
485


485

MINOS

MINOS

Main injector neutrino oscillation search

Main injector

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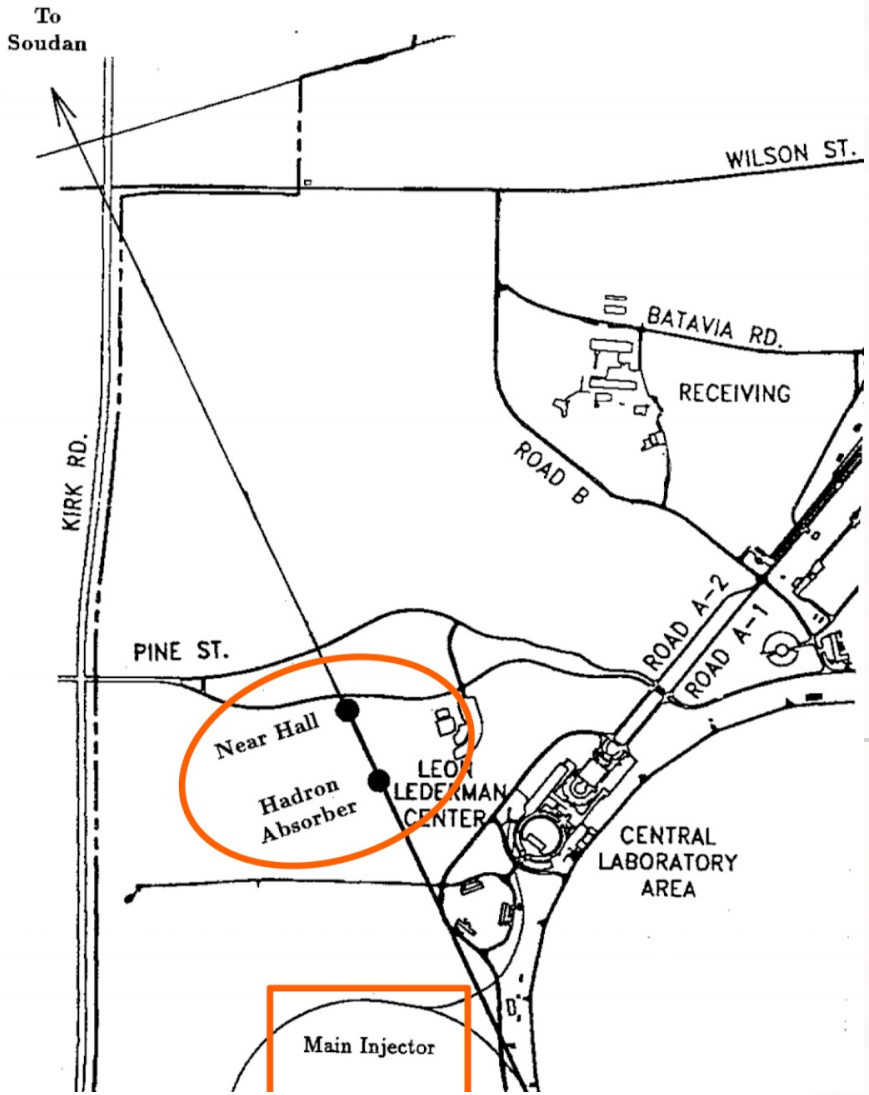
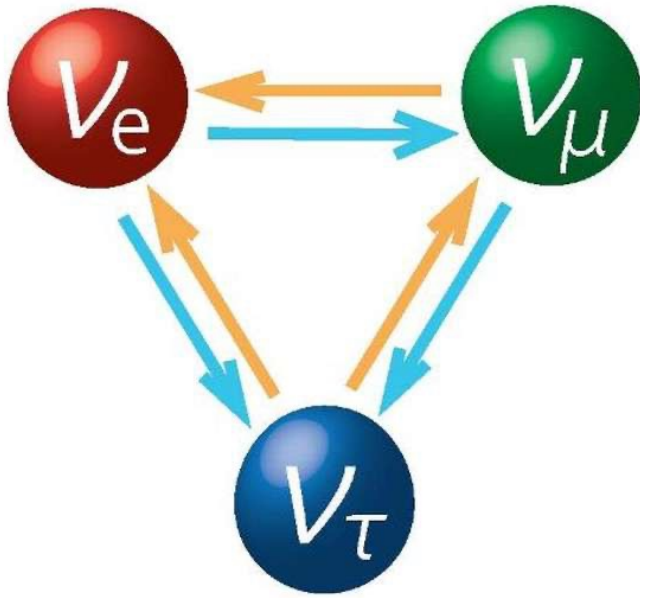


Fig 3.2 from [1] “The MINOS Detectors Technical Design Report”

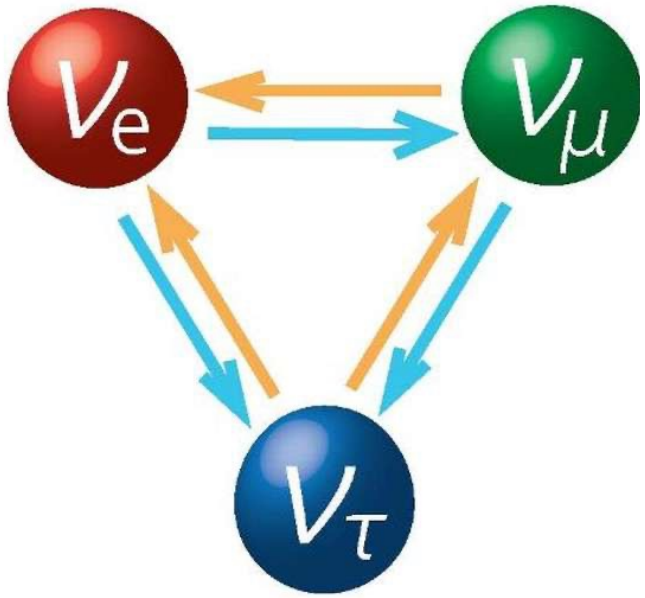
Neutrino oscillation

Neutrino oscillation



Neutrino oscillation

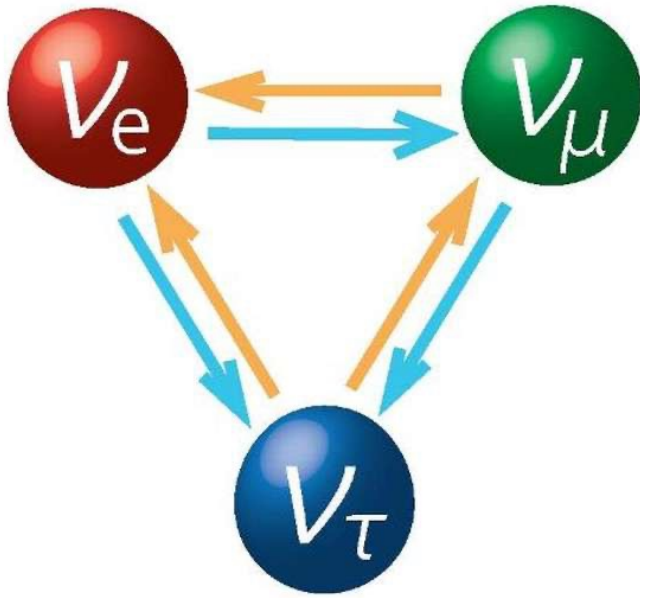
- A QM Phenomenon that involves the conversion of neutrinos between different flavors, as it propagates through space.

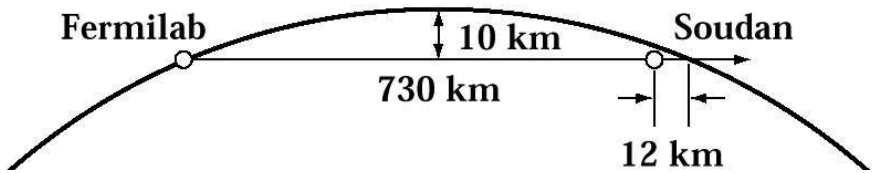


Neutrino oscillation

- A QM Phenomenon that involves the conversion of neutrinos between different flavors, as it propagates through space.

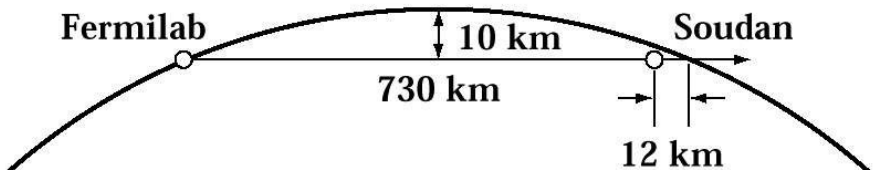
- It implies that the neutrino has a non-zero mass.





Adapted by UCL-Hep group [2]

Minos:



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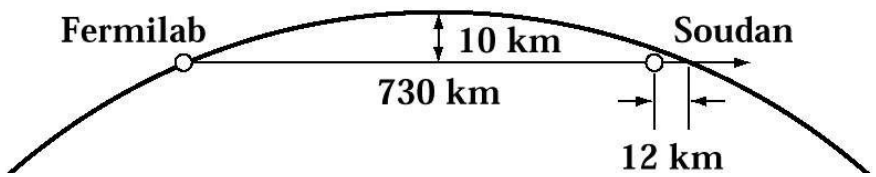
- To study neutrino oscillations.



Adapted by UCL-Hep group [2]

Minos:

- To study neutrino oscillations.

- Two detectors:

- A "near" detector is located at Fermilab.

- A "far" detector is located at a underground mine (to reduce the background).

Source

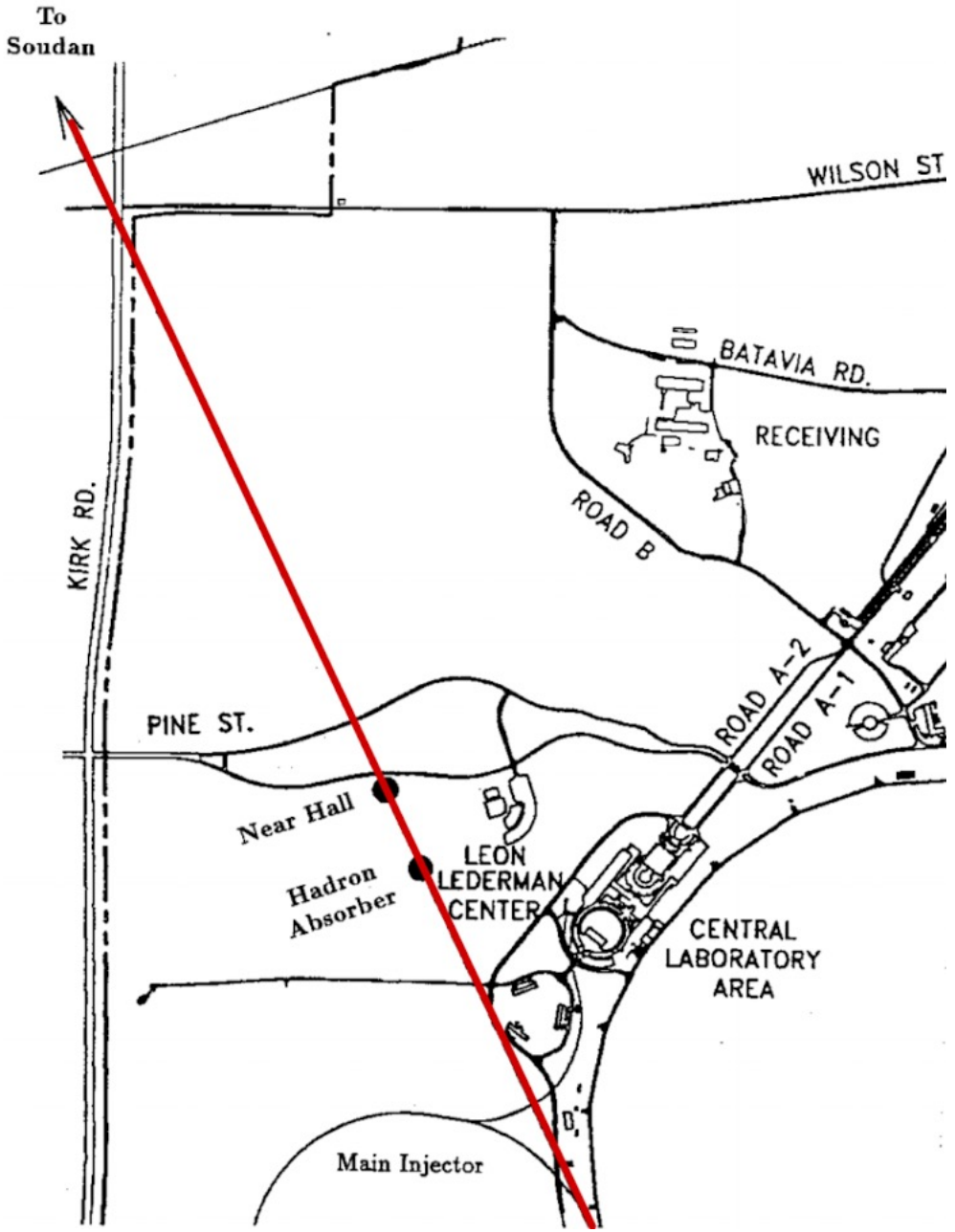
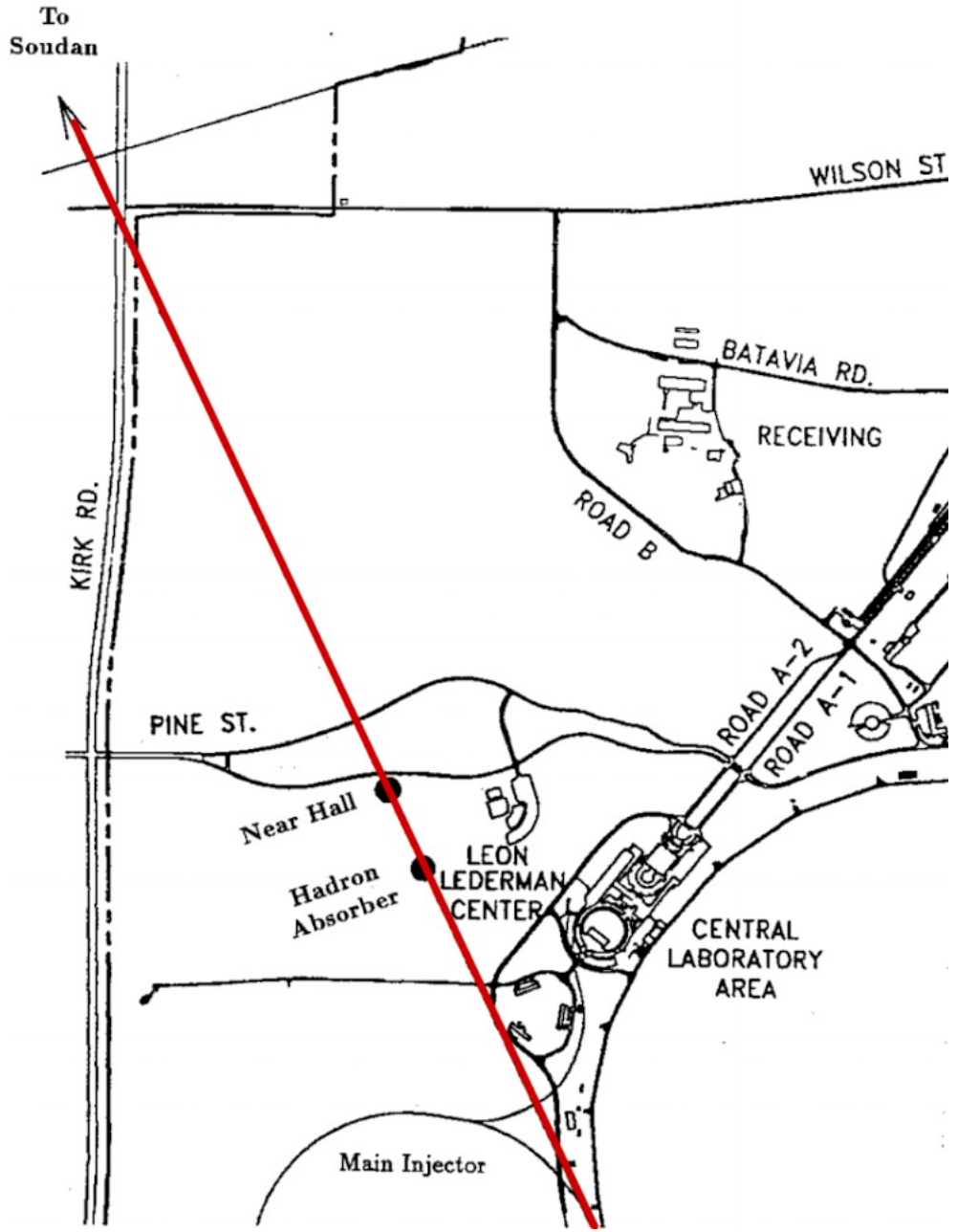


Fig 3.2 from [1] “The MINOS Detectors Technical Design Report”

Source

- Neutrino (ν_μ) beamlines are produced at the Fermilab, and guided through two detectors (red line).



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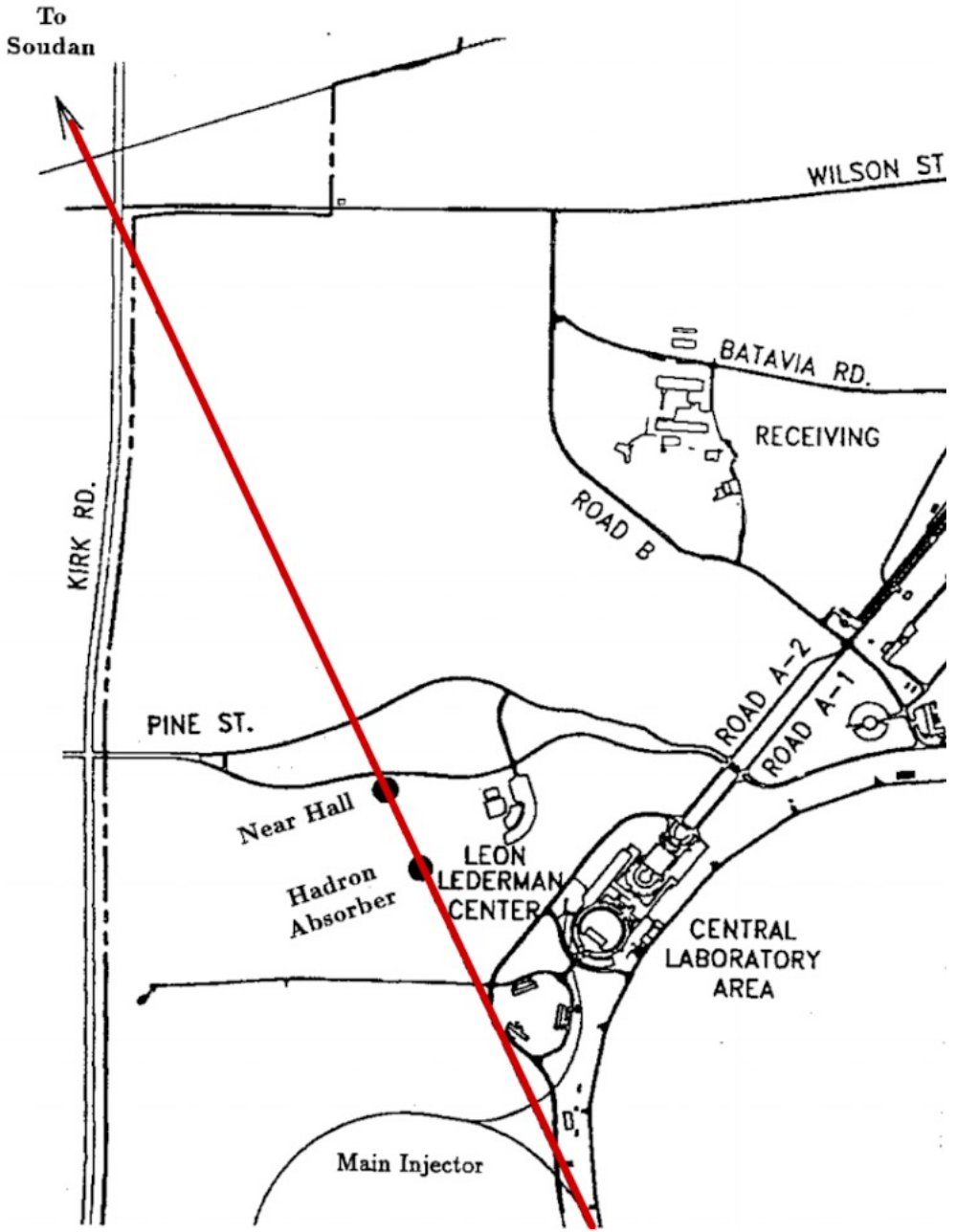

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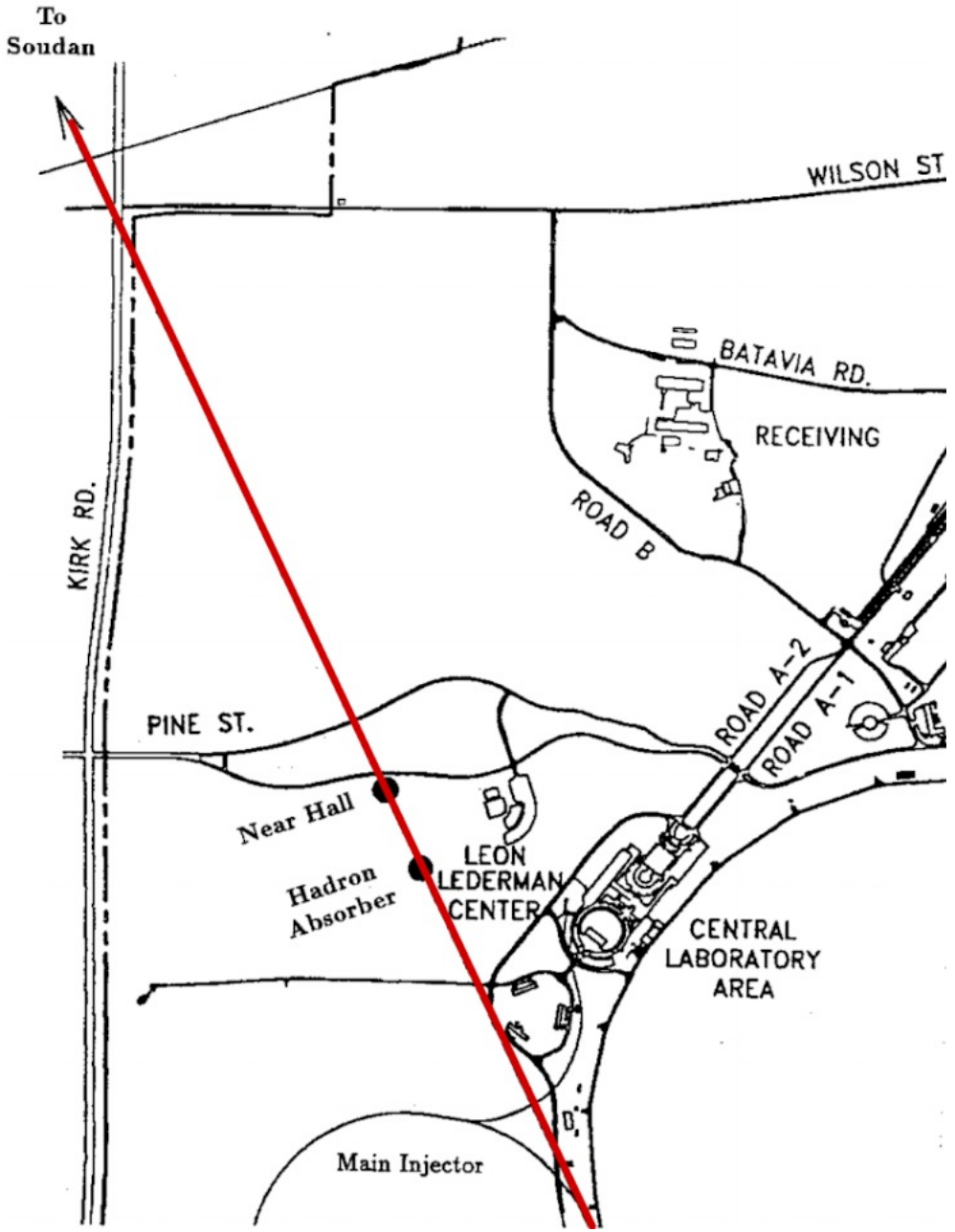
- Neutrino (ν_μ) beamlines are produced at the Fermilab, and guided through two detectors (red line).
- Two detectors detect the neutrinos originating from the same neutrino beam.
- The information is obtained by comparing the data collected from two detectors.



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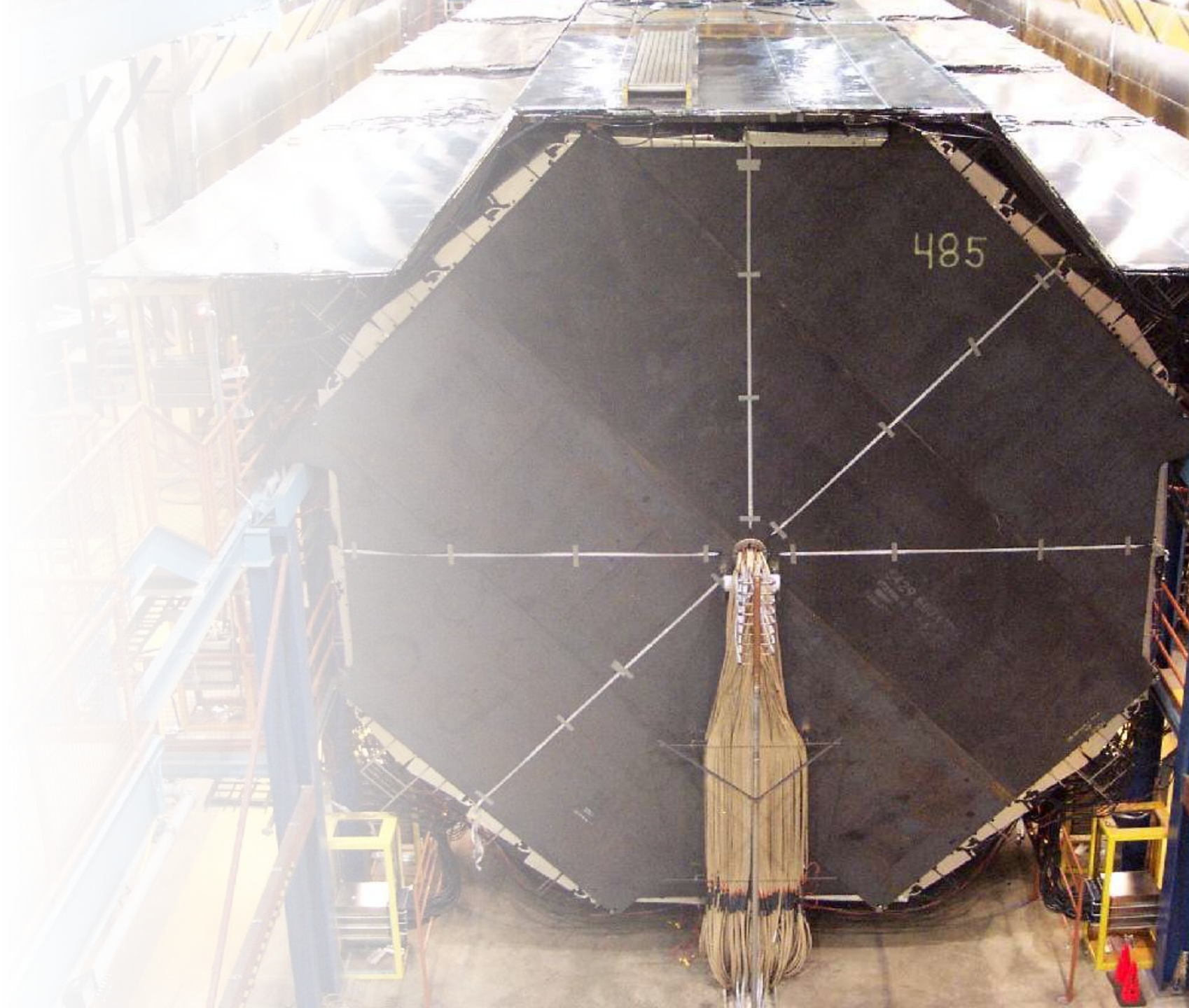
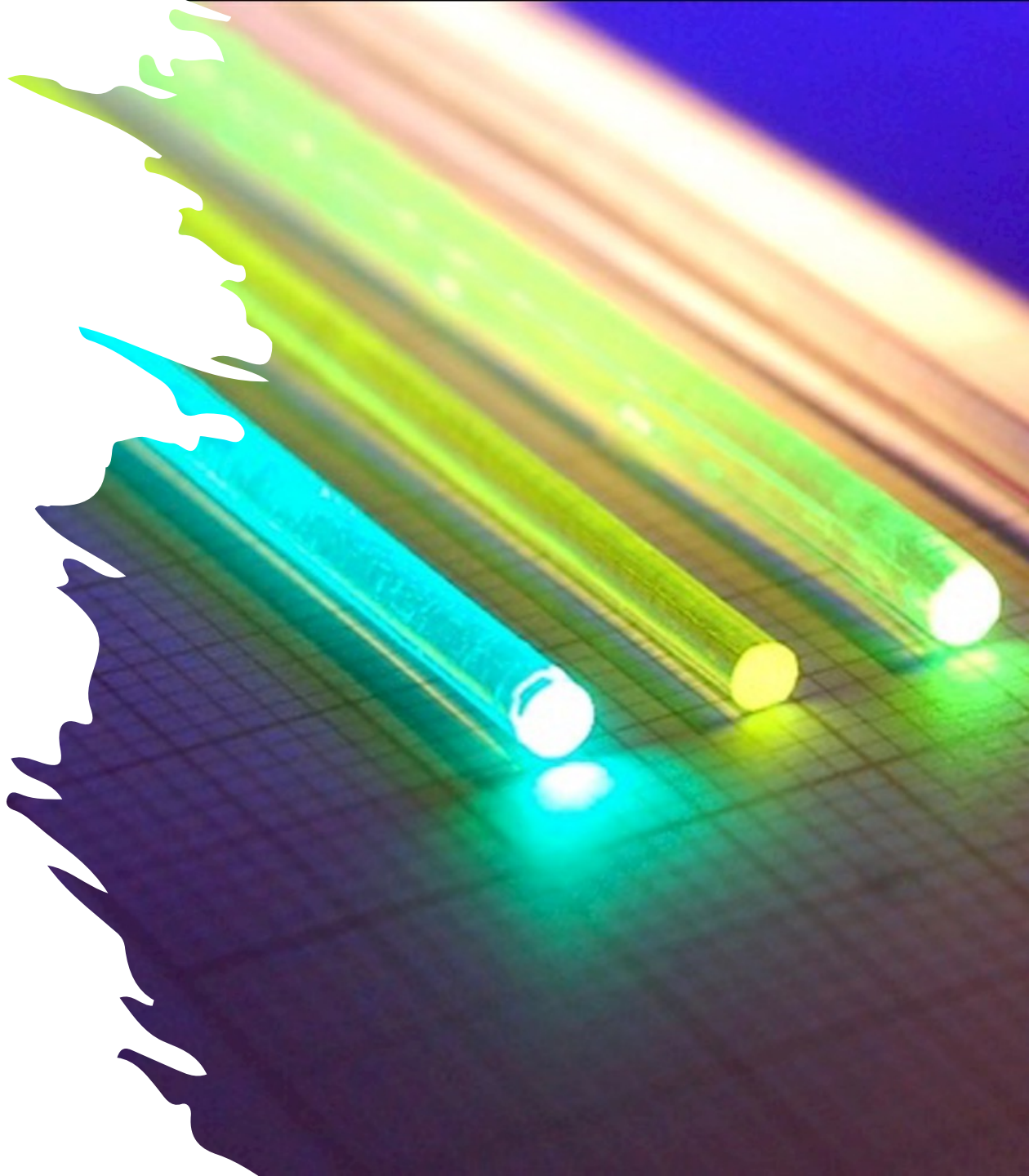

485

Detecting the neutrino

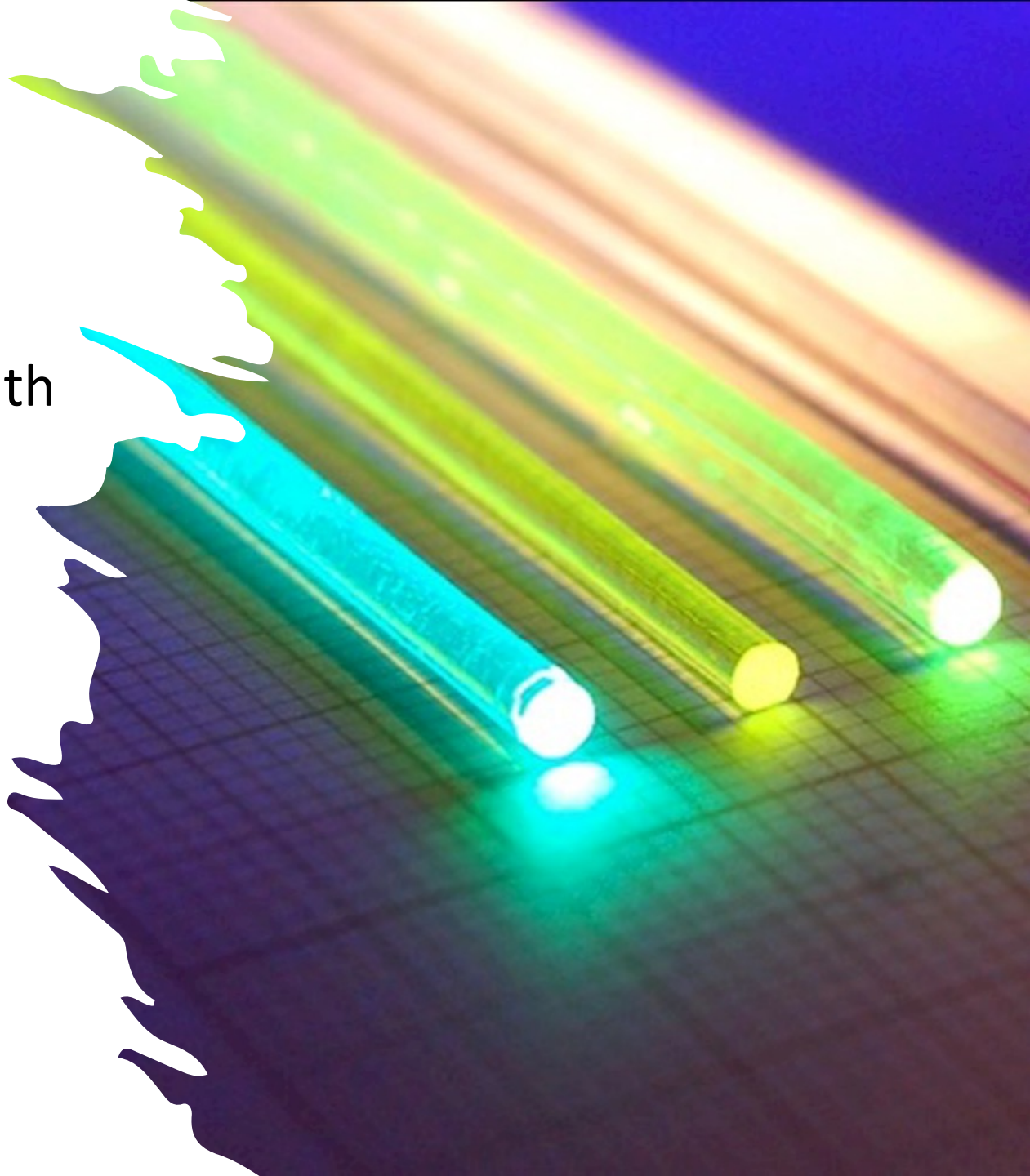
Scintillators in Neutrino Detection

Scintillators



Scintillators

- Scintillator is primarily composed of plastic: Polystyrene (PS), and doped with a small amount of fluorescent (PPO, POPOP).



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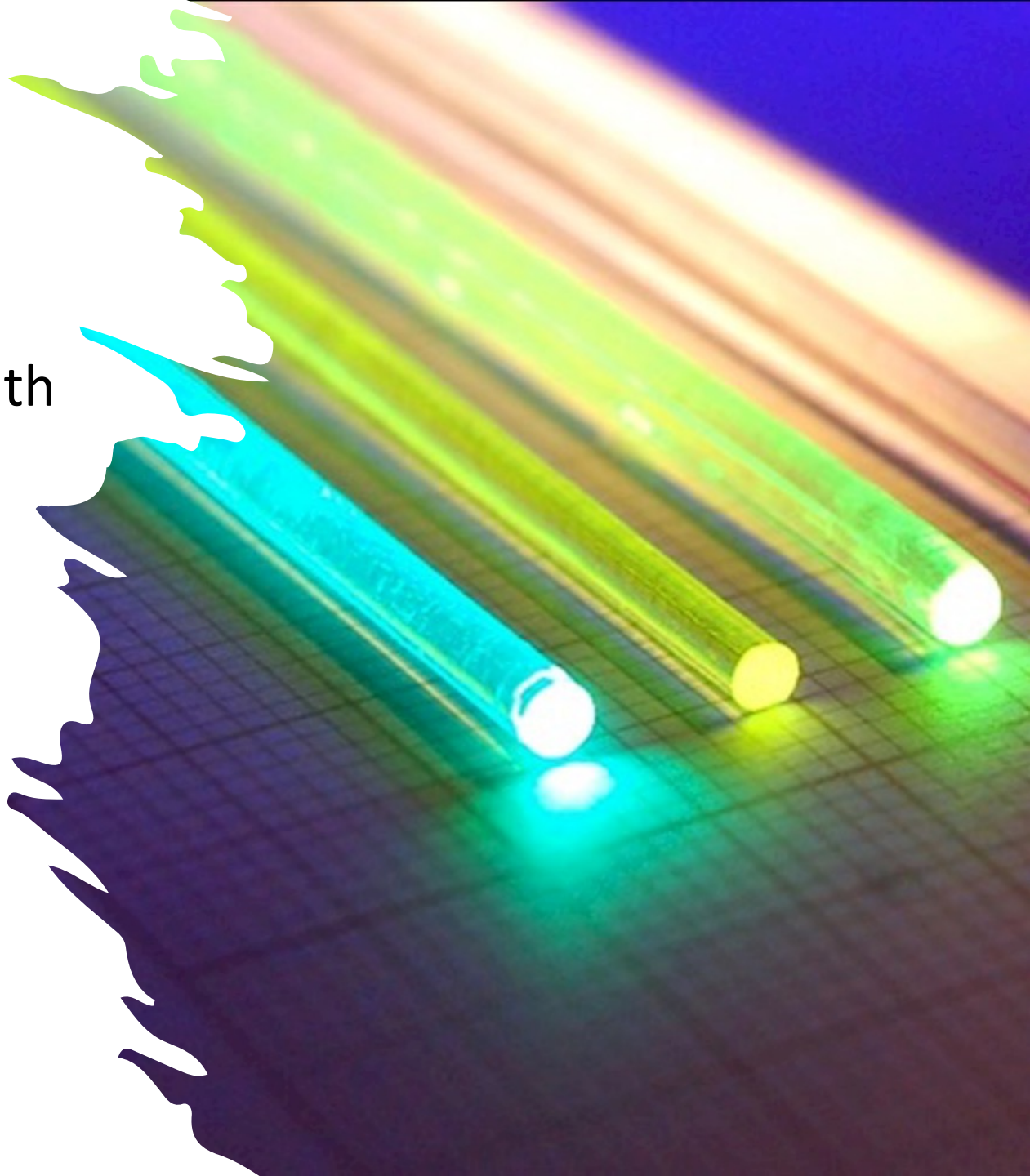
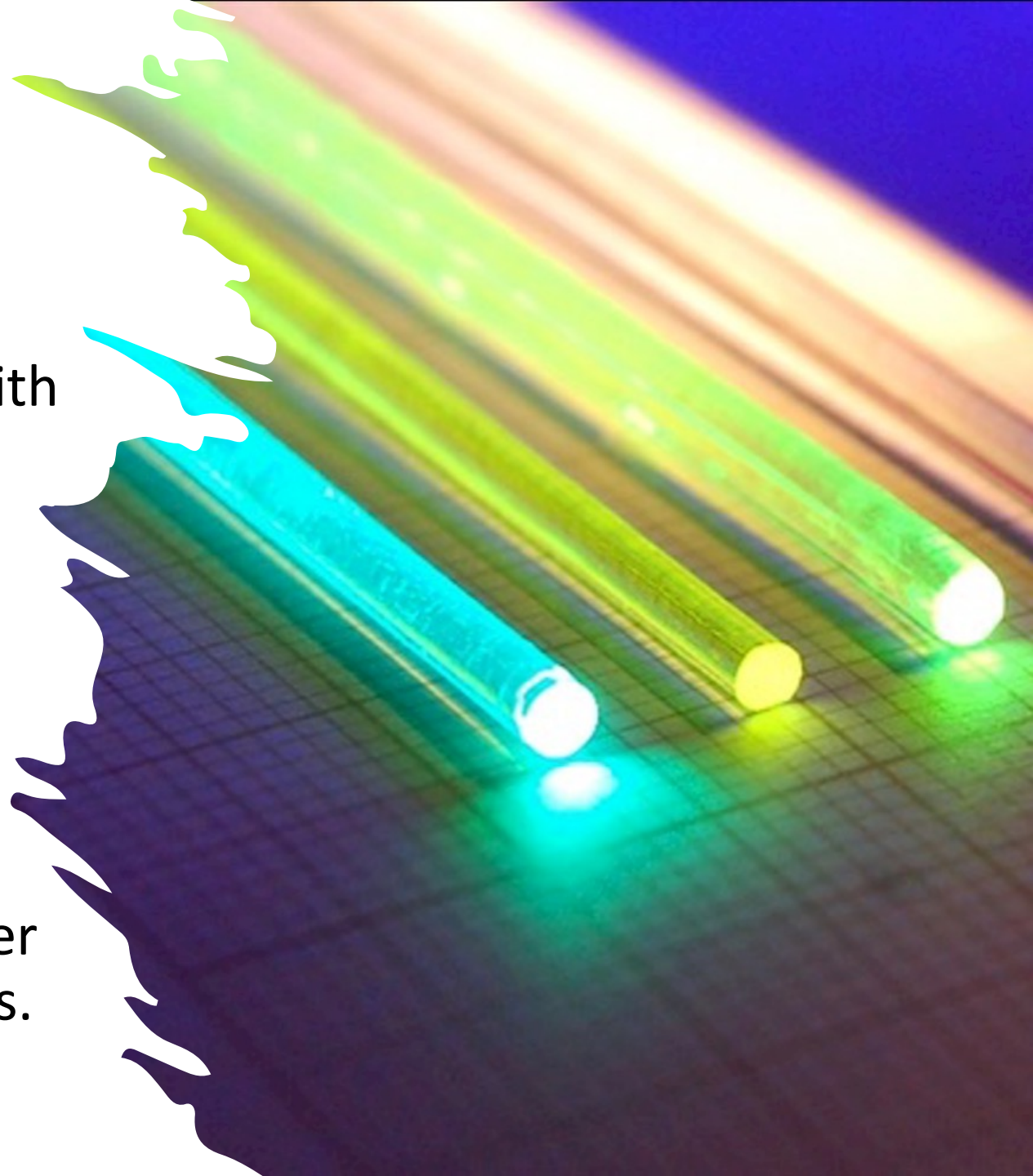
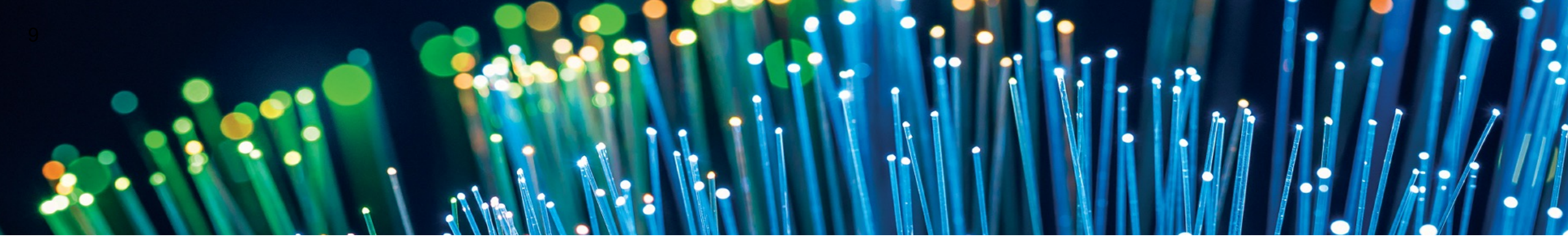
- Fibers are embedded into the scintillators.

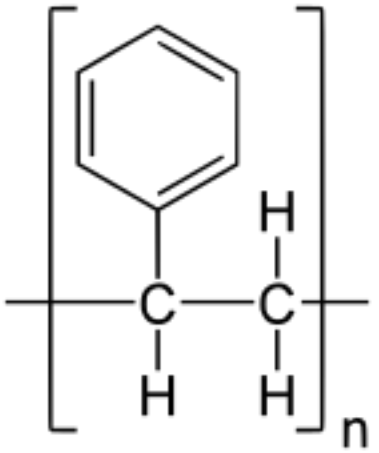


Scintillators

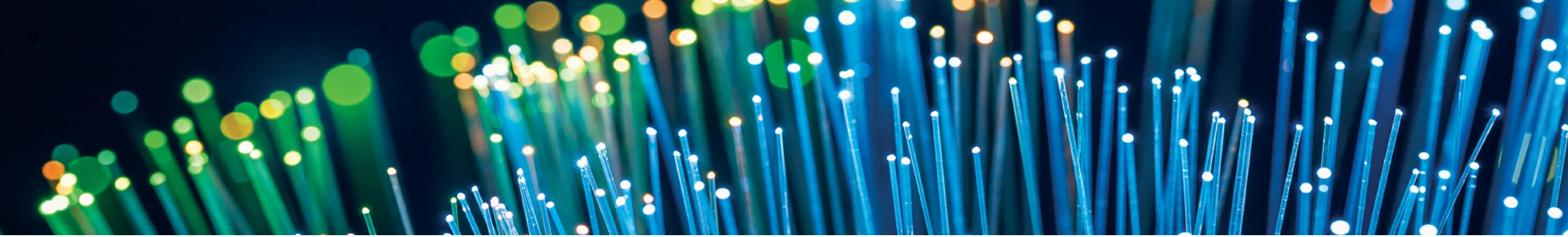
- Scintillator is primarily composed of plastic: Polystyrene (PS), and doped with a small amount of fluorescent (PPO, POPOP).
- Fibers are embedded into the scintillators.
- Fibers are connected to photomultiplier tubes (PMTs) or similar photodetectors.



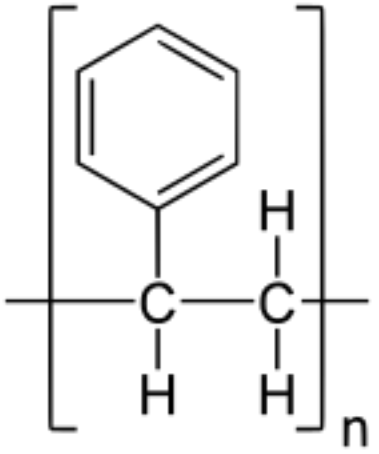




Polystrene



- Simple and Robust Construction.



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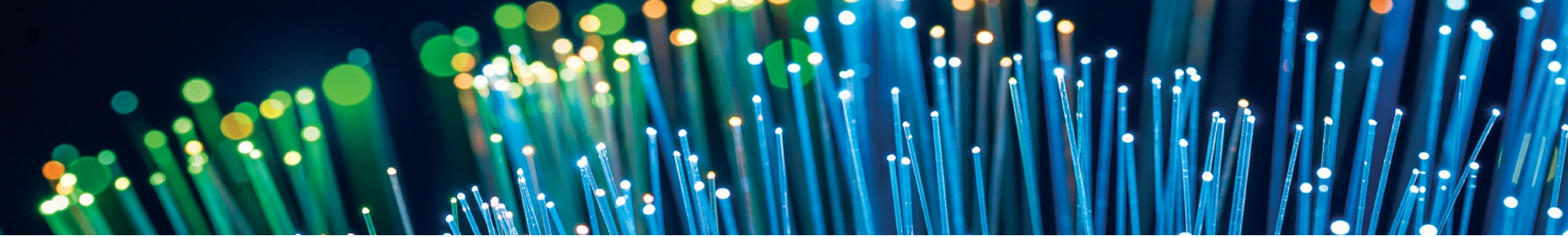

- Simple and Robust Construction.
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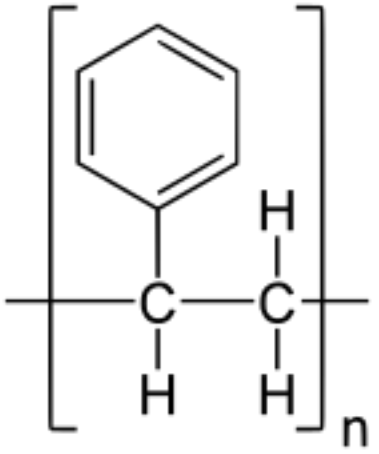

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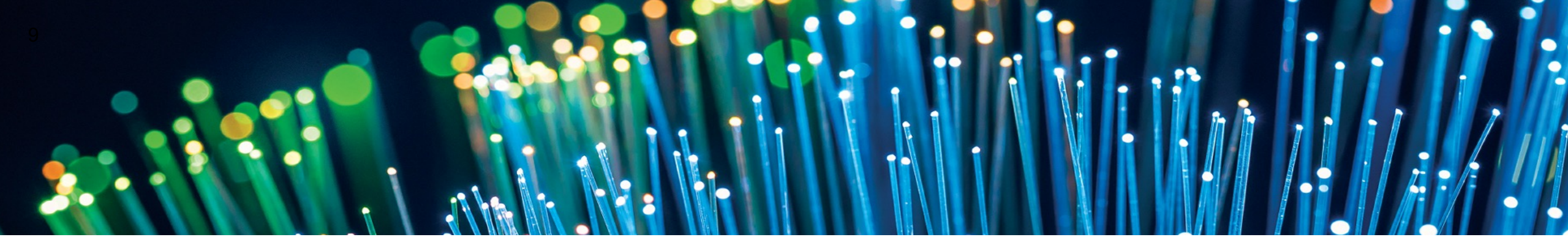
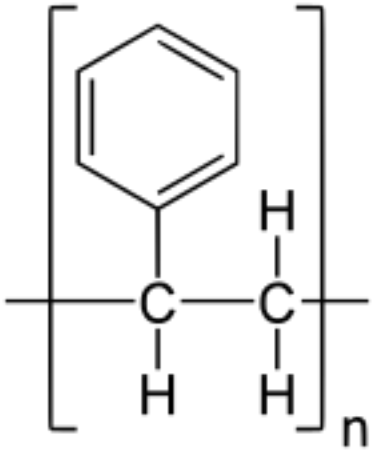


- Simple and Robust Construction.
- Long-Term Stability.
- Low Maintenance and High Reliability.



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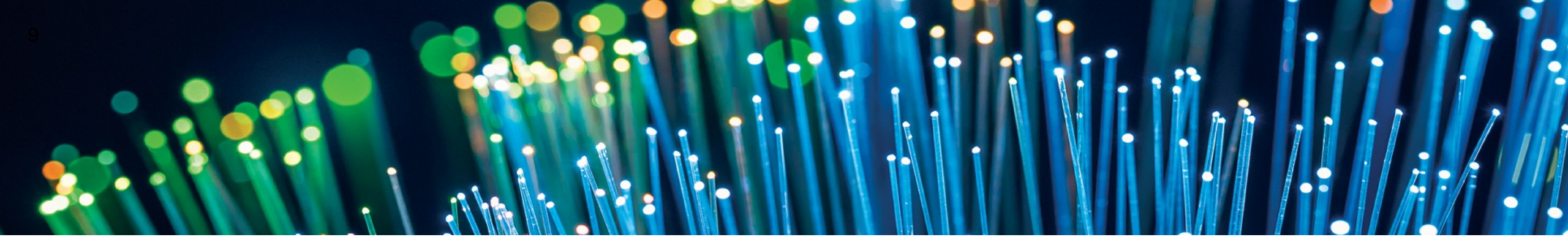
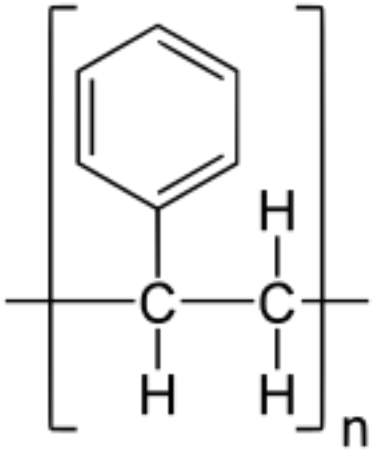


- Simple and Robust Construction.
- Long-Term Stability.
- Low Maintenance and High Reliability.
- Cost-Effectiveness.



Polystrene

Scintillators in Neutrino Detection

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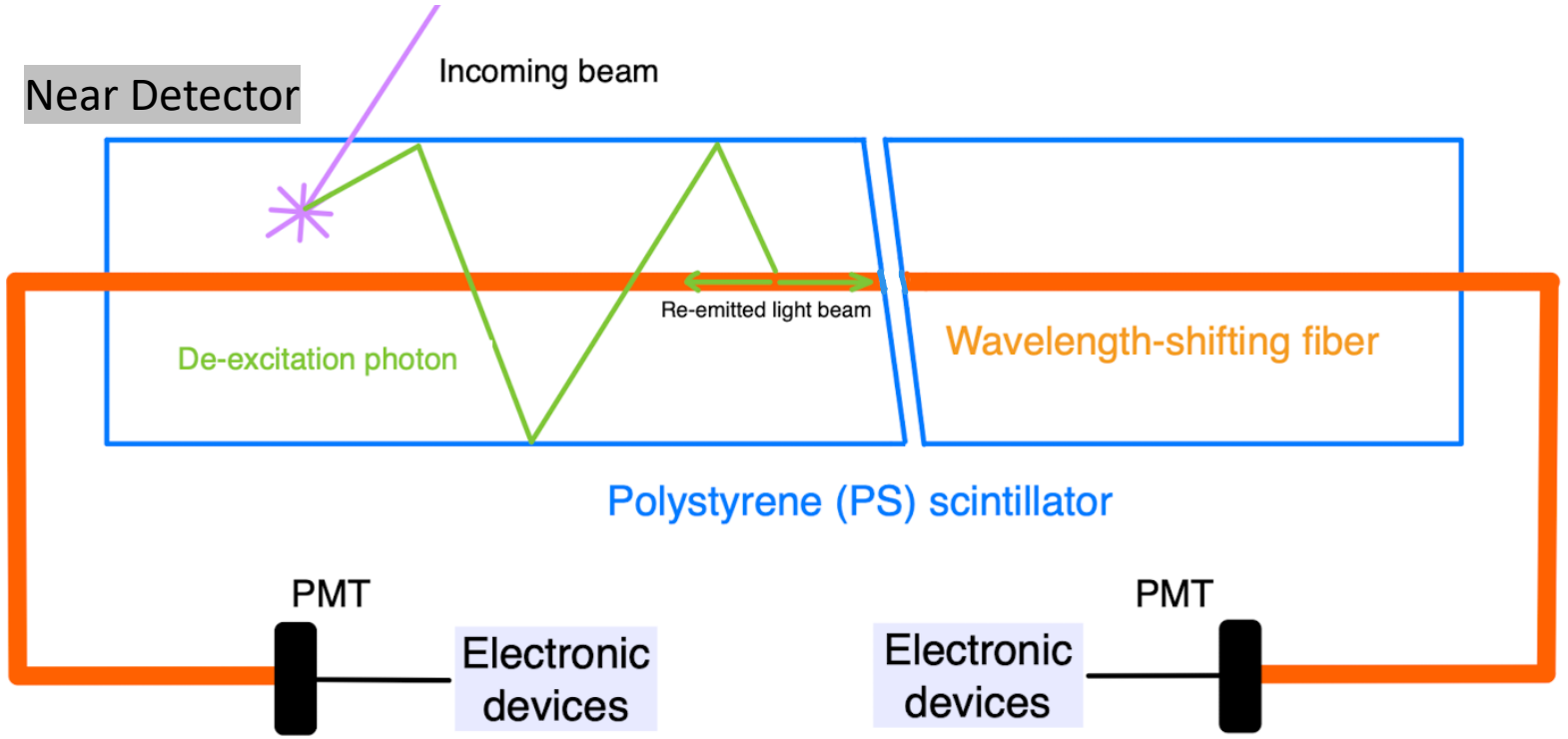
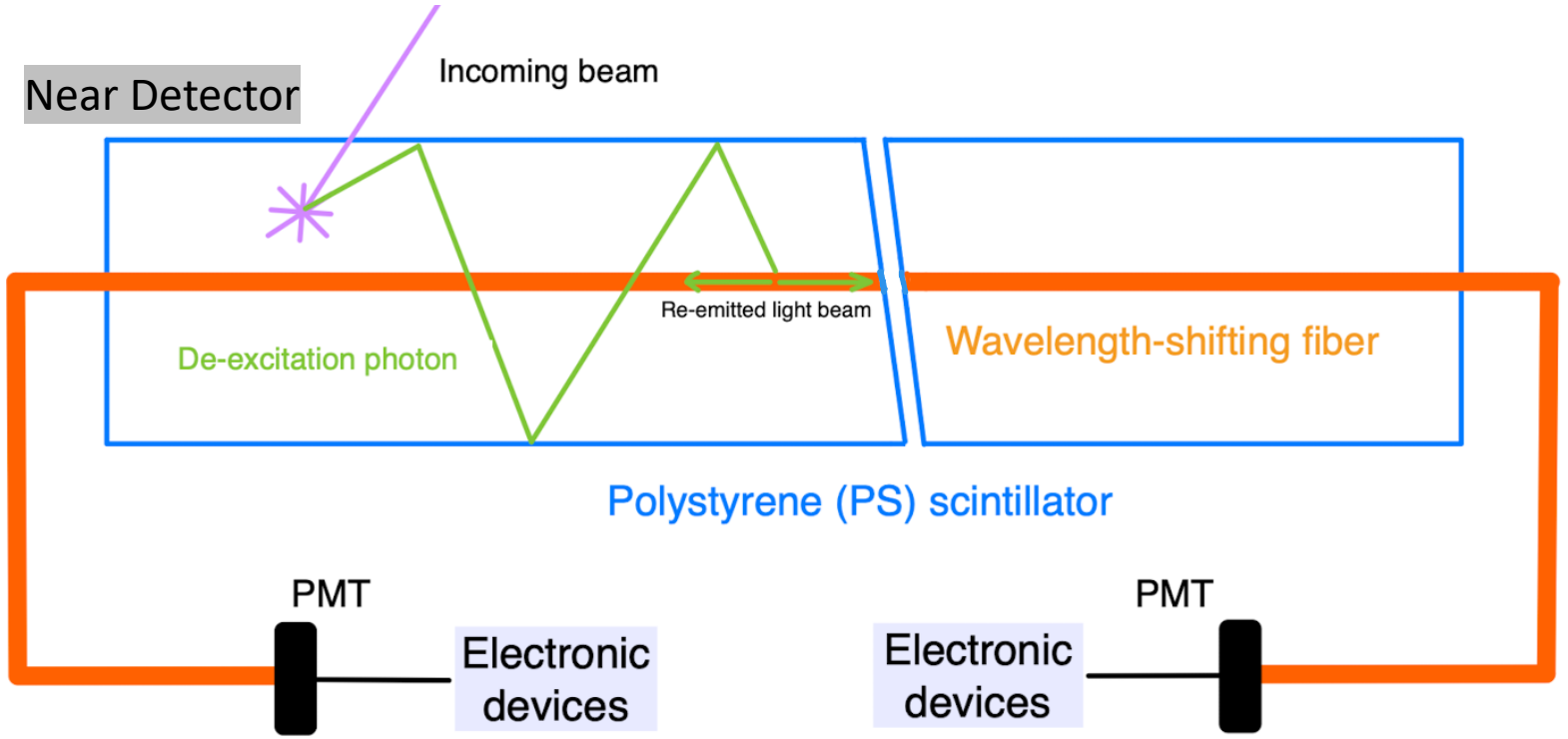
- Particles excite the molecules of the scintillator.
- The excited molecules return to their ground state, emitting photons in the process.

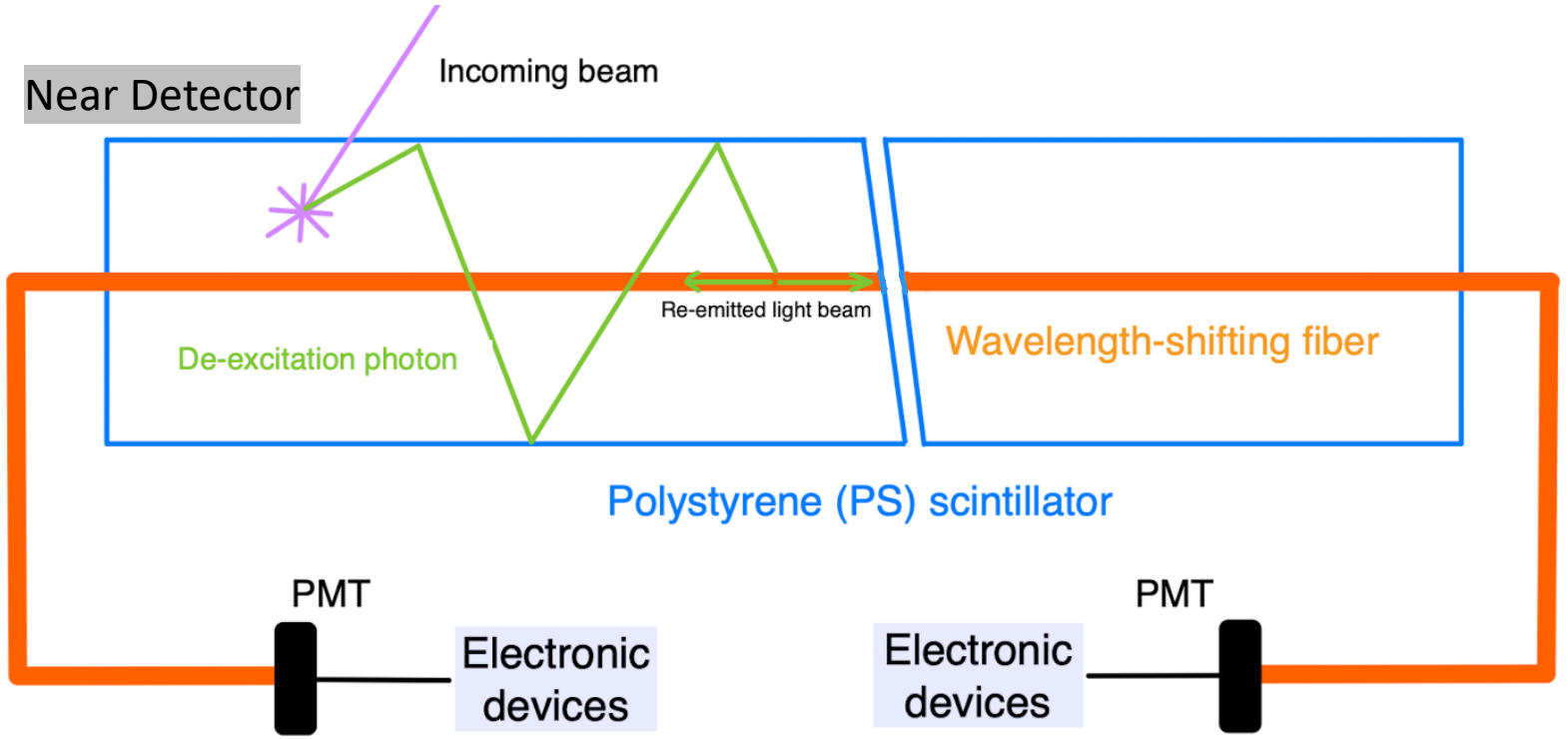

Near Detector
Incoming beam
Re-emitted light beam
De-excitation photon
Wavelength-shifting fiber
Polystyrene (PS) scintillator
PMT
Electronic devices
PMT
Electronic devices

- These fibers collect the scintillation light produced by de-excitation.



- These fibers collect the scintillation light produced by de-excitation.

- Fiber's material re-emits the light.



- These fibers collect the scintillation light produced by de-excitation.
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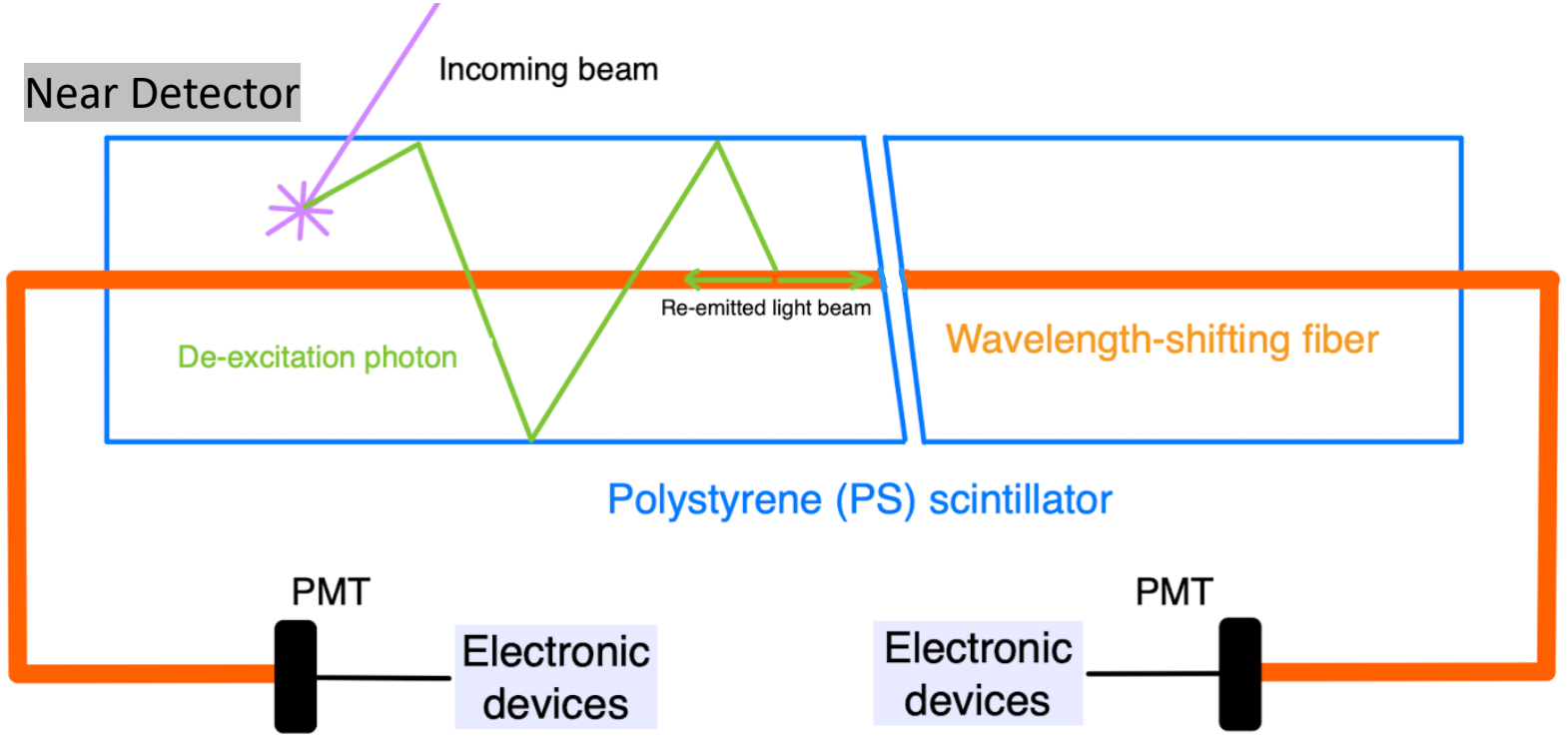
- PMTs can detect the light transmitted through the fibers and convert these light into electrical signals.



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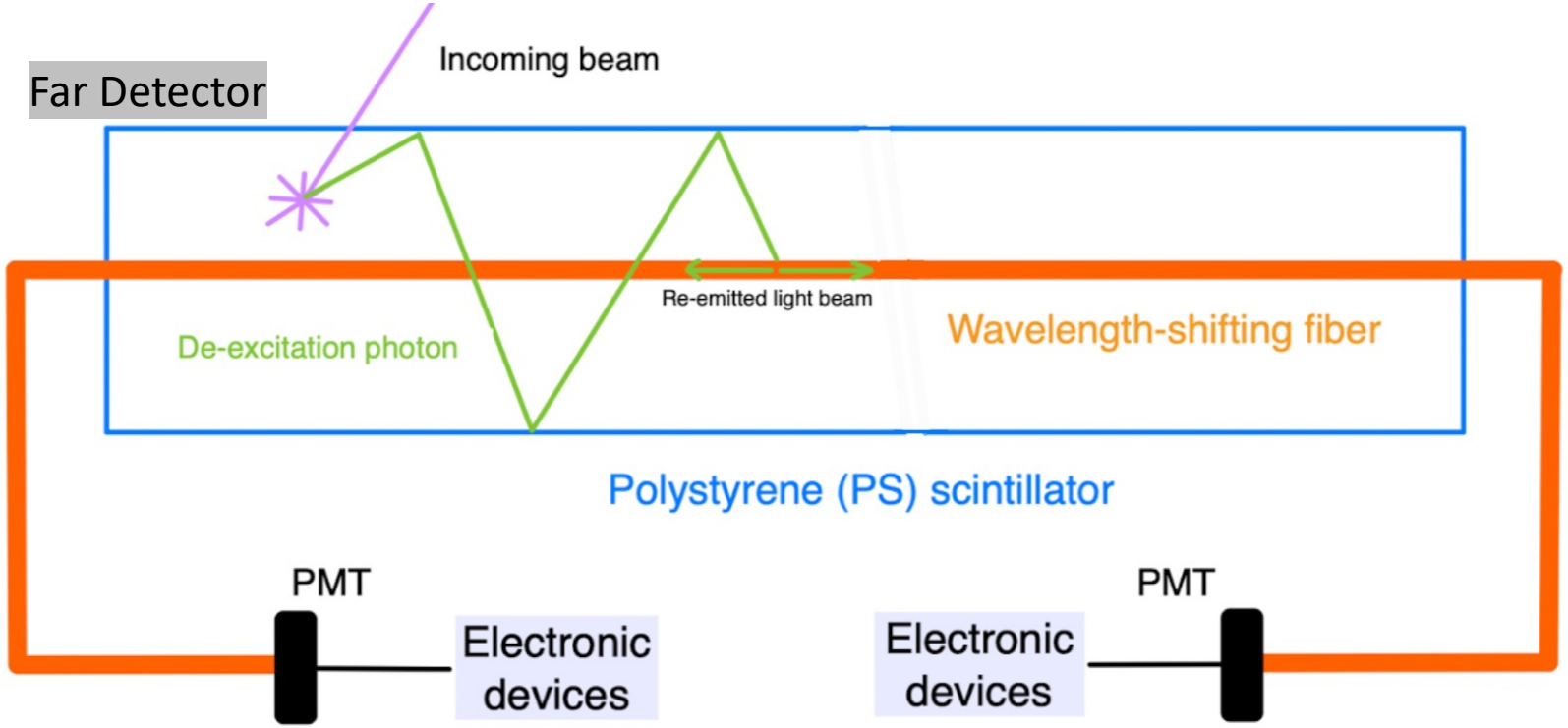

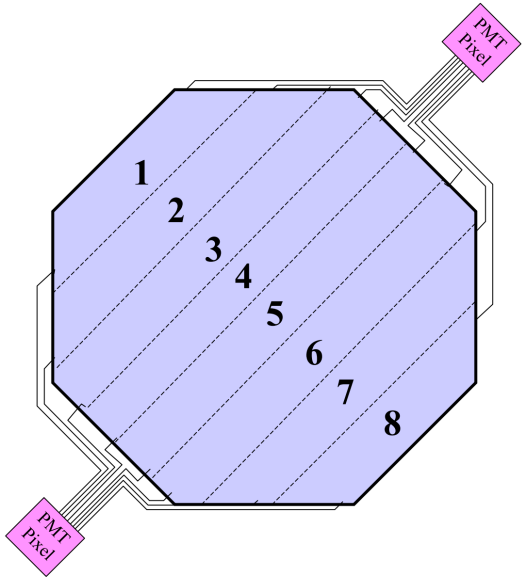

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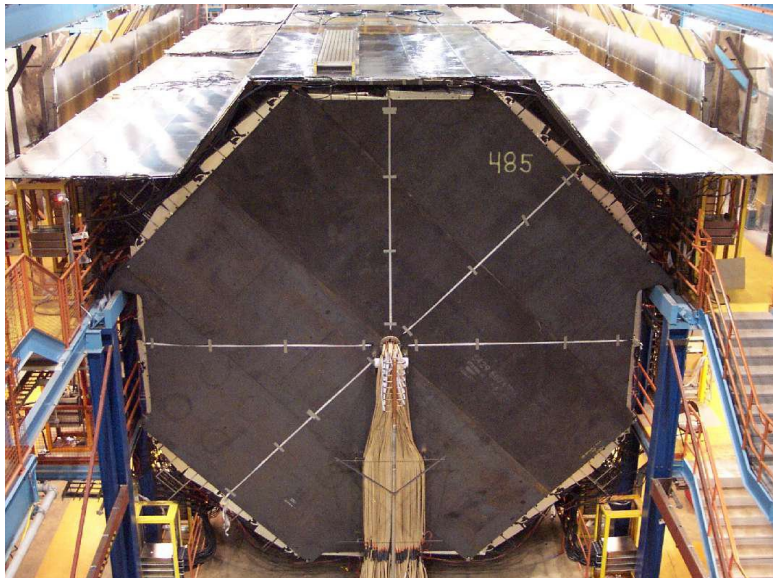
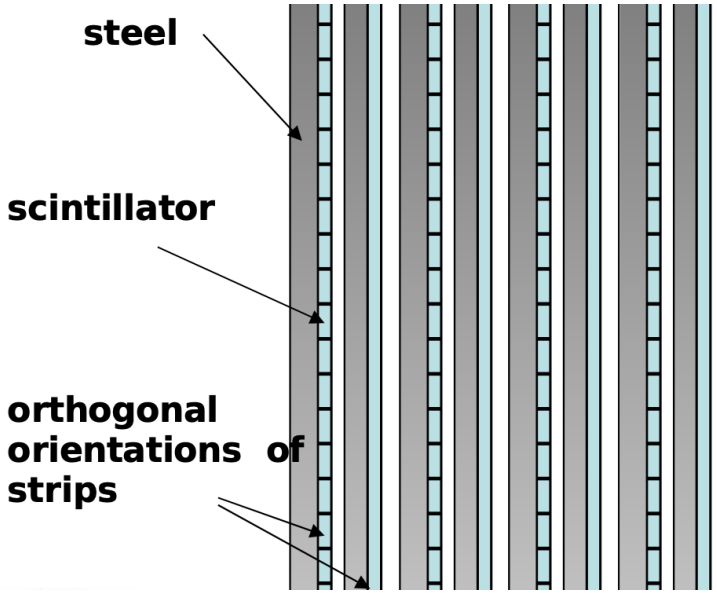
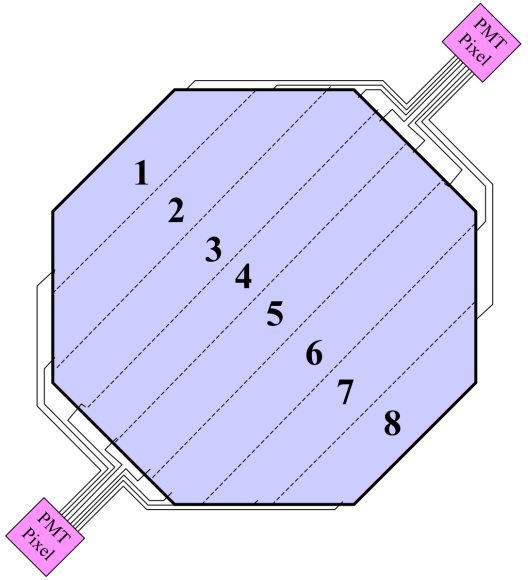




From John Chapman [4] .

- The steel plate is magnetized, providing a uniform magnetic field throughout the detector volume.



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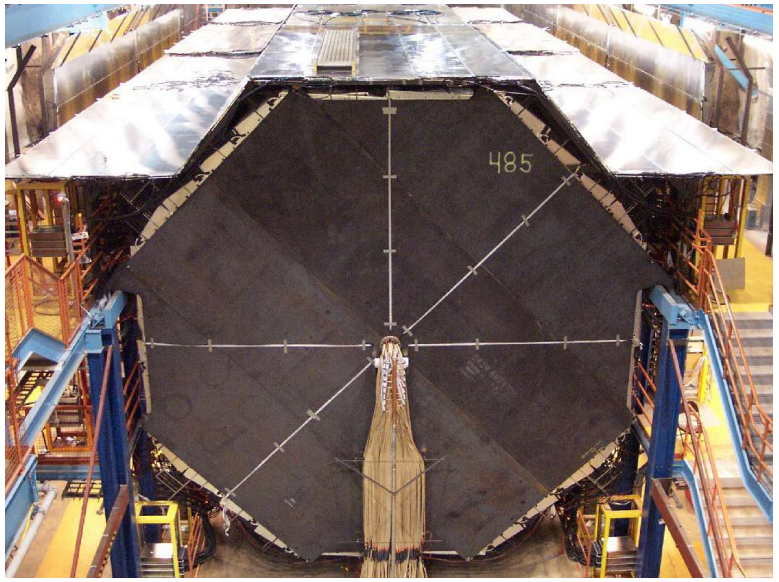

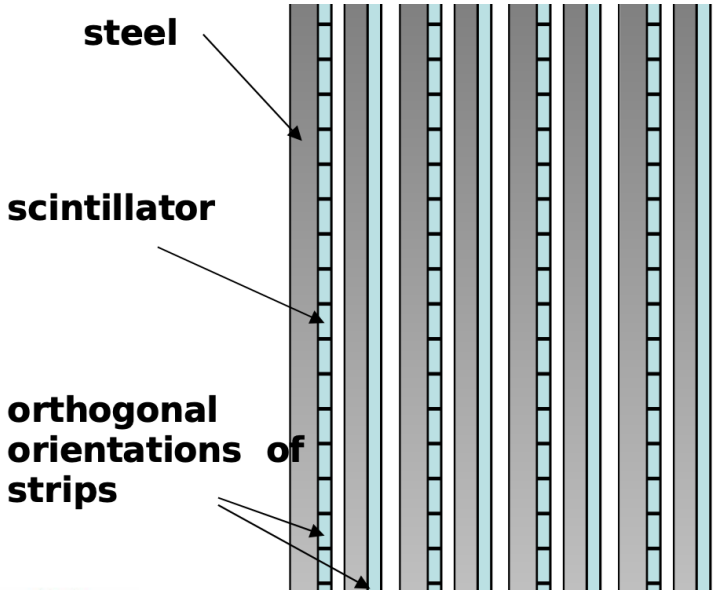

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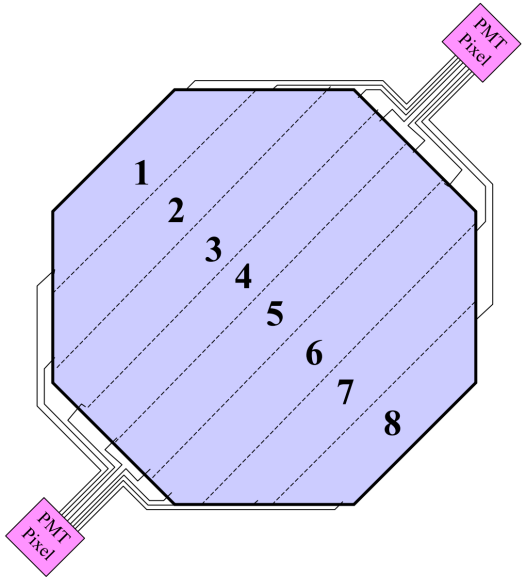

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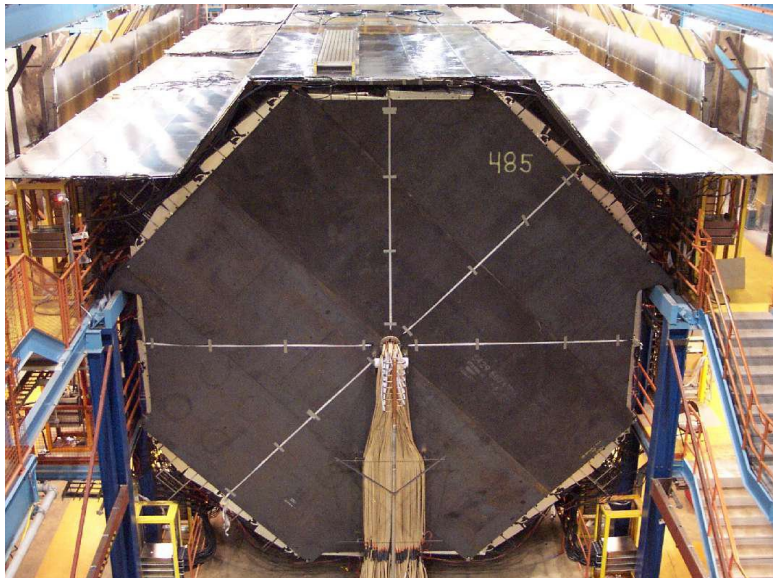

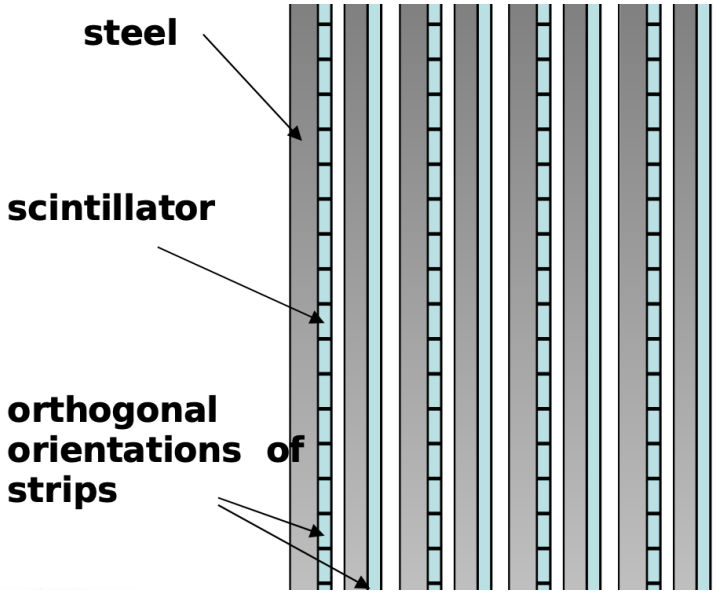

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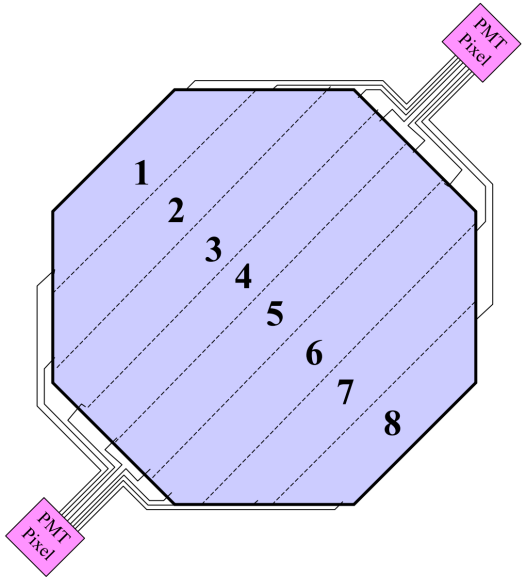
- Steel also causes particles to lose energy.



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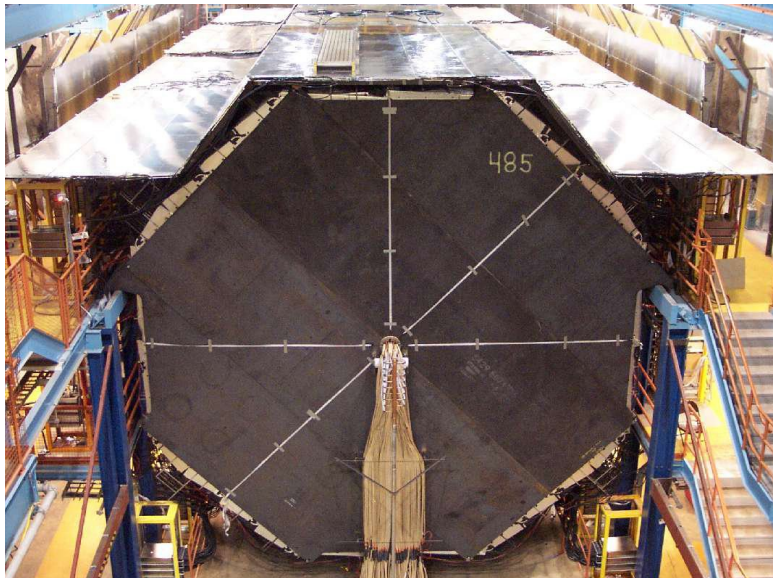

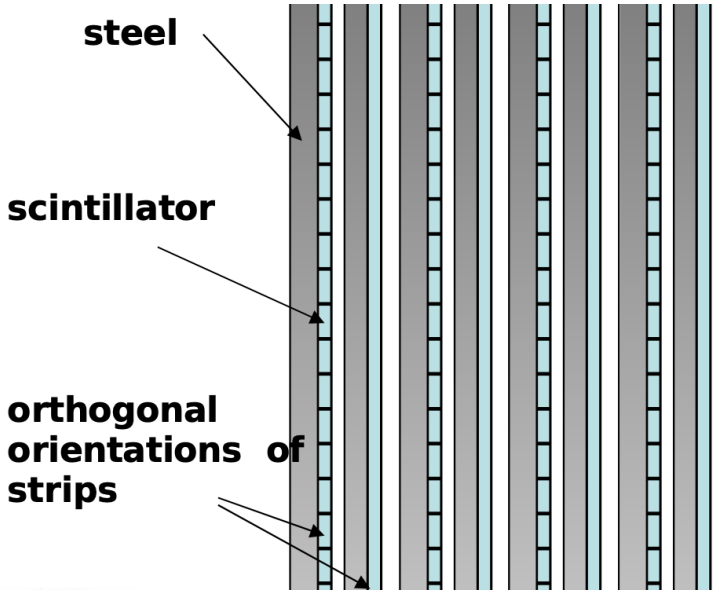

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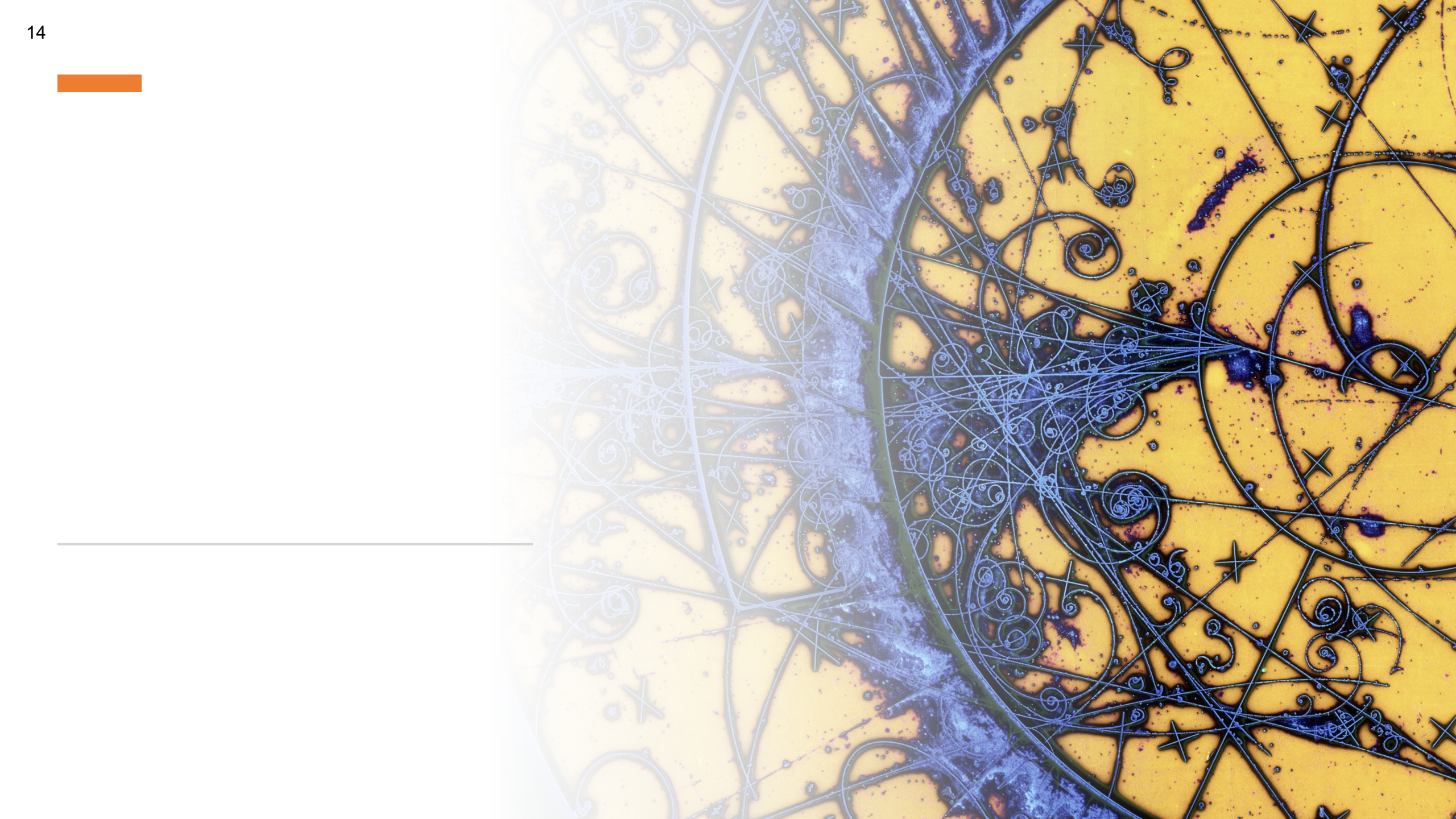
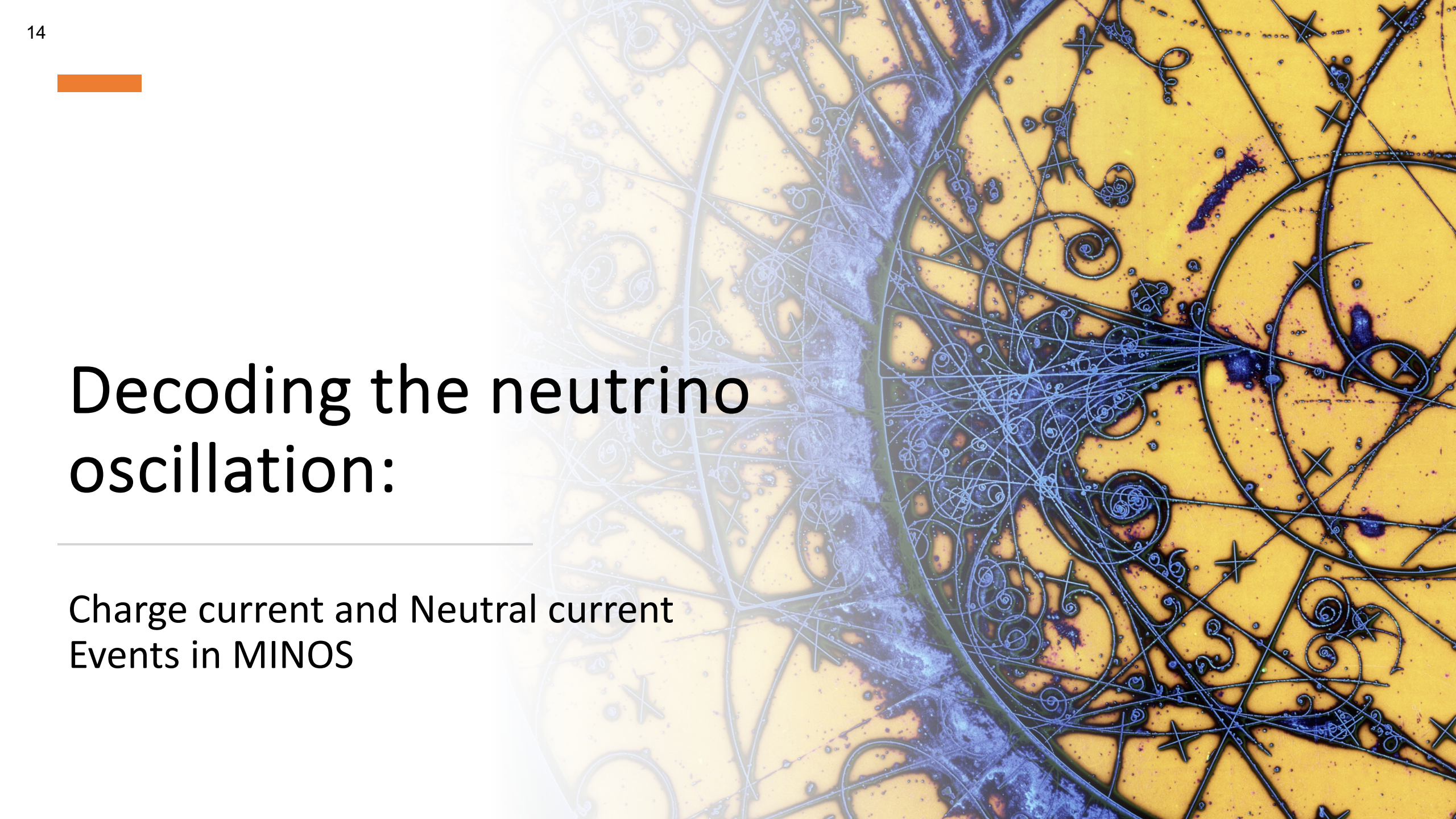
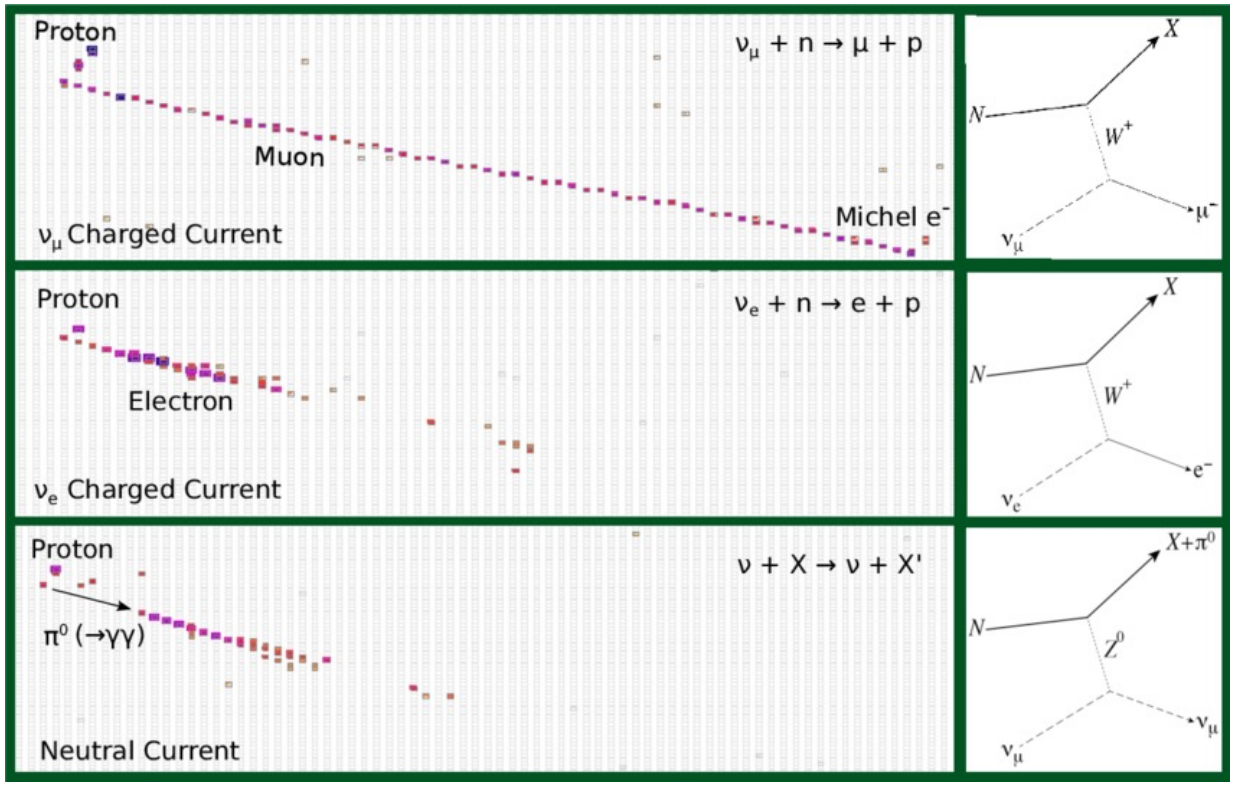


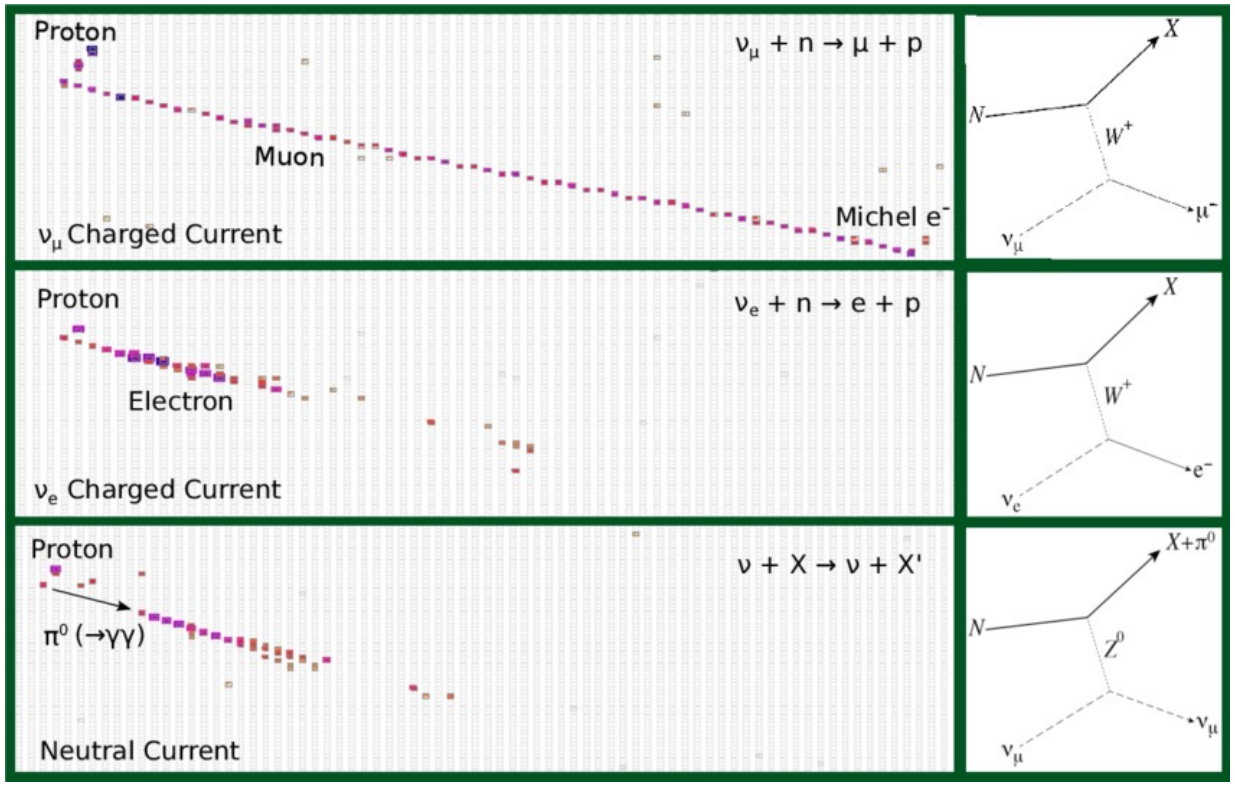
Decoding the neutrino oscillation:

Charge current and Neutral current Events in MINOS





Adapted from [3] “First Neutrino Oscillation Results from the NOvA Experiment ”



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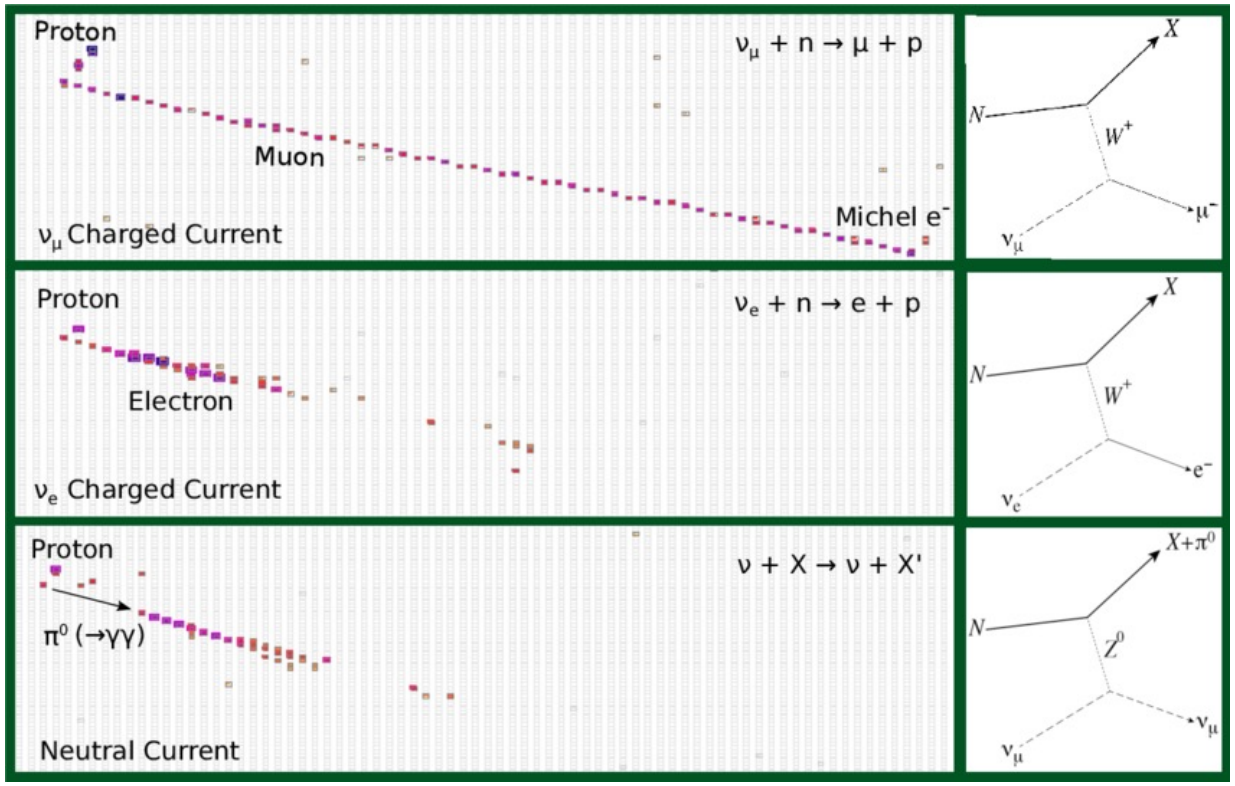
Charged current (CC) interactions:

- Interactions are mediated by the W boson, do change charge.
- Neutrinos interact with nuclei and produce the corresponding leptons.
- $\nu_\mu + n \rightarrow \mu + p$



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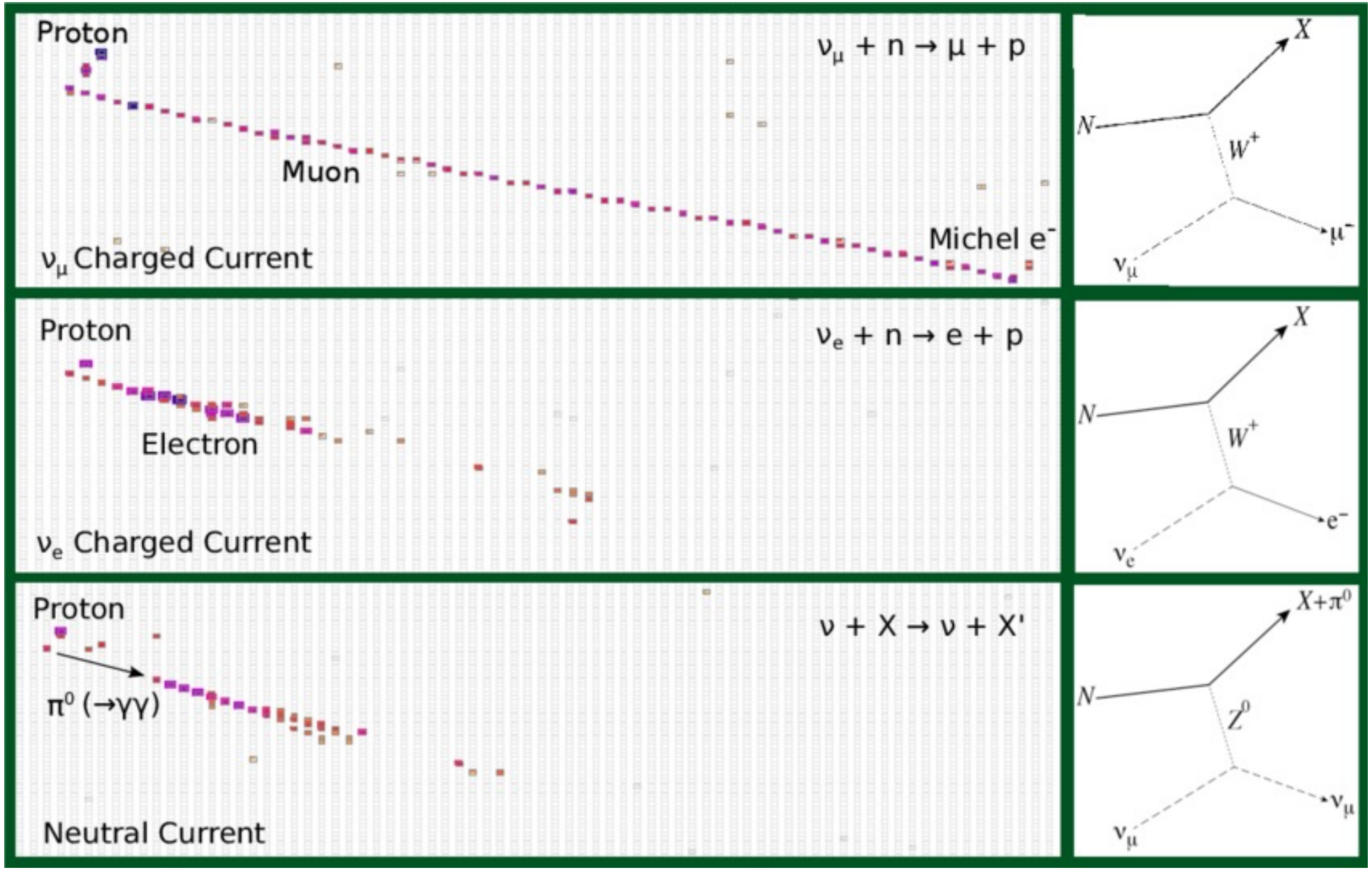
Neutral current (NC) interactions:

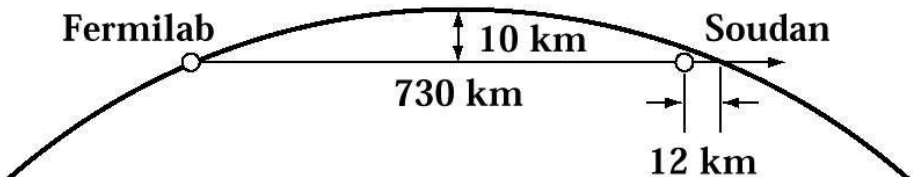
- Interactions are mediated by the Z boson, do not change charge.
- NC interactions are not easily observed directly, as they do not produce charged leptons


Proton
Muon
Michel e⁻
ν_μ Charged Current
$\nu_\mu + n \rightarrow \mu + p$
X
N
W^+
μ^-
ν_μ
Proton
Electron
ν_e Charged Current
$\nu_e + n \rightarrow e + p$
X
N
W^+
e^-
ν_e
Proton
π^0 ($\rightarrow\gamma\gamma$)
Neutral Current
$\nu + X \rightarrow \nu + X'$
$X+\pi^0$
N
Z^0
ν_μ
ν_μ

X is nucleon

- ν_μ beam is first measured by “near” detector in the Fermilab.

- After few second, this beams is detected and measured by “far” detector in the Soudan mine.



Comparing the Far detector and Near detector data：

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- The rate of NC events in the far detector should be numerically close to the rate in the near detector.

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- NC interactions confirm that the conversions are caused by neutrino oscillations.
- Spatial Resolution is important for reconstructing the paths of charged particles produced in neutrino interactions and for identifying the interaction vertices.

Neutrino energy spectrum:

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- Mass squared difference (Δm^2).
- Mixing angle.

Energy resolution

Energy resolution

- Magnetic field. (Improve in Minos+)
- Light attenuation in fibers. (Use two-end readout for Far detector)
- …


MINOS

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- The experiment was shut down on June 29, 2016.

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