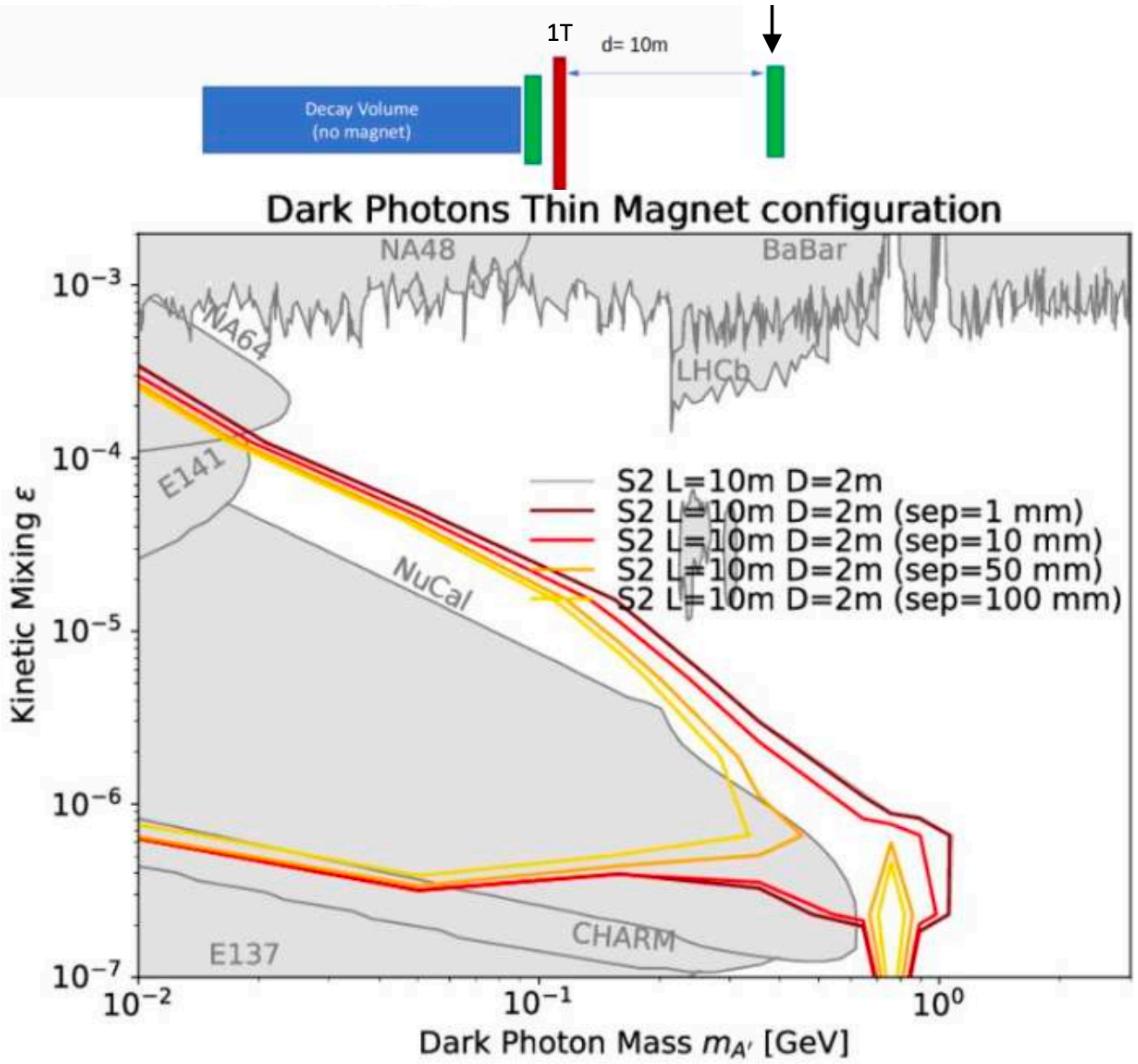
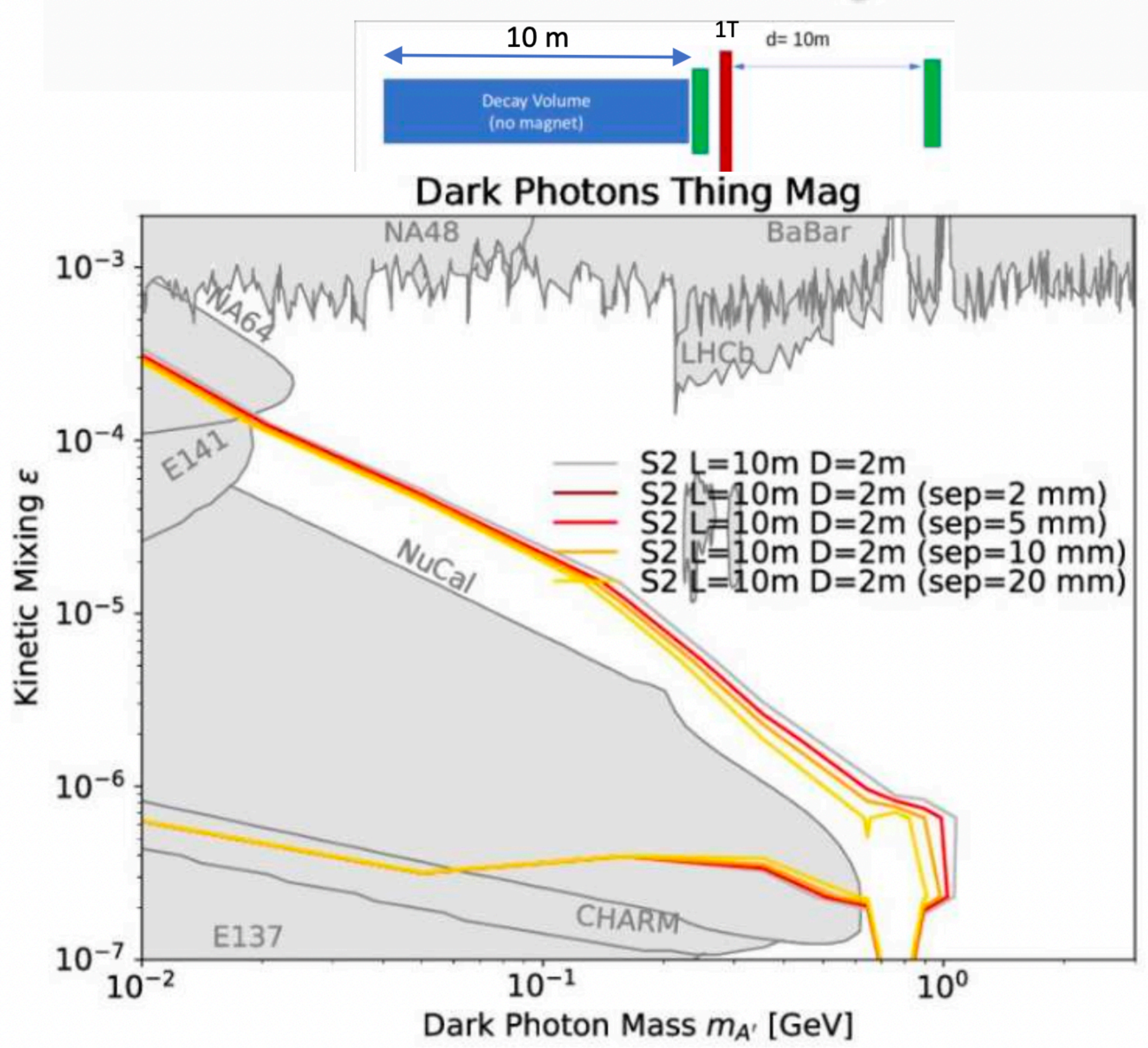


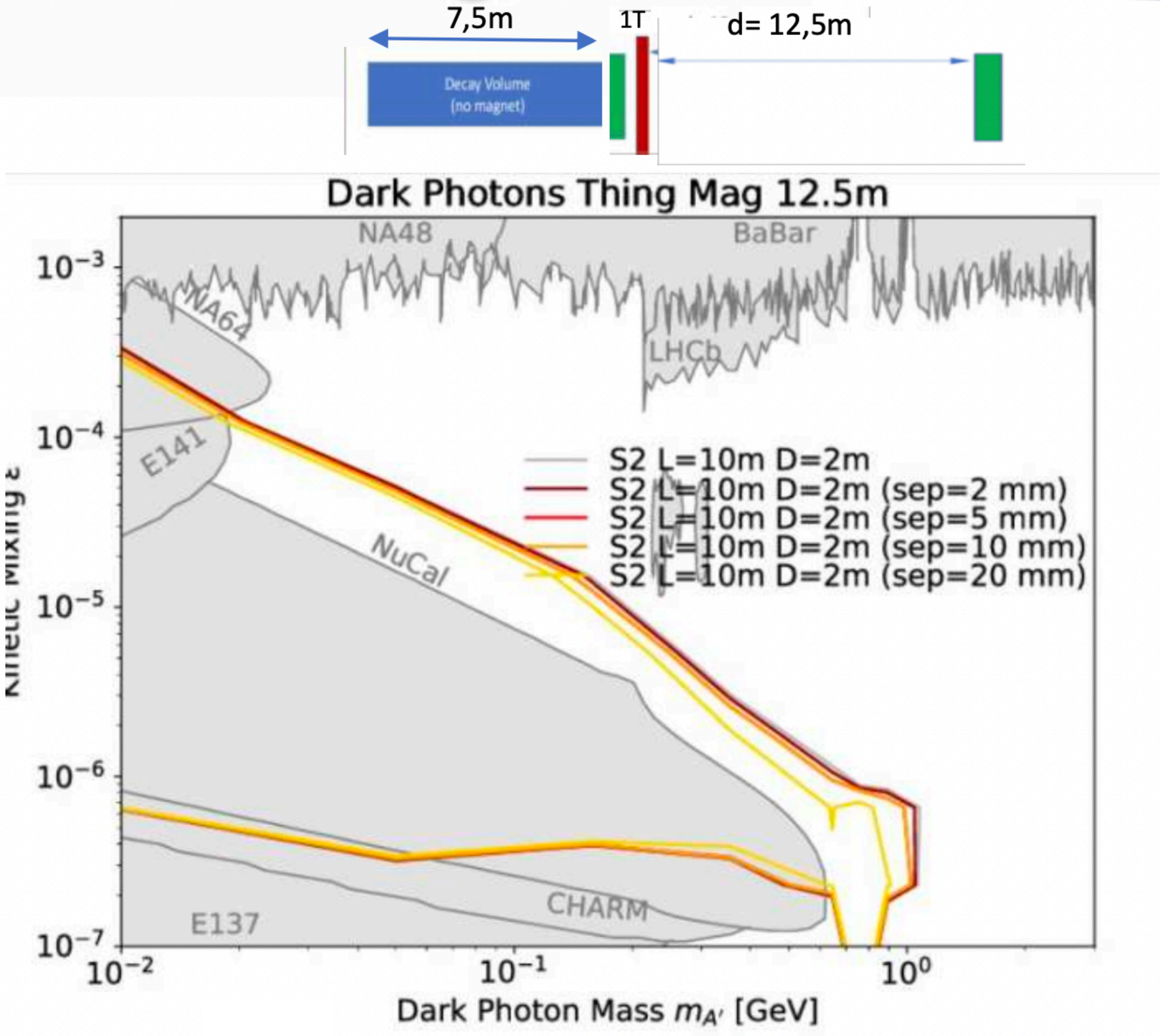


- Nominal (no B-field in decay volume) vs LHC-b like

New configurations

Olivier Salin & Alan Barr (Oxford)

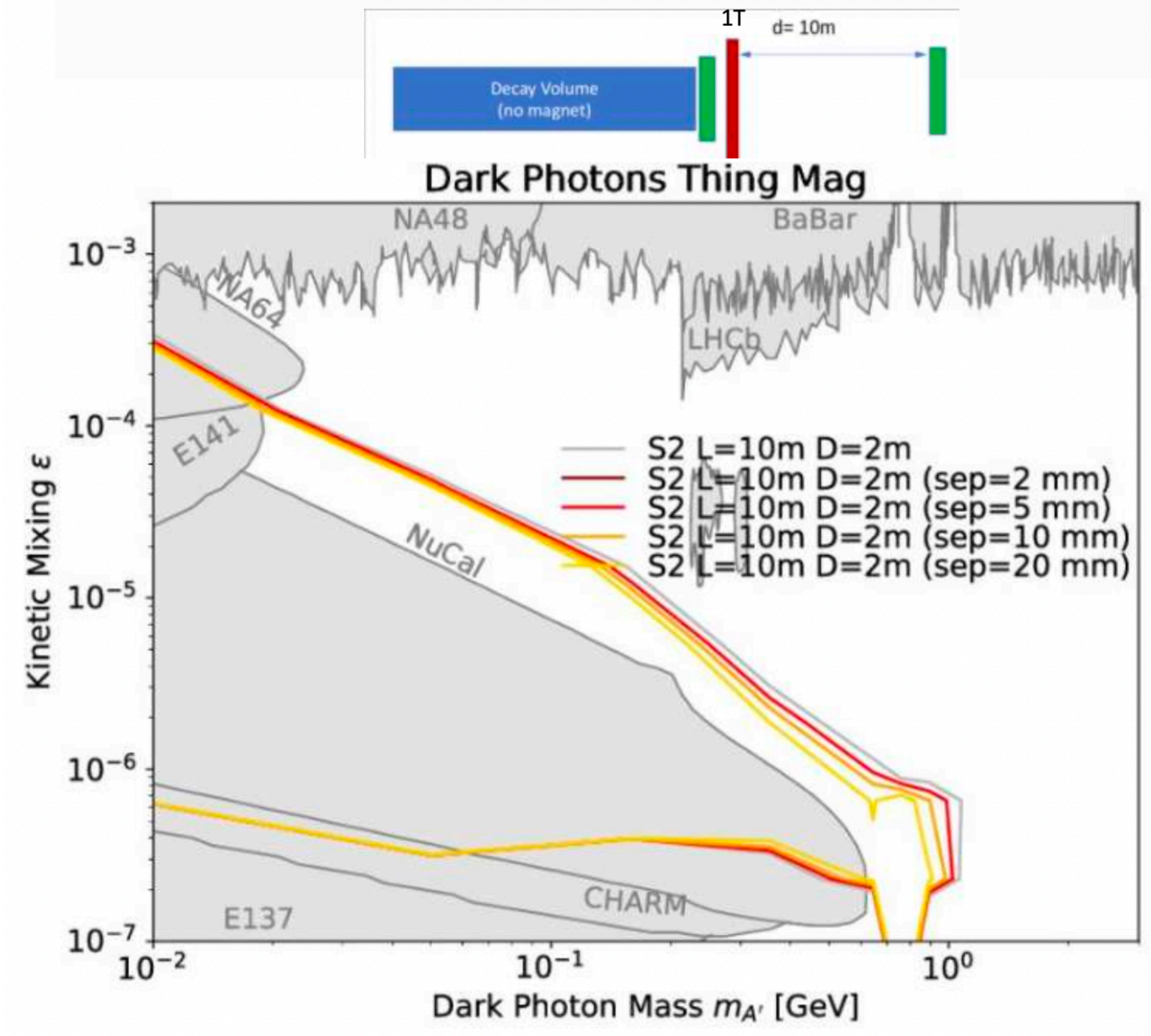


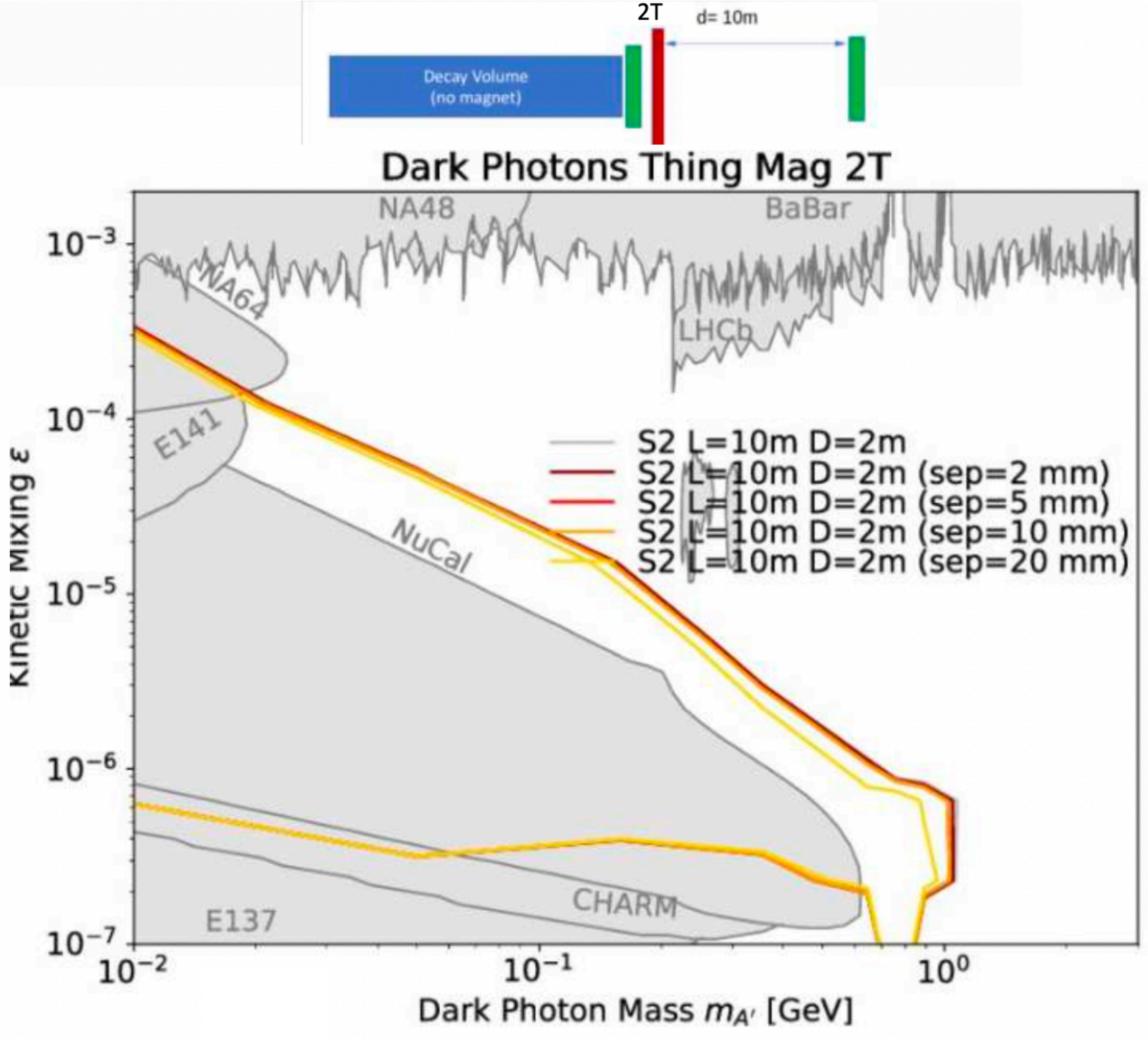


- 10 m vs 12.5 m distance to last tracker station

New configurations

Olivier Salin & Alan Barr (Oxford)





- 1T vs 2T magnet

Questions to ask

To see a signal…	Translates to requirements in detector	Translates to detector technologies
• Generic S/B	• Magnet strength and length ??	
• Pointing / z measurements	• Tracker resolution ?? Alignment requirements?? Timing?	• Pixels vs SciFi or a combination
• Mass reconstruction for "bump hunt"? Out of time signal?	• Track / Calorimeter resolution ?? Timing?	• High granularity calo vs Dual Calo read-out
• Track separation from what station?		
• Photon ID and separation?	• Calorimeter / preshower resolution?	
• Can we do anything with MET..?		
To characterise signal if you see it…	**To characterise signal if you see it…**	**To characterise signal if you see it…**
• PID ?	• Timing ??	• CMOS with timing
• Mass measurements	• Tracker resolution ??	
Backgrounds		
• Trigger rates?	• # Scintillator layers??	

Anna Sfyrla (UniGe)

Benchmark models?

Model	Unique in FASER2	Decay mode in FASER	Decay mode in FASER 2	Unique coverage
Dark Photons		ee	ee, hadrons, μμ	++
B-L Gauge bosons	x	ee	ee, hadrons, μμ, MET (dom low mass)	++
Dark Higgs Bosons	x		ee, pions, μμ, kaons, jets	+++
HNLs with e	x		MET + ee, MET (dom low mass), hadrons	+
HNLs with μ	x		MET + ee, MET (dom low mass), hadrons	+
HNLs with τ	x		MET + ee, MET (dom low mass), hadrons	+++
ALPs in photons		γγ	γγ	++
ALPs in fermions	x		ee, μμ, jets	+++
ALPs in gluons	x		γγ, hadrons	+
Dark pseudoscalars	x		γγ, ee, μμ, hadrons, jets	++
OTHER???				

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HNLs with e	x		MET + ee, MET (dom low mass), hadrons	+
HNLs with μ	x		MET + ee, MET (dom low mass), hadrons	+
HNLs with τ	x		MET + ee, MET (dom low mass), hadrons	+++
ALPs in photons		γγ	γγ	++
ALPs in fermions	x		ee, μμ, jets	+++
ALPs in gluons	x		γγ, hadrons	+
Dark pseudoscalars	x		γγ, ee, μμ, hadrons, jets	++
OTHER???				

Anna Sfyrla (UniGe)

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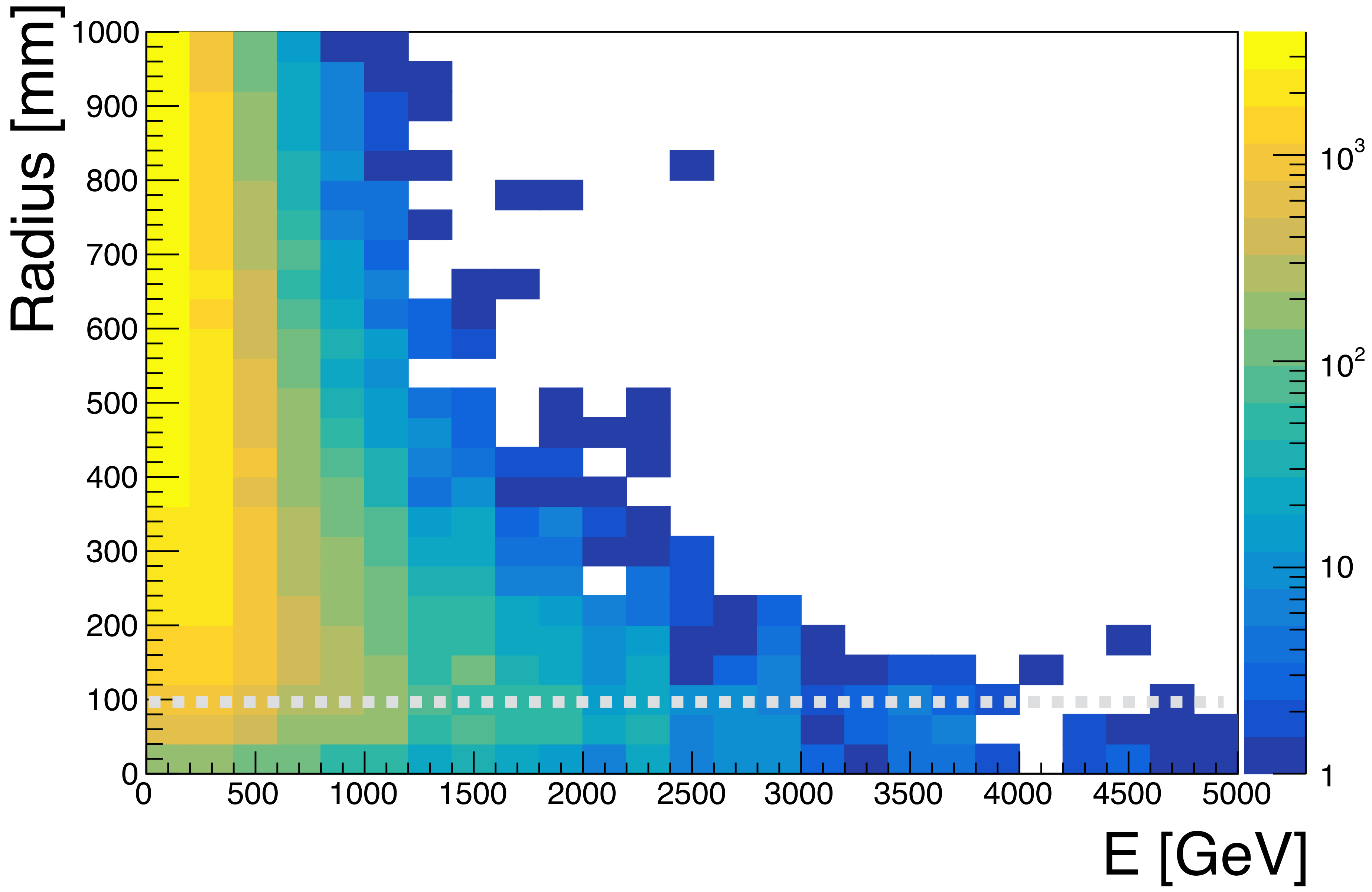
Dark Hi				
HNLs w				
HNLs w				
HNLs w				
ALPs ir				
ALPs in fermions	x		ee, μμ, jets	+++
ALPs in gluons	x		γγ, hadrons	+
Dark pseudoscalars	x		γγ, ee, μμ, hadrons, jets	++
OTHER???				

- Agree on objects we need to reconstruct: e, μ, jets, γ, MET?
- Also agree on higher level quantities (e.g. mass) and other figures of merit (e.g. angular separation, hadron ID?).

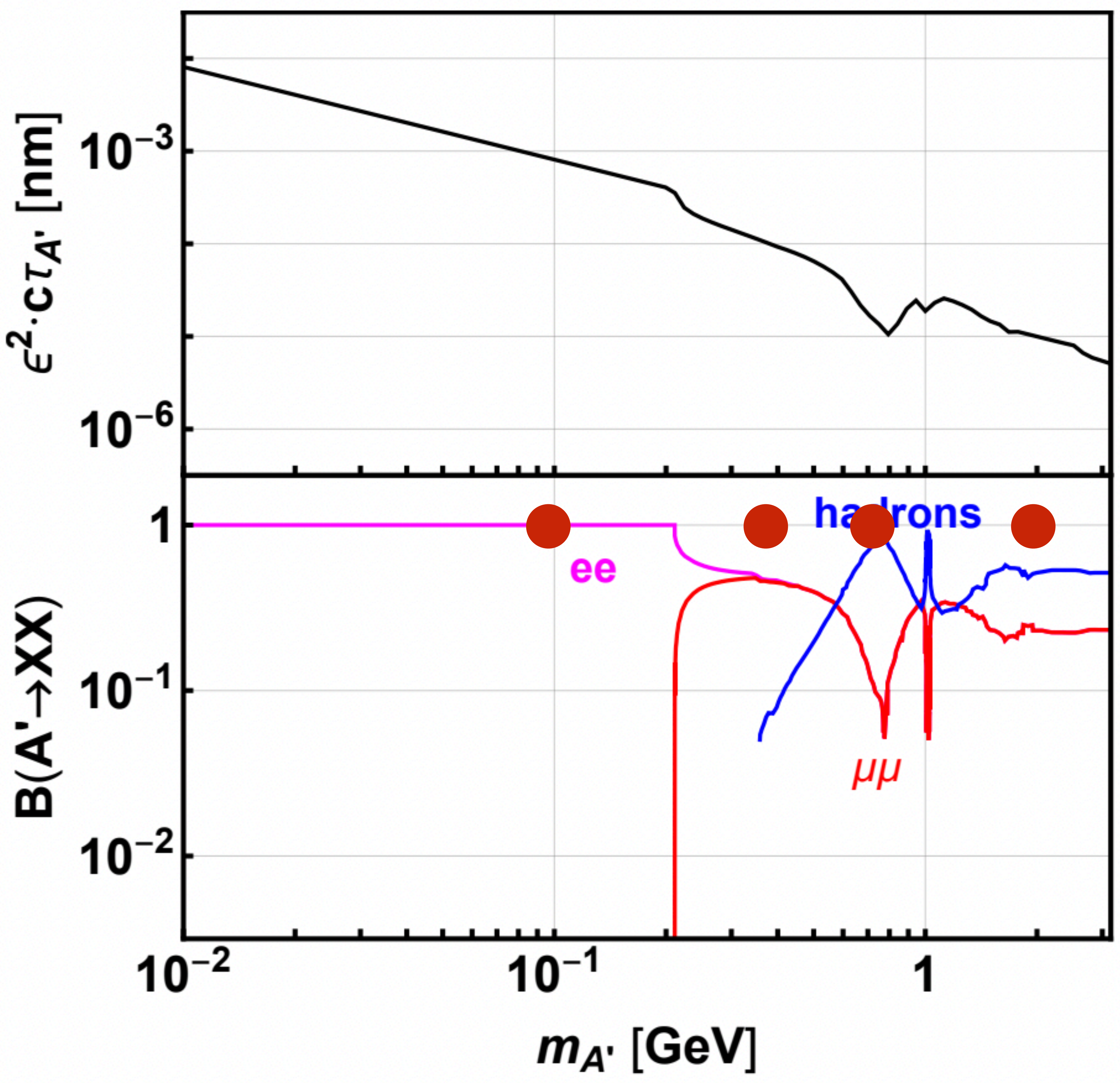
Anna Sfyrla (UniGe)

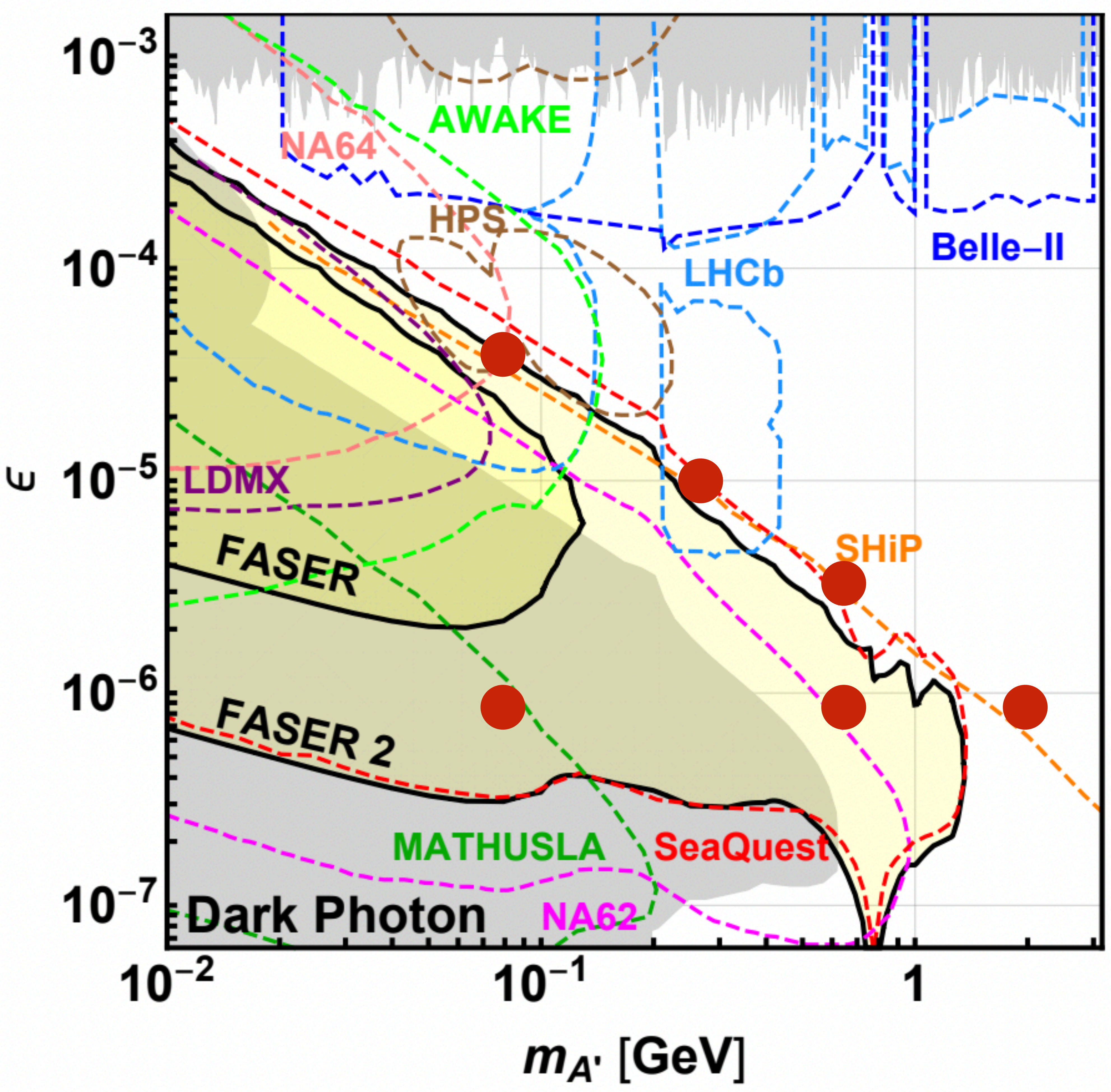
Benchmark models?

- Select benchmark model points that can be used as “representative” of the physics cases we want to study.
  - That cover various final states of interest
    - Cover different decay modes
  - That have “large enough” cross sections that are not hopeless
    - Scan mass range accessible in current reach estimates
    - But also look at phase-space outside top of existing excluded region
- Also consider different kinematic regions
  - Higher and lower LLP energies

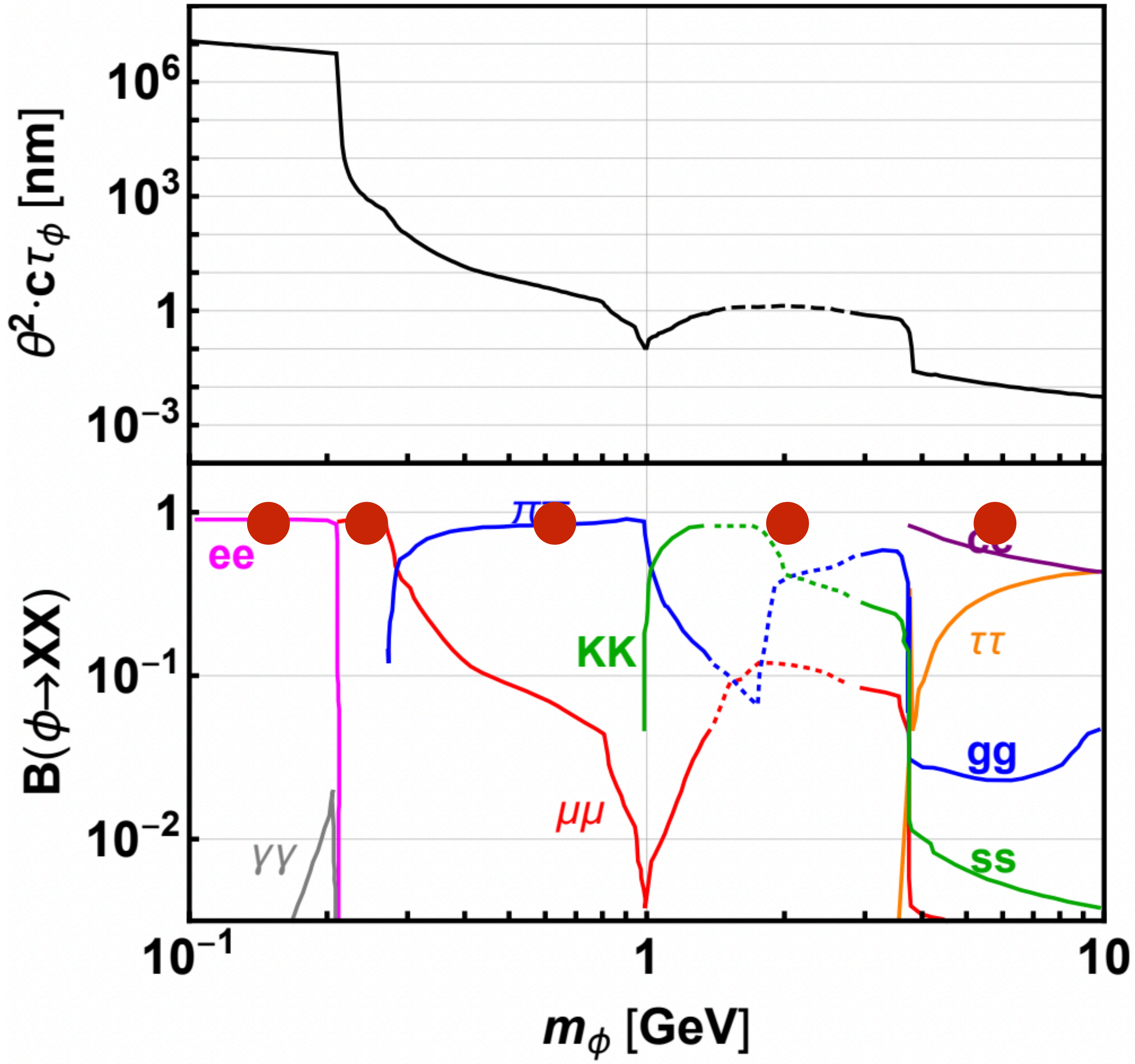


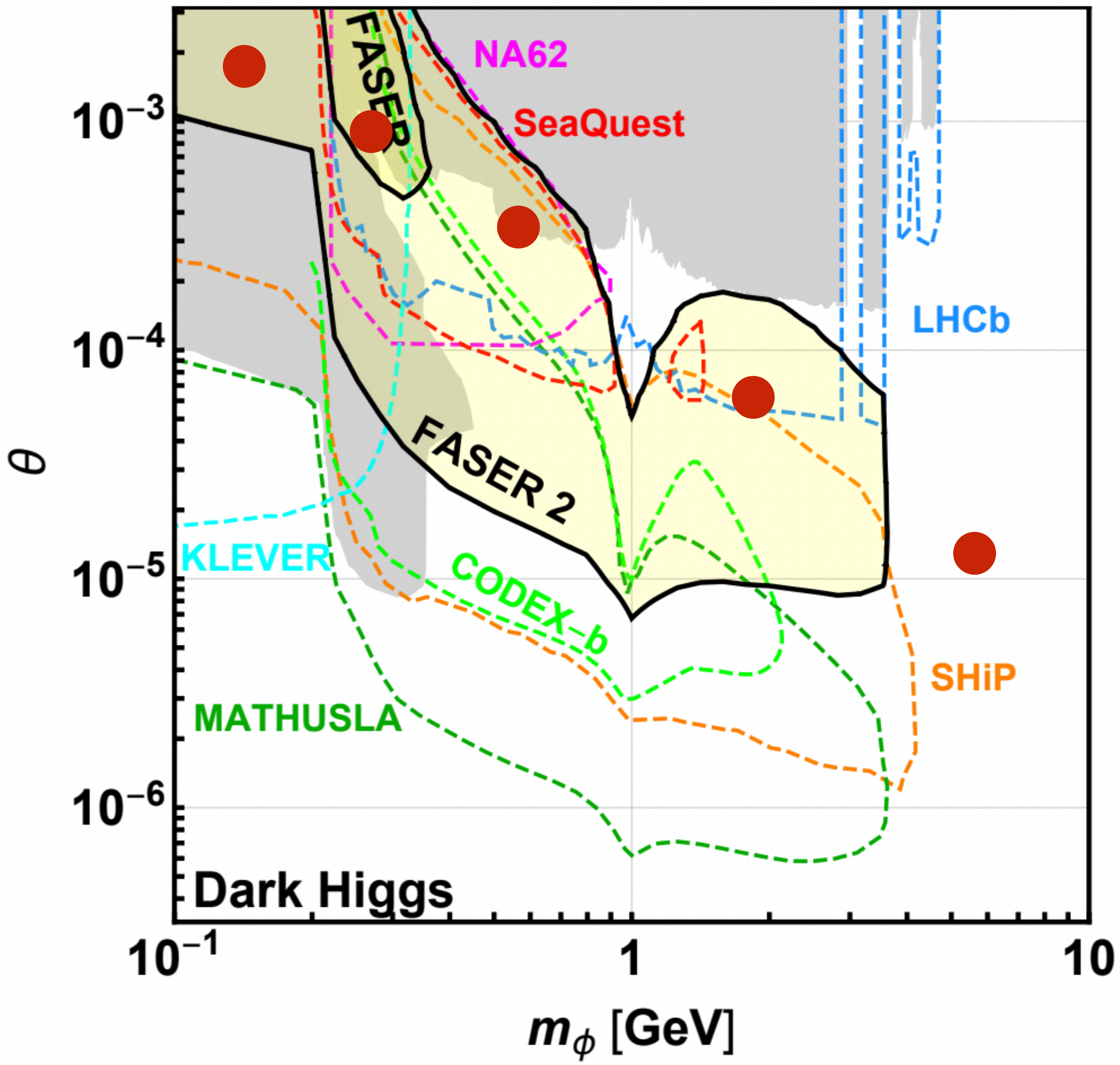
Benchmark models?



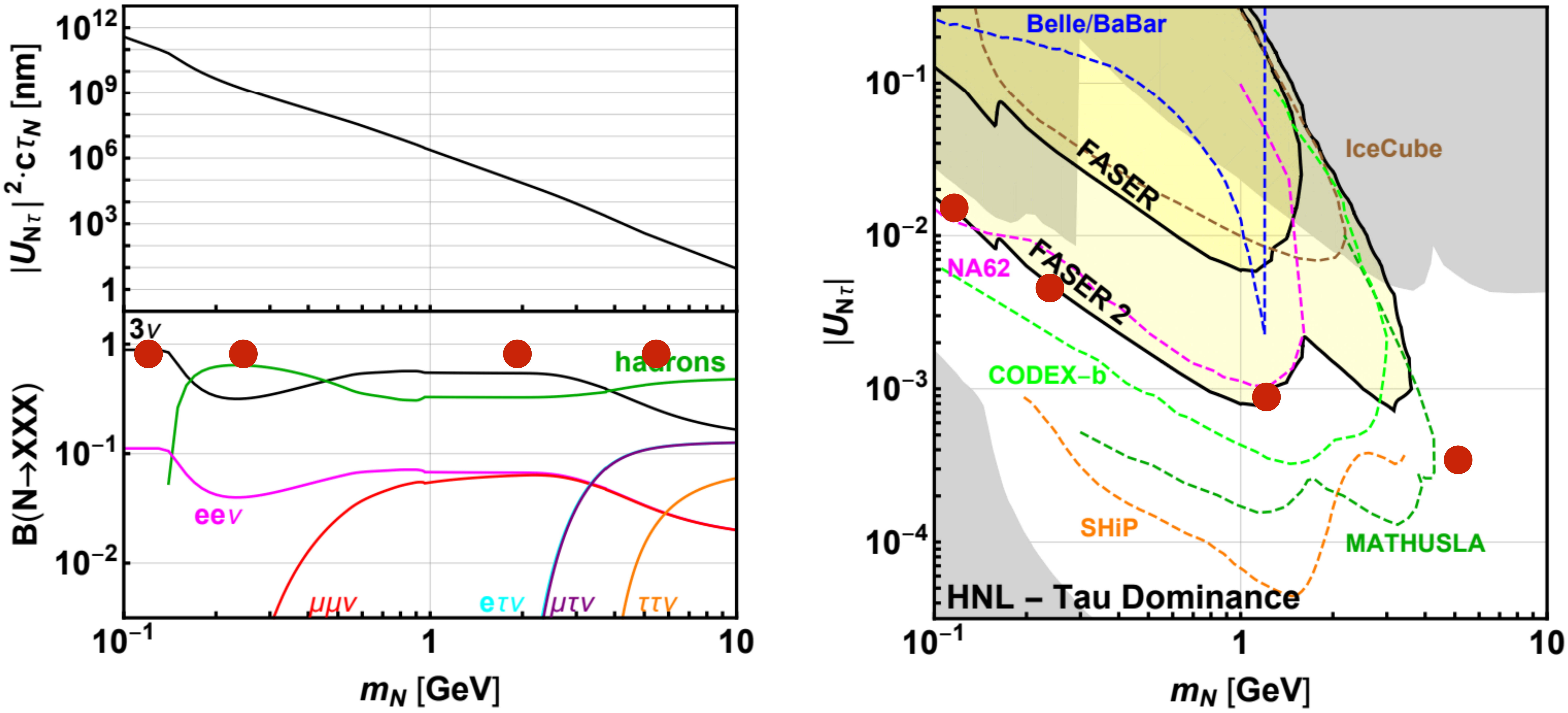


Benchmark models?

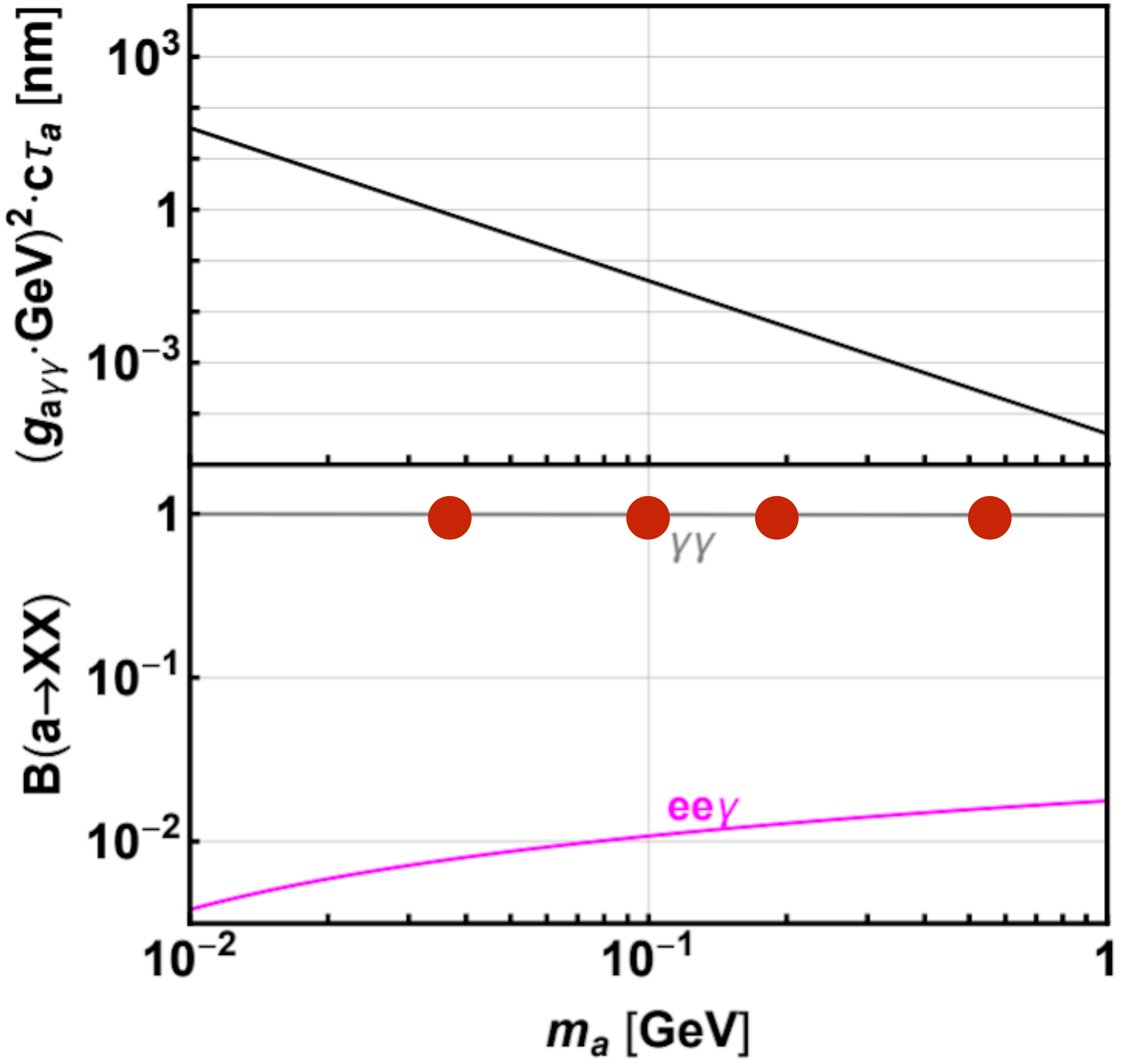


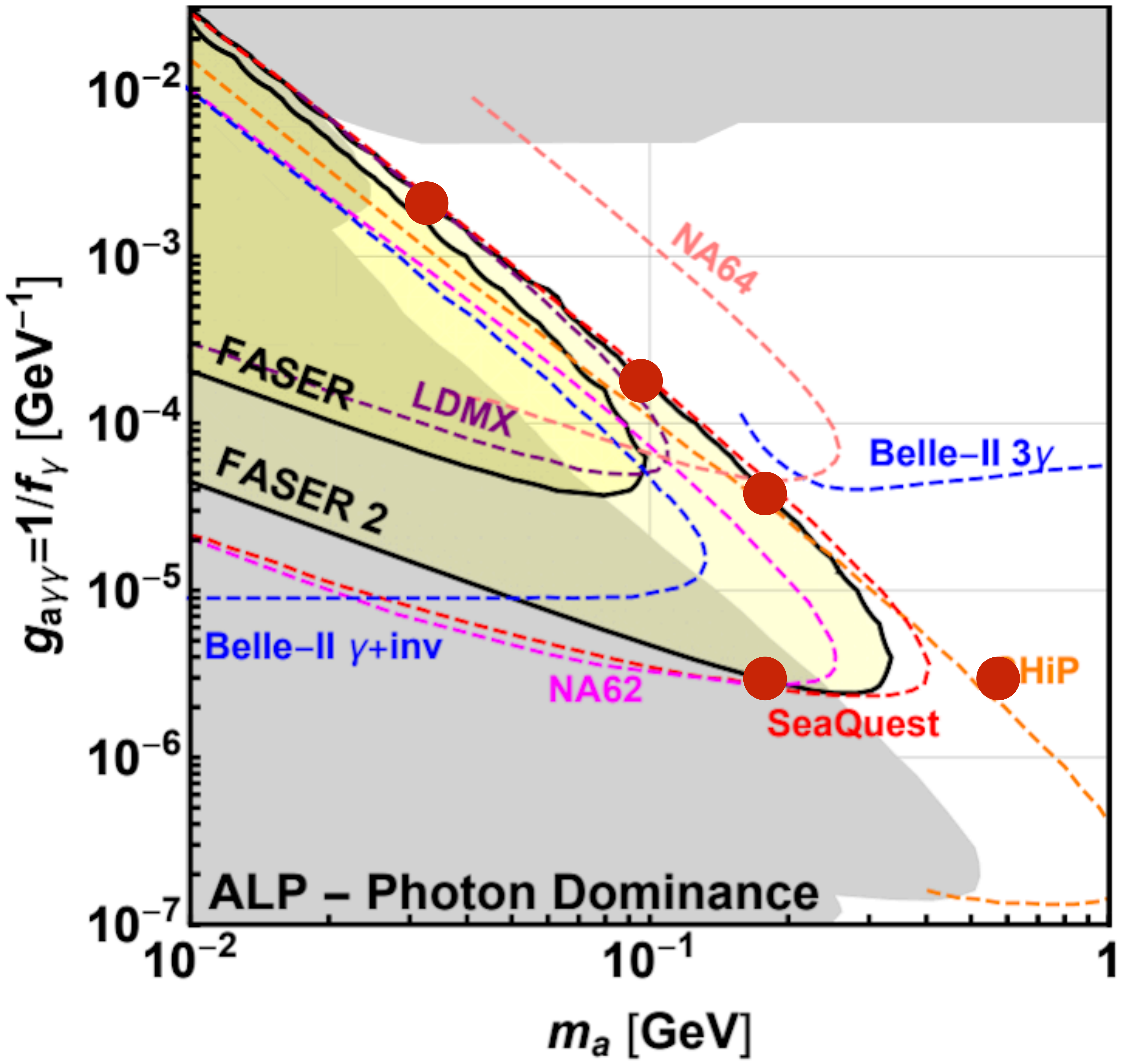


Benchmark models?

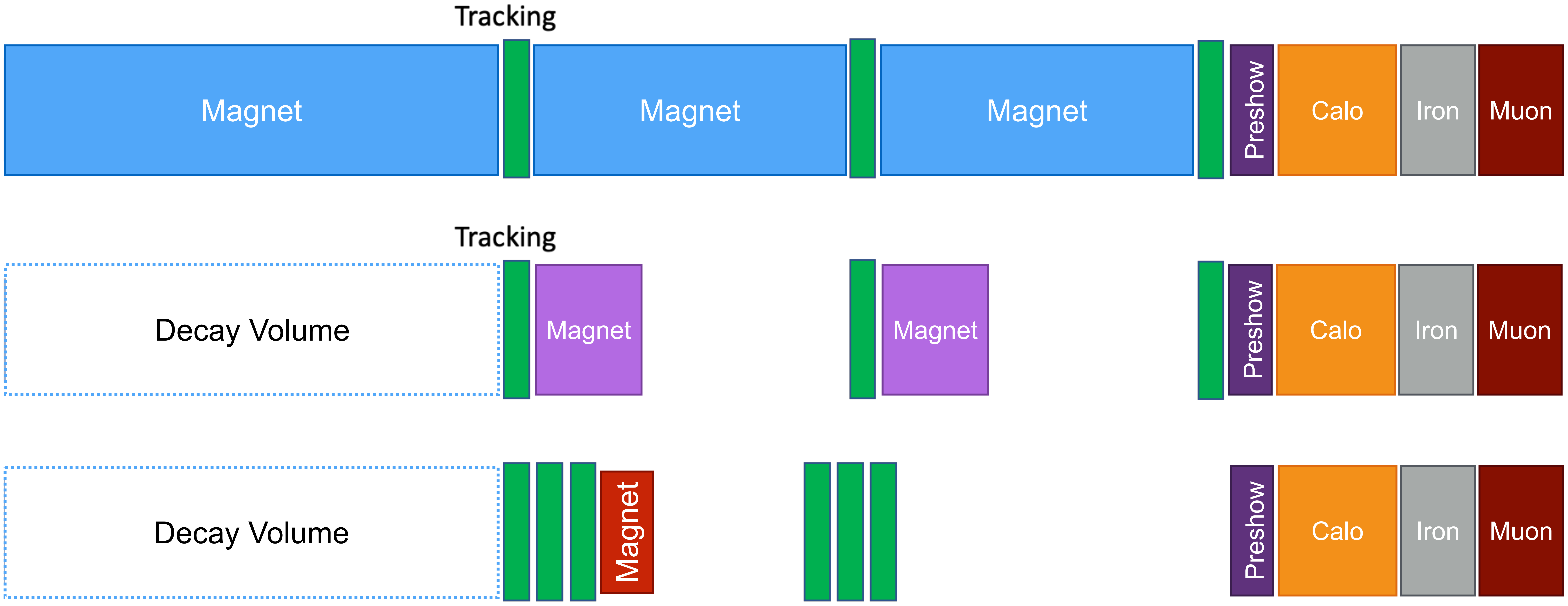


Benchmark models?

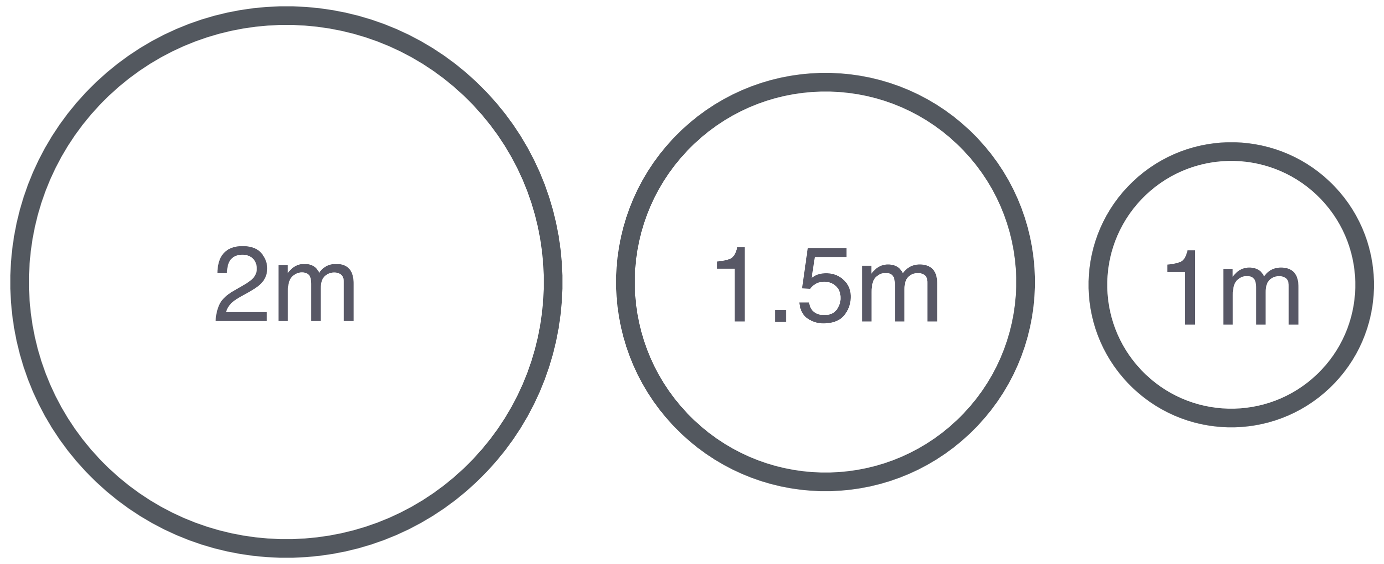




Benchmark geometries?



- Check different configurations (from one extreme to the other)
  - Revisit DV radius - smaller radius may mean more options for technologies



- Record particle positions at:
  - Tracker, preshower, calo and muon ID stations
  - Energy at calorimeter

Benchmark geometries?