MADMAX and the post-inflationary wasteland.

Ringberg 2021

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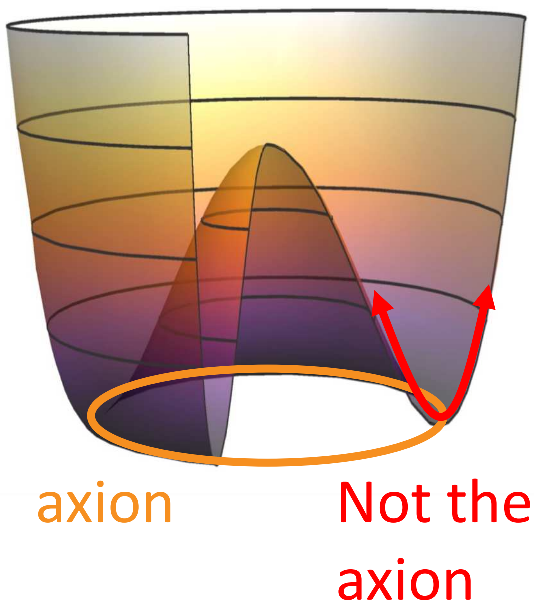
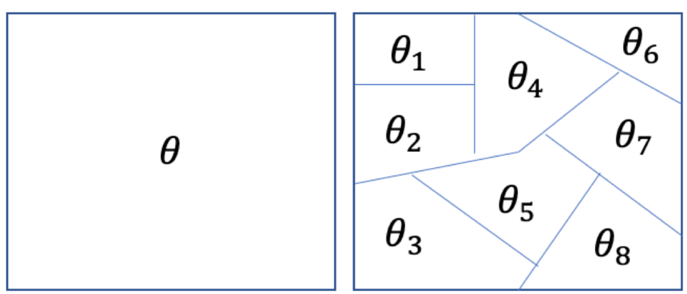
QCD Axion: Why do we care?

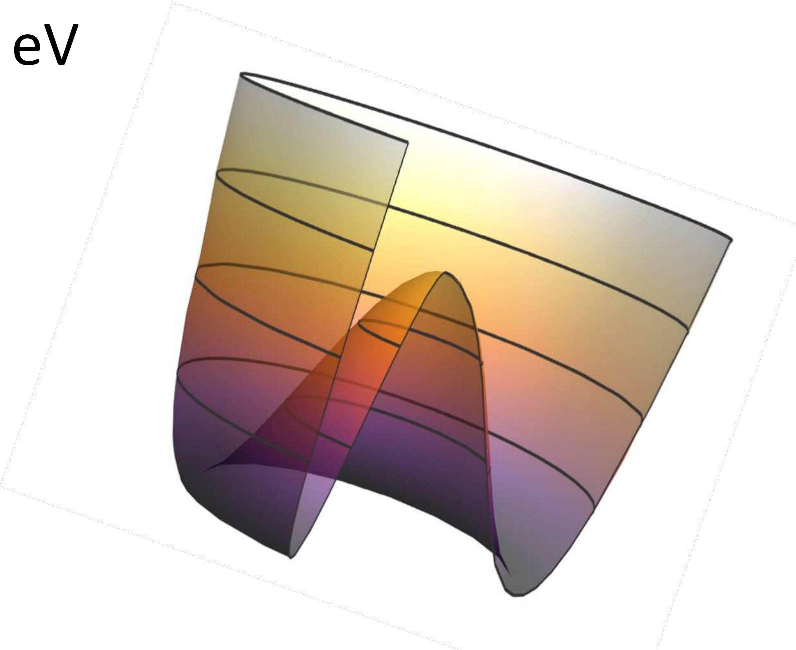
- Introduced to solve the CP problem of QCD
- Peccei, Quinn: global chiral $U(1)_{PQ}$ symmetry
- complex scalar field w/ spont. sym. breaking potential
  → mexican hat
- Breaking before inflation ("pre-inflationary").
  → only one θ
- Breaking after inflation ("post-inflationary")
  → multiple values for θ, structures which can decay





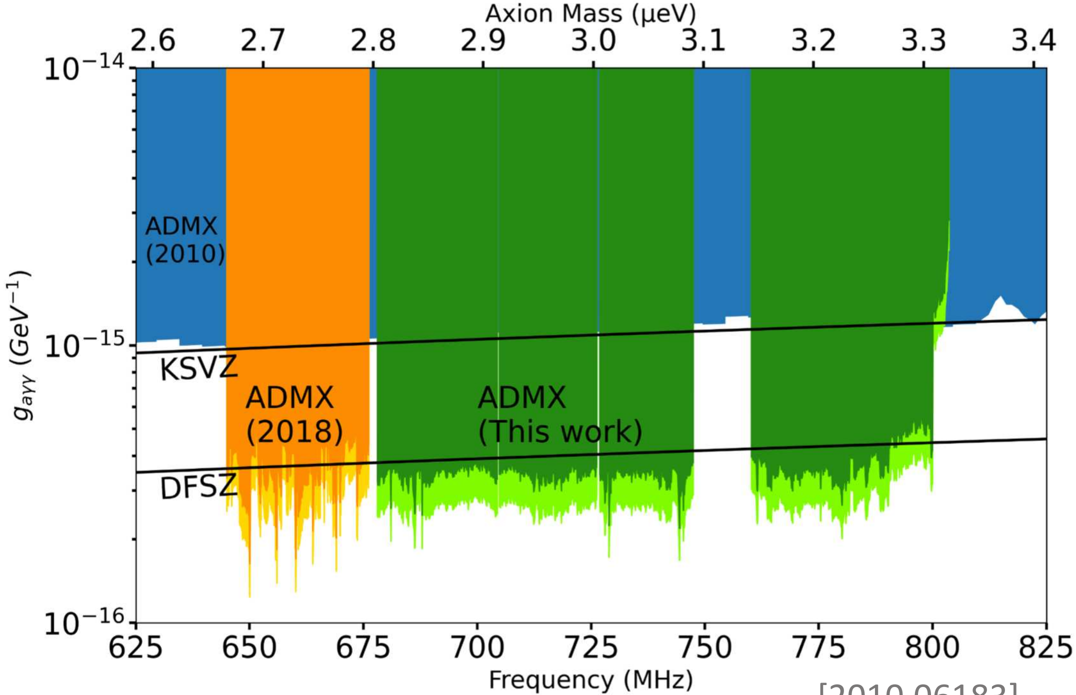
QCD Axion: Why do we care?

- Pretty pathetic CDM candidate so far:
  - No mass
  - No interactions
- Noether: symmetry = conserved current, charge
- QFT anomaly: current not entirely conserved $\rightarrow$ mexican hat tilted $\rightarrow m_a \sim 10^{-5}$ eV
  - N QCD anomaly coefficient
  - E QED anomaly coefficient
- Which particles have PQ charges?
  - KSVZ: new heavy quarks
  - DFSZ: all SM quarks, second Higgs



MADMAX, ADMX = haloscopes

- Observes **local DM** density on earth via **axion-photon coupling** scanning over photon-**frequencies**



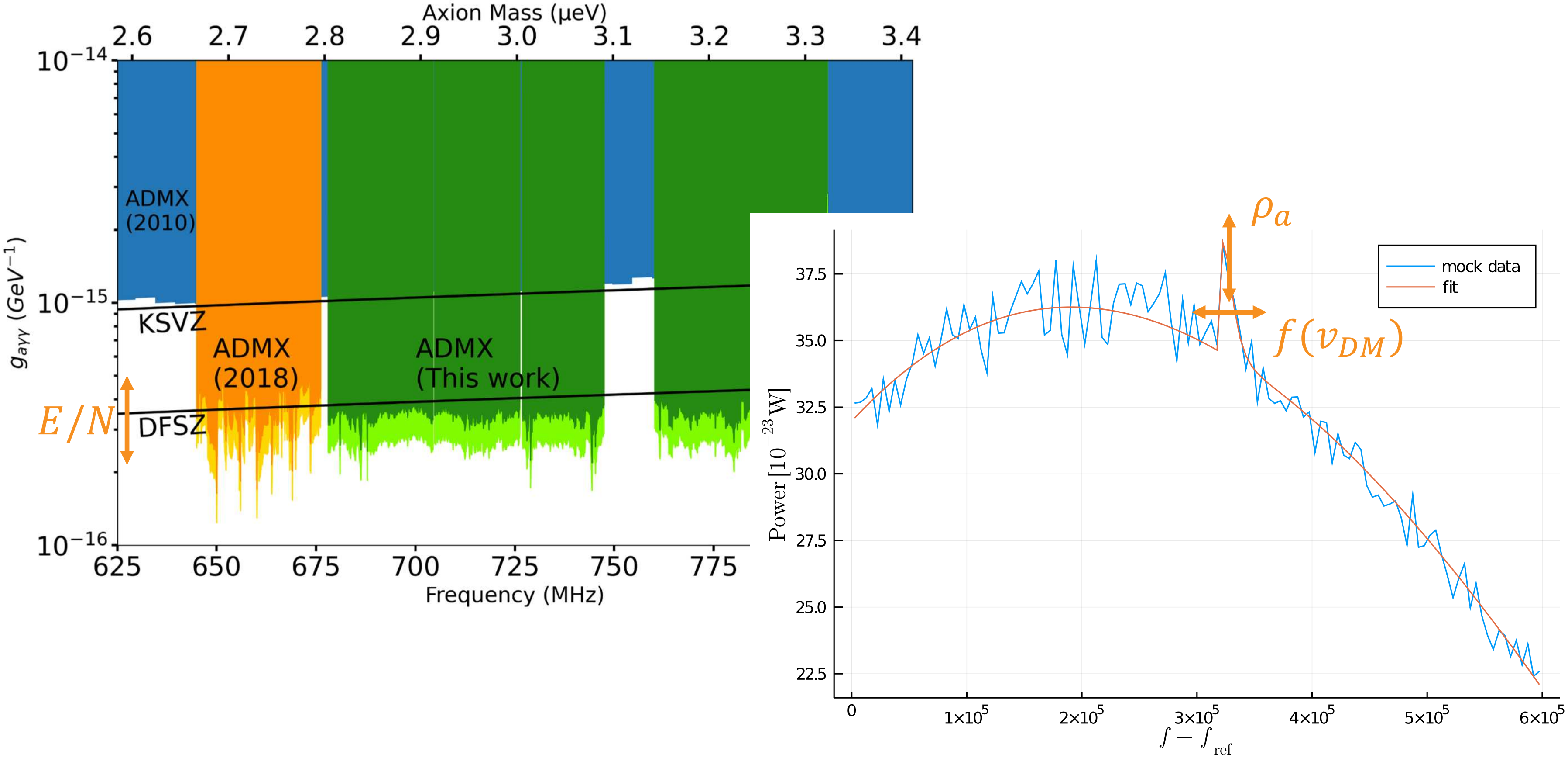
[2010.06183]

Haloscope signal strength

$$\frac{dP}{d\omega} \propto \frac{\rho_a \; g_{a\gamma}^2(E/N)}{m_a^2} \cdot f(v_{DM})$$

- m_a axion mass
- ρ_a axion energy density
- $f(v_{DM})$ dark matter velocity distribution
- $g_{a\gamma}(E/N)$ axion-photon coupling (which depends on anomaly ratio E/N.

Pre-inflationary Problems



ρ_a

- $\rho_a \neq \rho_{DM}$!
- Seems to be increasing

DePanfilis+ 87

n a search for galactic axions in the frequency range $1.09 < f_a$
h $\Gamma_a \leq 200$ Hz we obtain the experimental limit $(g_{a\gamma\gamma}/m_a)^2 \rho_a$
ction is $(g_{a\gamma\gamma}/m_a)^2 \rho_a = 3.9 \times 10^{-44}$ with $\rho_a = 300\ \text{MeV/cm}^3$. We

ADMX 09

FIG. 5: Axion-photon coupling excluded at the 90% confidence level assuming a local dark matter density of 0.45 GeV/cm^3 for two dark matter distribution models. The

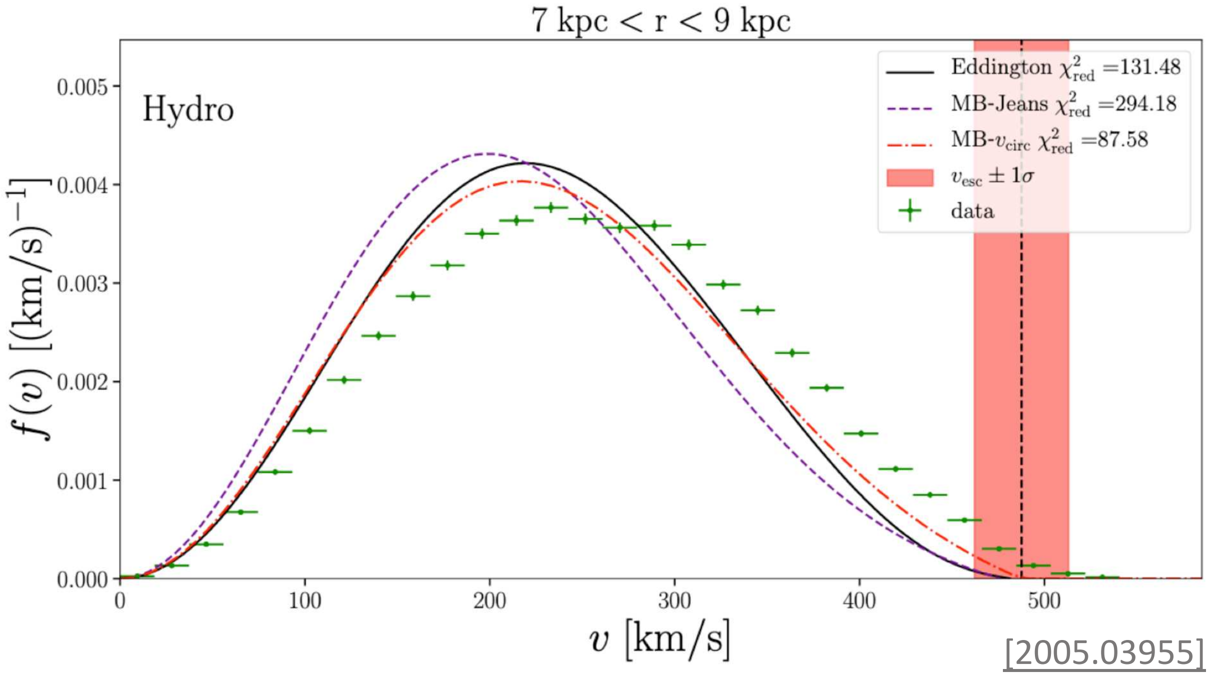
ADMX 18, 21

whereas the N-body filter used a local dark matter density of 0.63 GeV/cm^3. Regions where there are gaps in the data are

- Assumption: homogeneous

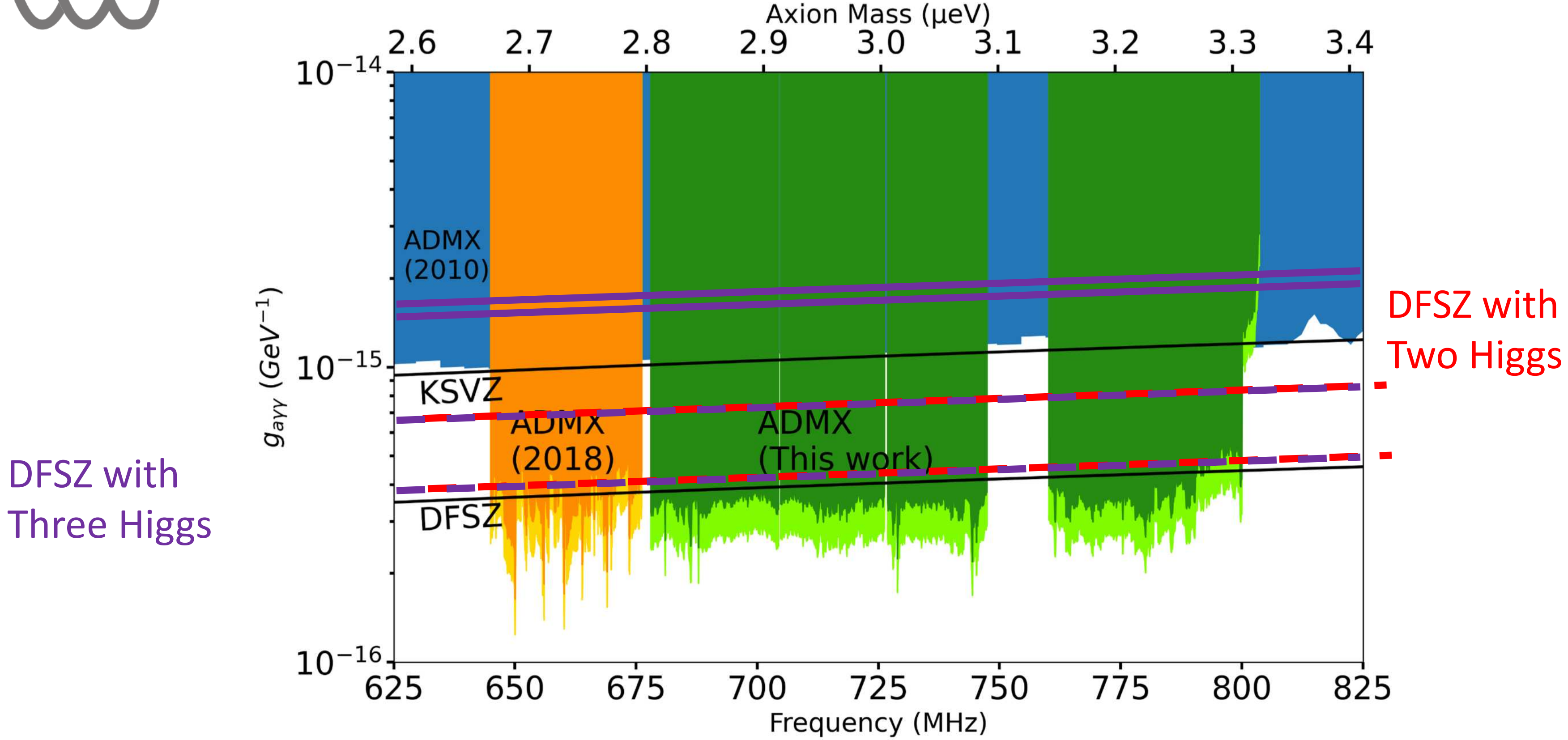
$f(v_{DM})$

- Relatively accurate by now



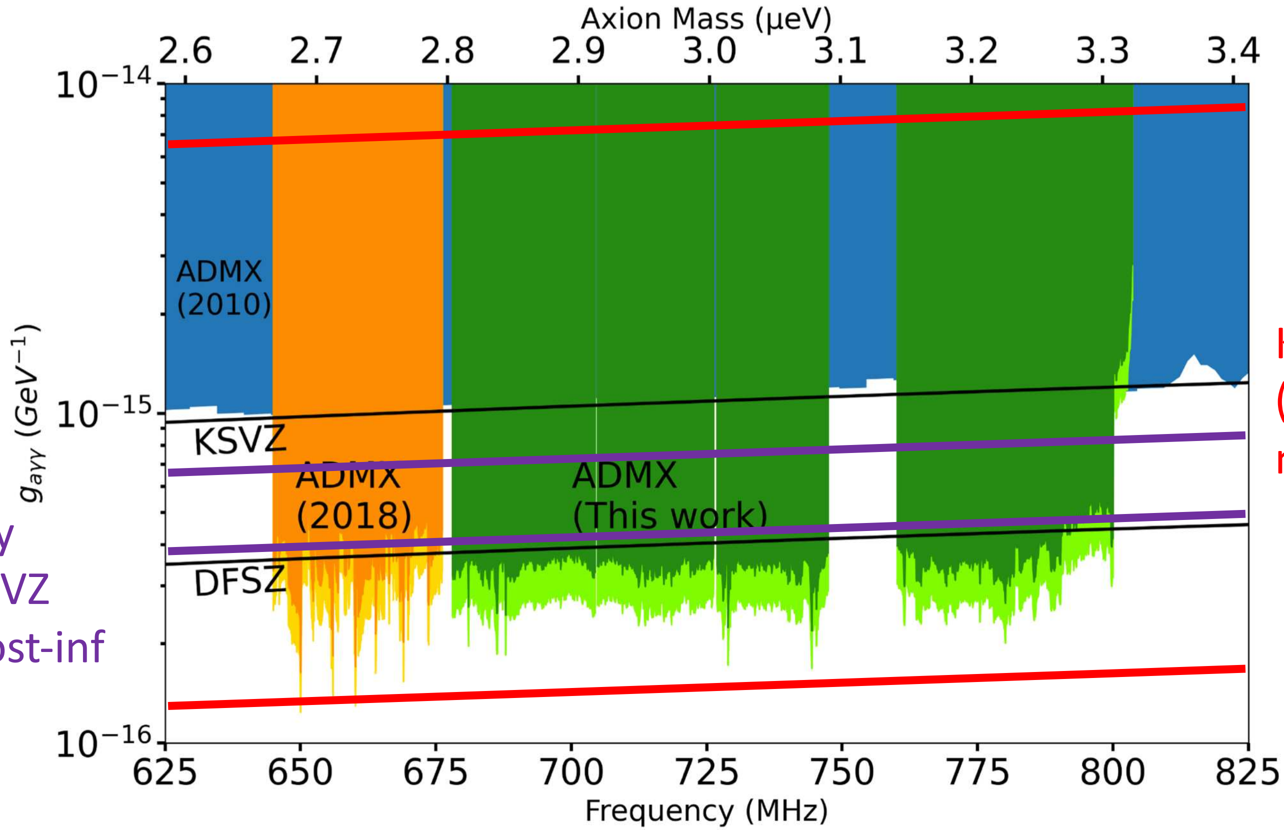
[2005.03955]

E/N



Main Freedom: Which SM particles have what PQ charge?

E/N



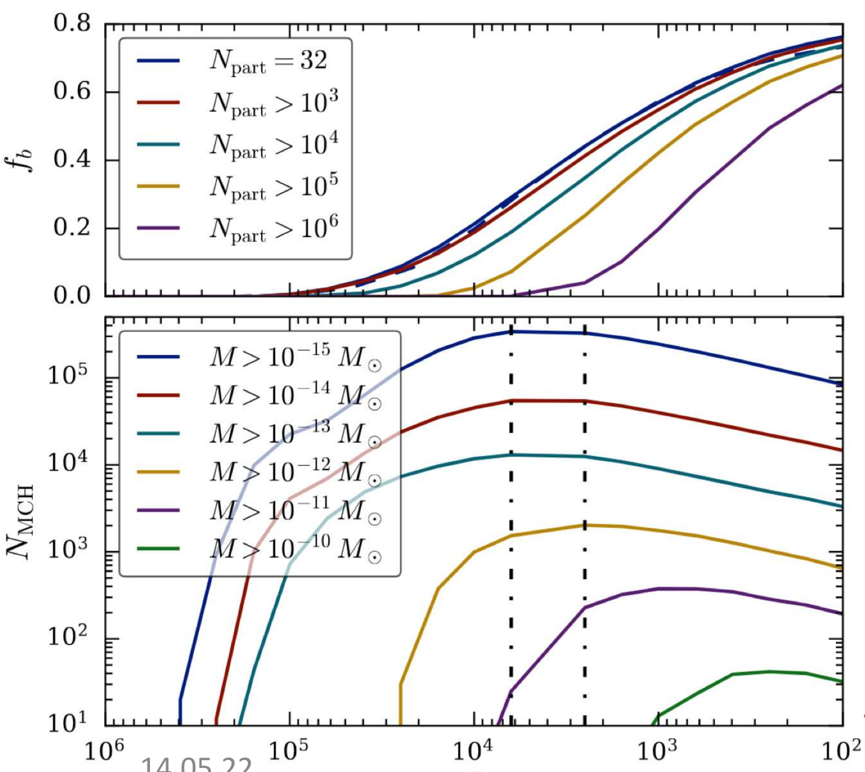
KSVZ range (multiple discreet models)

Two especially Interesting KSVZ Models for post-inf

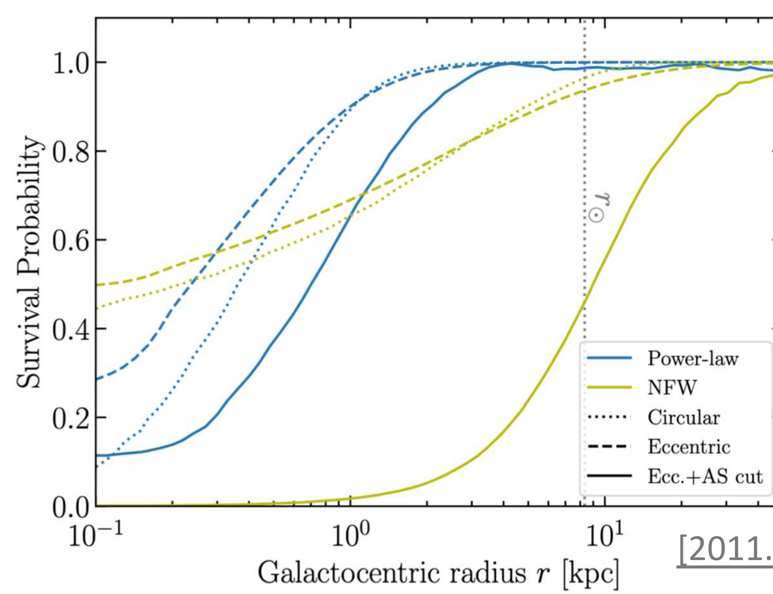
Main Freedom: Properties of new quark?

Post-inflationary Problems

Topological defects decay → Miniclusters Get tidally disrupted → Streams



[1911.09417]

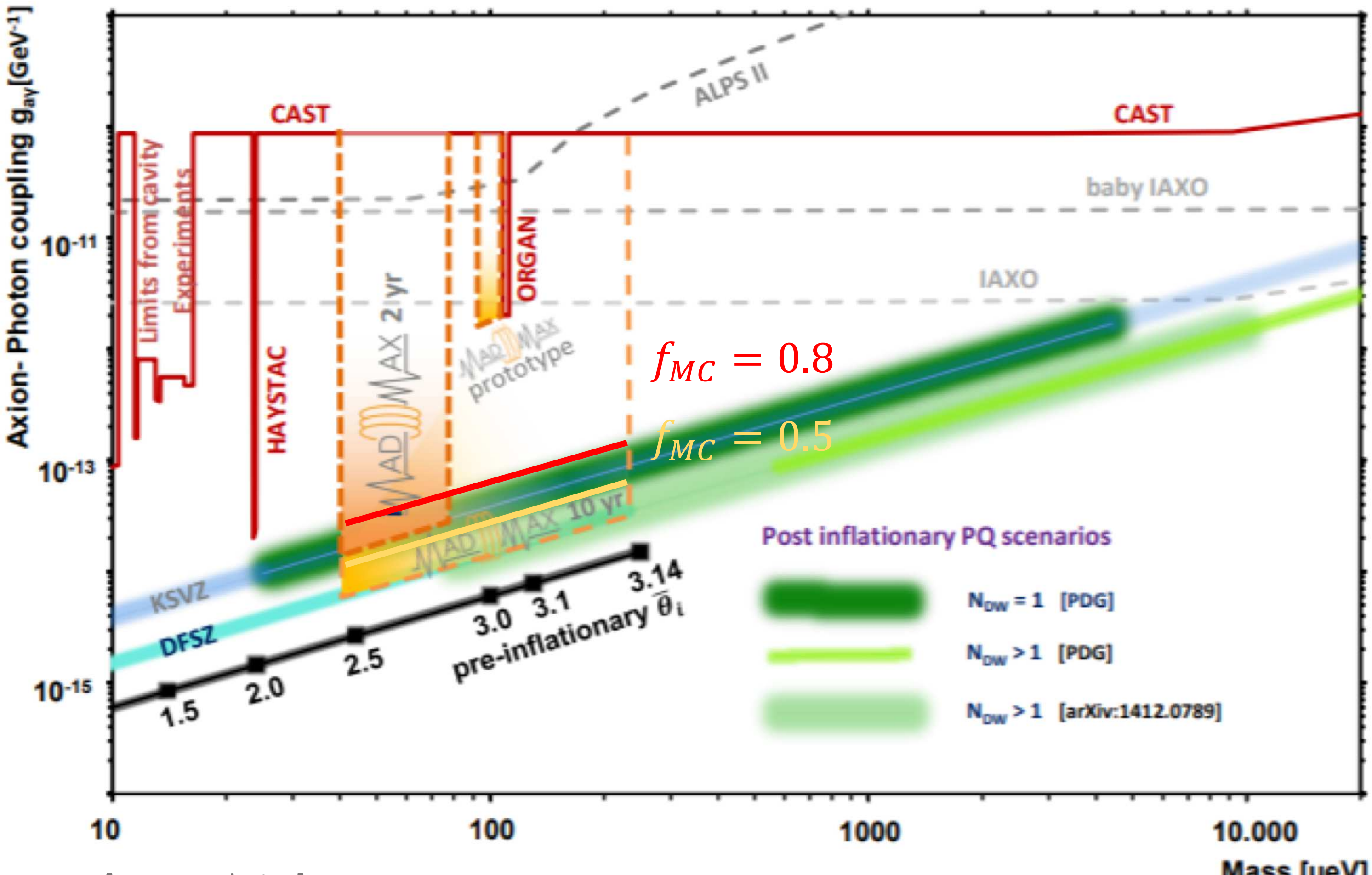


[2011.05377]

Post-inflationary Problems

- Three components: diffuse, miniclusters, streams
- Encounter rate
  - minicluster $\sim 10^{-4} - 10^{-6}$ 1/year
  - Stream $\sim$ every few years
- Domain Walls produce too much DM (if $N_{DW} > 1$) $\rightarrow$ phenomenologically challenging

Post-inflationary Problems



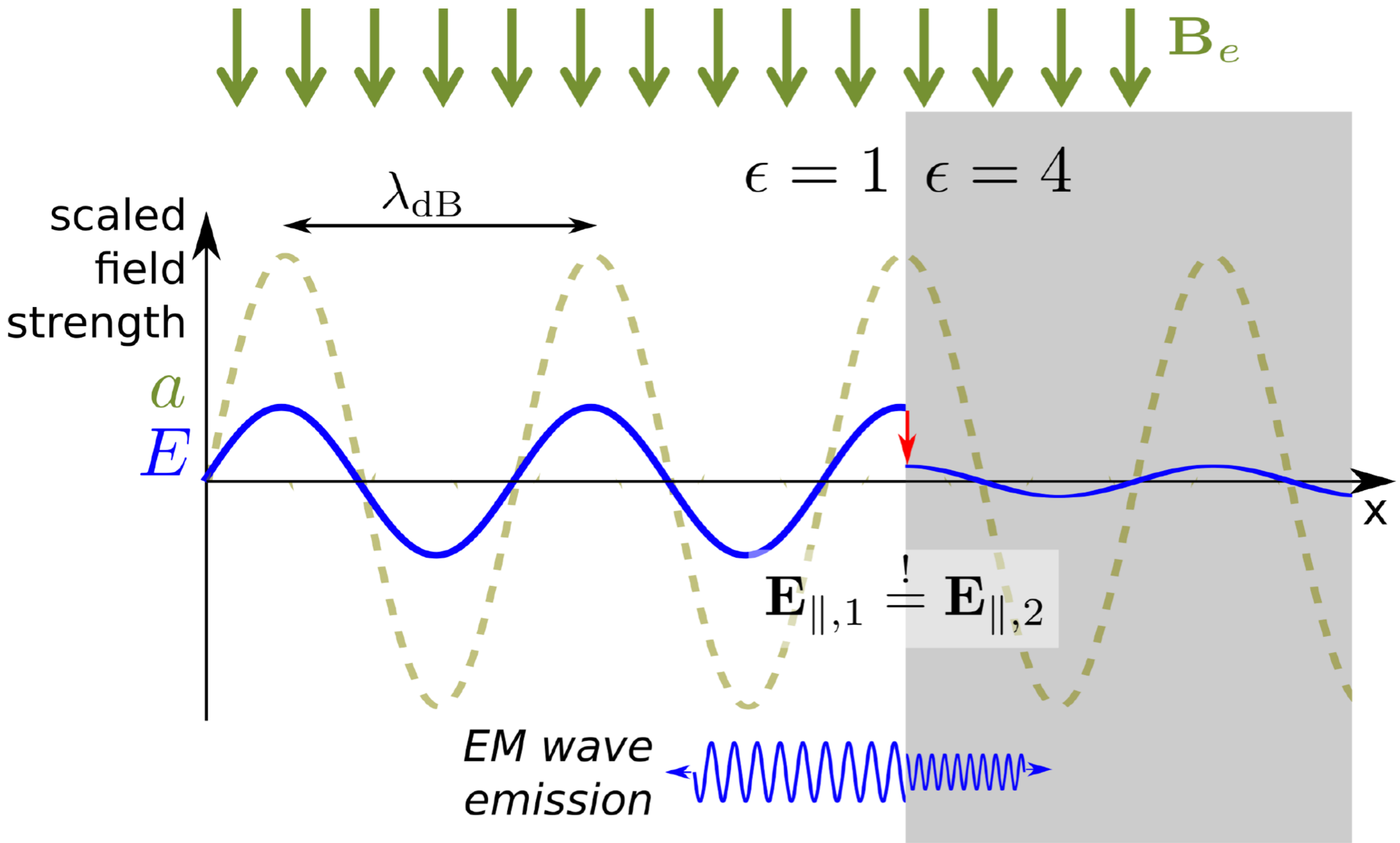
[Cern website]

Summary

- MADMAX @ $\sim 10^{-4}$eV : Axion production pre-inflation and post-inflation possible
- General problem: Prediction for $g_{a\gamma}(E/N)$
- Post-inflation problems:
  - Domain walls produce too much DM
  - Clumpy DM consisting of homogeneous, minicluster and stream component → invisible to MADMAX
- Next year: How to get all this under control!

Addendum

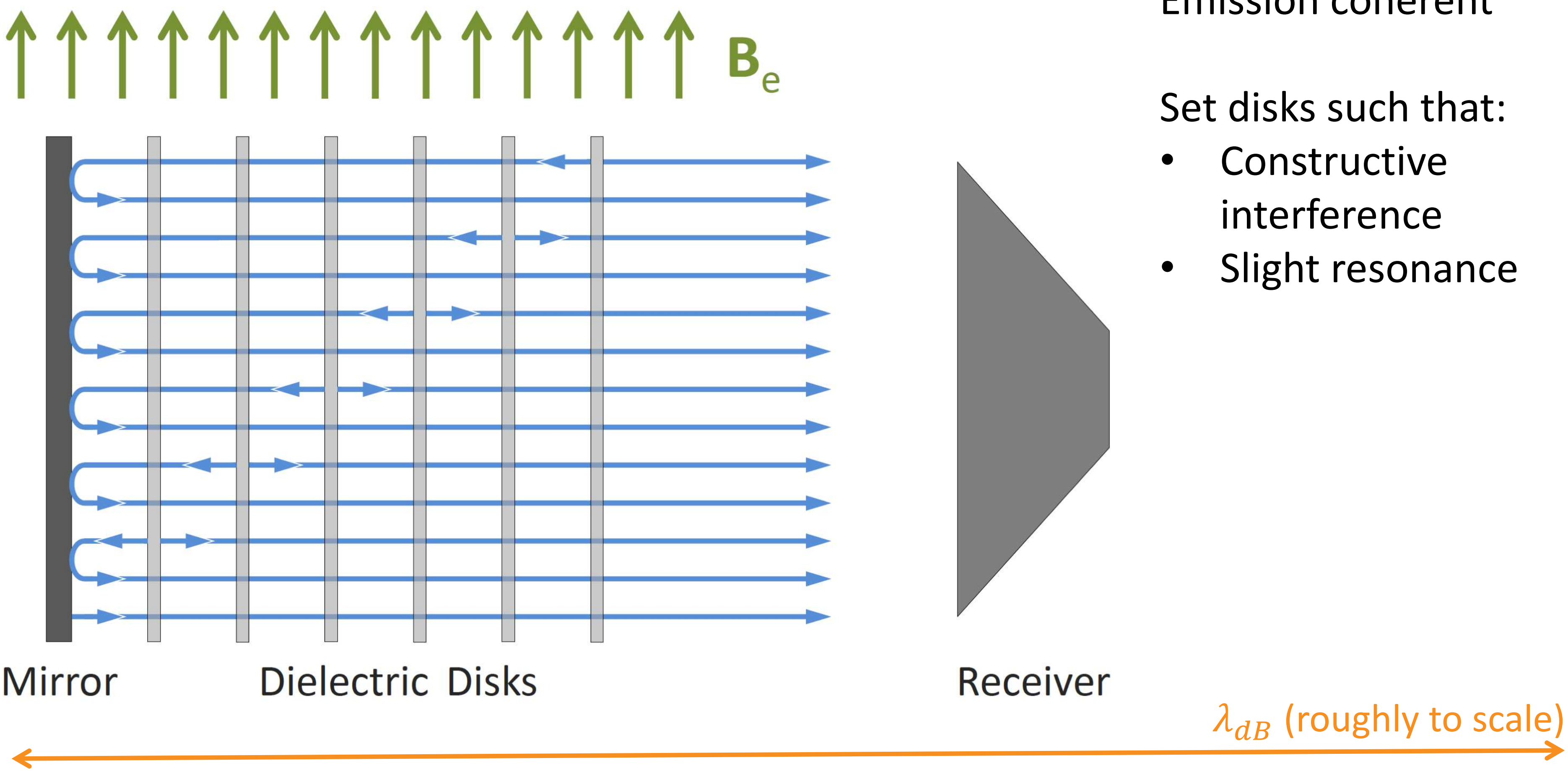
MADMAX plan to find the axion



1. Dielectric boundary in magnetic field
2. Step in induced E field leads to photon emission

Problem:
Which frequency (i.e. mass)?

MADMAX plan to find the axion



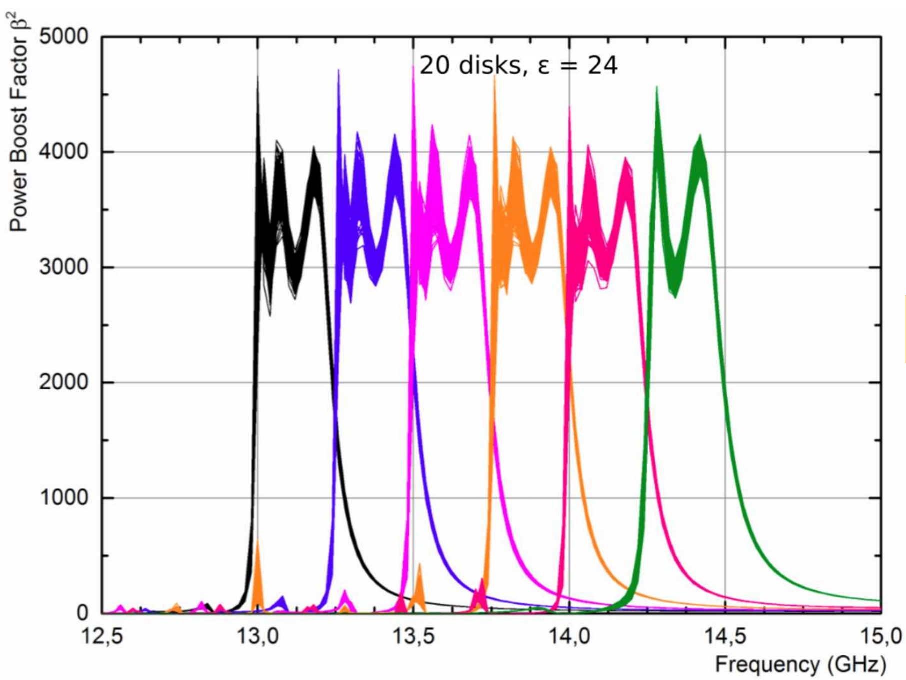
Emission coherent

Set disks such that:

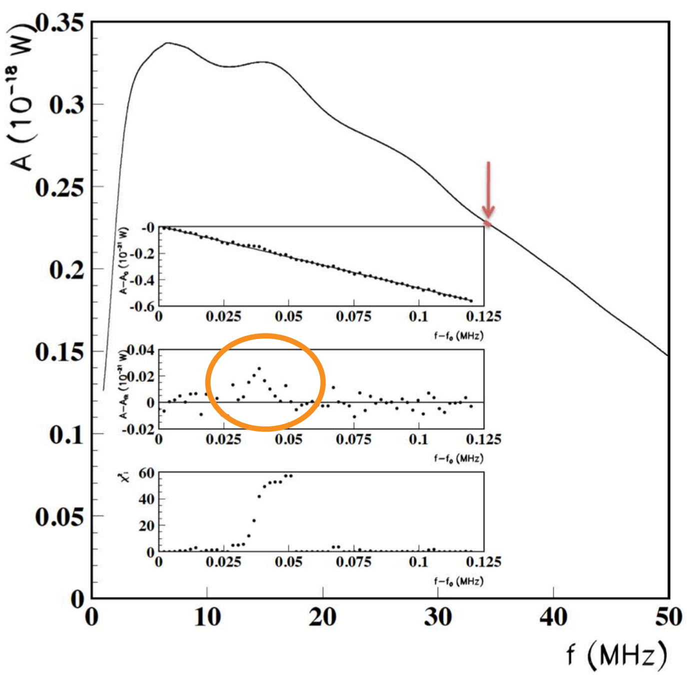
- Constructive interference
- Slight resonance

MADMAX plan to find the axion

Huge Power Boost β



Enormous signal

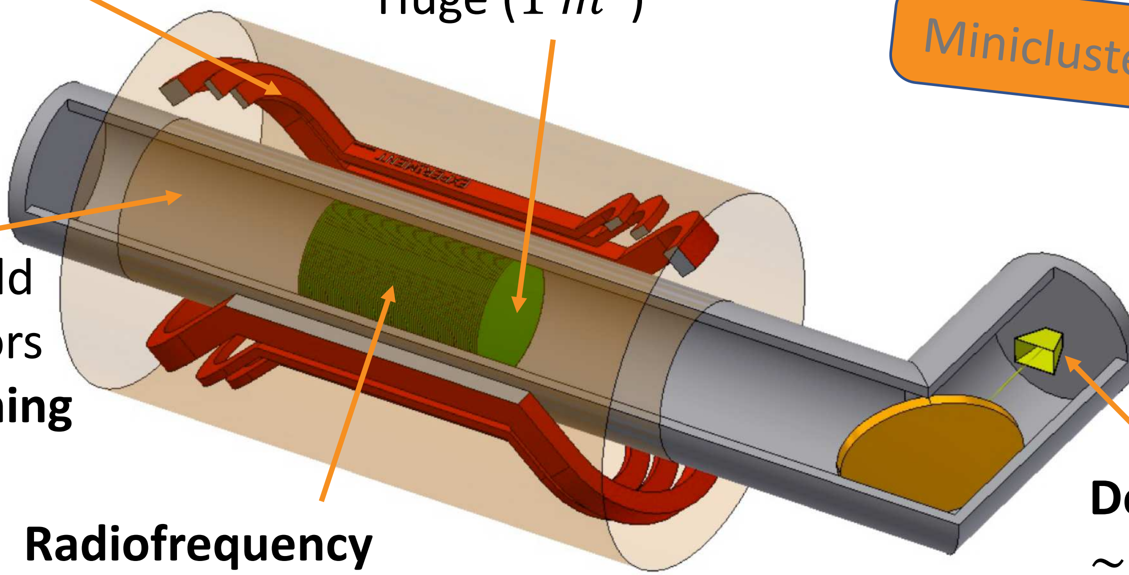


Design & Challenges

Magnet
High-T
Huge bore

Disk-Material
High-ϵ, Low loss
High precision
Huge ($1\ m^2$)

E/N ρ_{DM} $\langle v_{DM} \rangle$
Theory?
Minicluster Streams



Cryogenics + B-Field
= Trouble for motors
for **disk-positioning**

Radiofrequency
Simulation of full system
! CANNOT MEASURE β DIRECTLY !

Detector
$\sim 10^{-22}$ W
@ 10-100 GHz

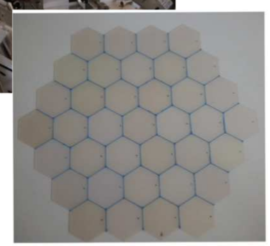
Timeline

Experiment

Closed booster

Open booster

Tiled disks



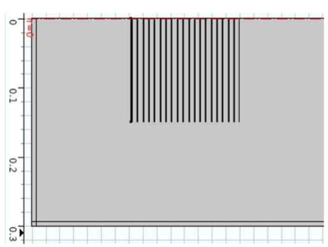
Prototype run @CERN
Starting end of 2022

Data run @DESY
2026? 2027?

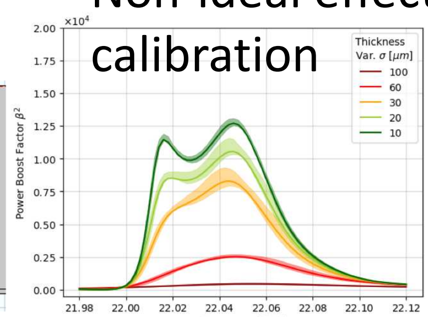
Now

Theory

Simulate slow
Full system



Simulate fast
Non-ideal effects/
calibration



Re-calibration

Indirect
boost factor
measurment

Tiled
disks