

Using a Liquid Xenon Positron Target

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ABSTRACT

Usage: Secondary publications and information retrieval purposes.

Structure: You may use the `description` environment to structure your abstract; use the optional argument of the `\item` command to give the category of each item.

I. OUTLINE

- Introduction
 - What is the problem that we are trying to solve?
 - What are the issues with "traditional" positron targets?
 - What approaches have been tried already?
 - How many positrons-per-second are needed for Linear Collider applications?
 - Introduction is basically a literature survey/review.
- Comparing Positron production in Xenon vs W or Ta
 - This is where the GEANT simulations go.
 - How thick/dense does Xenon need to be to match positron production in W or Ta?
- Cryo-cooled Xenon gas jets
 - Does this exist?
 - Describe work with liquid Xenon and work with cryo-cooled gas jets at SLAC.
 - Vacuum challenges?
- Conclusion
 - Describe next steps. How would we actually build/implement this?

II. INTRODUCTION

A common scheme for producing positrons is by colliding high energy electrons into a high-Z target. The collision between an electron beam and a solid target

generates an electromagnetic particle shower, in which positrons are produced. Because the collision is such high energy, a great deal of energy is deposited in the target in the form of thermal energy. As a result, solid targets tend to degrade over time [1]. Since positron yield increases as a function of radiation length [2], a thicker target implies a greater positron yield, but that also implies a greater energy will be deposited into the target, leading to a quicker degradation of the target.

There are various methods for increasing the life span of solid targets, such as using a cooling system [3] and rotating the target so that the beam doesn't hit the same spot of the target every pulse [4].

Previous experiments have been carried out to explore alternatives to using solid targets, such as using liquid Mercury (Hg), but the apparent hazards that Hg presents are too dangerous to implement in any efficient manner. Other approaches include...

For typical Linear Collider applications, around 10^{14} e^+ per second need to be produced [5].

In this paper, we explore the possibility of using a liquid Xenon (Xe) target to produce positrons.

III. SIMULATION RESULTS

A. Comparing Liquid Xe and Ta Targets

Comparison study between Tantalum (Ta) and liquid Xe because we have a reference study on Ta [6]. We used GEANT4 to simulate the collision between 10 GeV e^- and a target. We compare the results of using a Ta target and a liquid Xe target.

See Table I for parameters used in the simulation.

Material	Z	Density [$\text{g} \cdot \text{cm}^{-3}$]	Radiation Length [cm]
Tantalum (Ta)	73	16.654	0.4094
Liquid Xe (Xe)	54	2.953	2.872

TABLE I: Parameters used in GEANT4 simulation when comparing targets.

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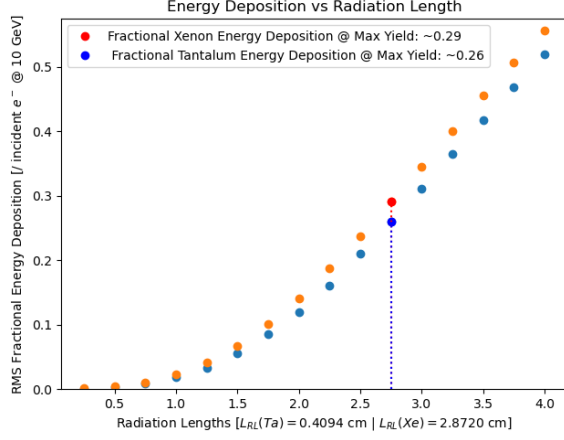
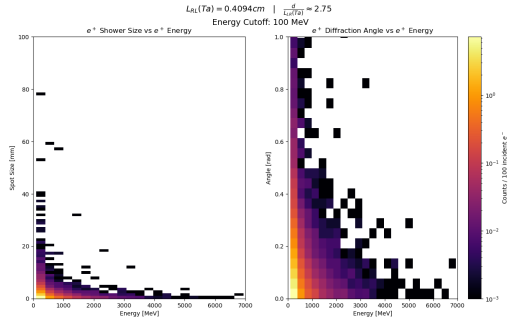
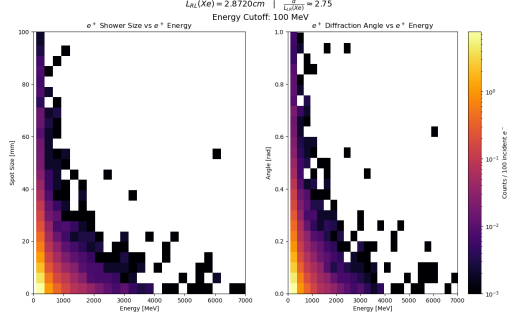


FIG. 1: Energy deposition in Ta and liquid Xe targets per incident electron at 10 GeV.

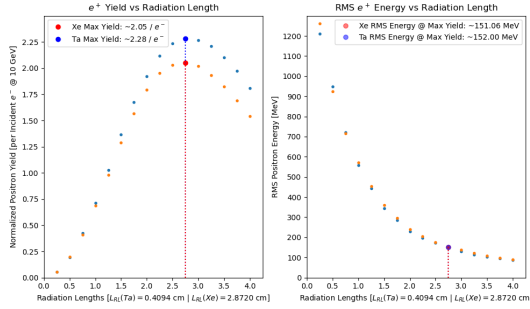


(a) Tantalum target.

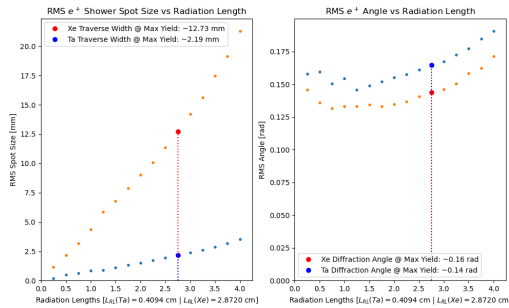


(b) Liquid Xenon target.

FIG. 3: Traverse width and angular diffraction of positrons as a function of their energy upon production. Data is shown for widths of 2.75 radiation lengths (max e^+ yield).



(a) Positron yield per incident electron at 10 GeV.

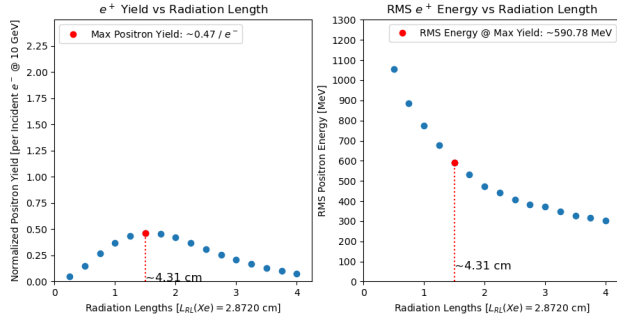


(b) Positron spot size and diffraction angle at the exit of the target.

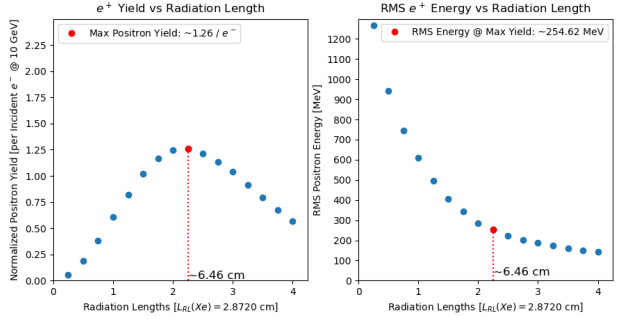
FIG. 2

B. Setting a Cutoff Energy and Traverse Width

Although the max yield for liquid Xenon is on par with that of the Tantalum target, according to Figures 2b and 3, the physical spread of positrons produced from the liquid Xenon target is much larger than that of the Tantalum target. As a result, only a small fraction of the positrons that exit the target will have the correct parameters to make it down the rest of the accelerator. In order to accurately assess the plausibility of using a liquid Xenon positron target, we set cutoffs for the traverse width of positrons created during the collision.

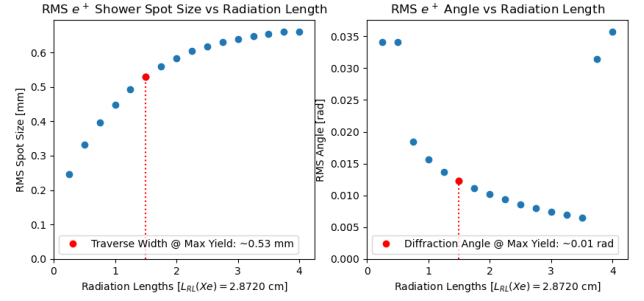


(a) 1 mm cutoff

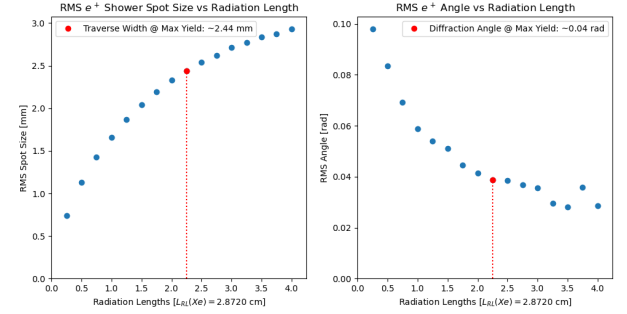


(b) 5 mm cutoff

FIG. 4: Positron yield and energy using a liquid Xenon target with a 1 mm cutoff and 5 mm traverse width cutoff.



(a) 1 mm cutoff



(b) 5 mm cutoff

FIG. 5: Positron spot size and angular diffraction using a liquid Xenon target with a 1 mm cutoff and 5 mm traverse width cutoff.

IV. CRYO-COOLED XENON GAS JETS/LIQUID XENON

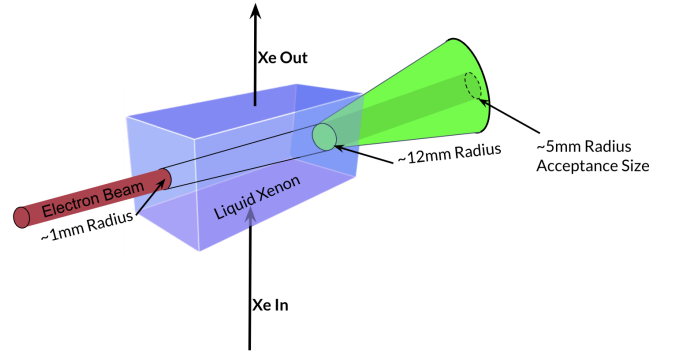


FIG. 6: Schematic of liquid Xenon setup

Info about stuff yeah!

A. Calculating the Liquid Xenon Flow Rate

To calculate the flow rate of the liquid Xenon, we first calculate preliminary values using the information given in the table below.

Quantity	Value	Units
Heat of Vaporization	12.636	$\text{kJ}\cdot\text{mol}^{-1}$
Radiation Lengths ($\frac{d}{L_{\text{RL}}}$)	2.25	L_{RL}
Energy Deposition	.66581	GeV
Beam Rep Rate	10	Hz
Beam Charge	2	nC
Target Density (ρ)	2.953	$\text{g}\cdot\text{cm}^{-3}$

TABLE II: Parameters used in GEANT4 simulation when comparing targets.

V. CONCLUSION

Source code for GEANT4 simulations can be found at <https://github.com/MaxVarverakis/LiquidXenonSims.git>.

ACKNOWLEDGMENTS

We wish to acknowledge the support of the author community in using REVTeX, offering suggestions and encouragement, testing new versions,

Appendix A: Appendixes

To start the appendixes, use the `\appendix` command. This signals that all following section commands refer to appendixes instead of regular sections. Therefore, the `\appendix` command should be used only once—to setup the section commands to act as appendixes. Thereafter normal section commands are used. The heading for a section can be left empty. For example,

```
\appendix
\section{}
```

will produce an appendix heading that says “APPENDIX A” and

```
\appendix
\section{Background}
```

will produce an appendix heading that says “APPENDIX A: BACKGROUND” (note that the colon is set automatically).

If there is only one appendix, then the letter “A” should not appear. This is suppressed by using the star version of the appendix command (`\appendix*` in the place of `\appendix`).

Appendix B: A little more on appendixes

Observe that this appendix was started by using

```
\section{A little more on appendixes}
```

Note the equation number in an appendix:

$$E = mc^2. \tag{B1}$$

1. A subsection in an appendix

You can use a subsection or subsubsection in an appendix. Note the numbering: we are now in Appendix B 1.

Note the equation numbers in this appendix, produced with the subequations environment:

$$E = mc, \tag{B2a}$$

$$E = mc^2, \tag{B2b}$$

$$E \gtrsim mc^3. \tag{B2c}$$

They turn out to be Eqs. (B2a), (B2b), and (B2c).