Possible designs for a Liquid-Scintillator based Surround Background Tagger for the He-bag option

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Conical SBT:

Since optimized geometry not yet defined, use conservative dimensions:

\[ 5 \text{ m} \times 10 \text{ m} \times 50 \text{ m} \]

SBT: built from rectangular boxes filled with LS
Liquid Scintillator costs/weight/handling

- Dimensions larger than elliptical shape in TP → increase in LS volume
  
  30 cm layer of LS: 450 m³ → 387 tons LAB + PPO (1.5 g/l) → 538 kEuro

- Handling, storage, purification, detector mantling efforts scale with LS volume
  
  → Would like to minimize the amount of LS as much as possible!
**Reduction of LS thickness?**

- Can we reduce the LS layer thickness without significant loss in efficiency?

  $\varepsilon > 95\%$ with $10 \times 40 \times 50 \text{ cm}^3$ boxes with low-quality LS ($\mu_{\text{abs}} \sim 5 \text{ cm} @ \lambda < 380 \text{ nm}$) viewed by one Mini-WOM+PMT (with mirror on other side)

Efficiency will significantly increase with
1. High-quality LS
2. Large-area WOM

For high-quality LS:
Can increase the efficiency further with PMMA-mirror plates as inner box walls
Reduced thickness & “high” granularity

- Assume: 10 cm thick LS layer → 150 m³ → 129 tons LAB+PPO → 179 k€

- Plastic scint. option: quite high granularity! LS option with high granularity?

- Assume 10 x 50 x 50 cm³ LS-filled boxes (~ prototype @ HU Berlin)
  → 6000 boxes → 6000 WOMs/PMTs → 1900 k€ (w/o HV and electronics)
  + PMMA-mirror walls (if needed): 300 k€

Prototype design 0

WOM area: 100 (length) x 20 (diam.) mm² = 2000 mm²

WOM diameter/\(D_{\text{max}}\) = 0.056
**Design 1**

- LS: 179 kEuro
- 2667 boxes (10 x 75 x 75 cm³) → 2667 WOMs → 2667 PMTs
  
  \[320 \text{ } € \times 2667 \text{ (PMT)} = 853 \text{ } k€\]
- PMMA-mirror inner box walls: 100 € x 2667 = 267 k€
- Costs (w/o HV, electronics and cabling) in k€:

<table>
<thead>
<tr>
<th>LS thickness</th>
<th>10 cm</th>
<th>20 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>with mirror box walls</td>
<td>1299</td>
<td>1478</td>
</tr>
<tr>
<td>w/o mirror box walls</td>
<td>1032</td>
<td>1211</td>
</tr>
</tbody>
</table>

WOM area:
100 (length) x 50 (diam.) mm²
= 5000 mm²

WOM diameter/D\(_{\text{max}}\) = 0.094

Some efficiency drop @ WOM loc.
Design 2

- Photo-sensor alternative: e.g. Hamamatsu S13360-6075PE SiPM (6 x 6 mm² area) ($\varepsilon=50\%$ @ 450 nm)

Further studies needed, e.g. concerning dark count rate

- Costs: 35 € (SiPM) + 40 € (power supply) for several thousand SiPM

→ Need to reduce WOM diameter → Loss in efficiency → Use long Mini-WOM

WOM area: 500 (length) x 6 (diam.) mm² = 3000 mm²

WOM diameter/D_max = 0.024

Two-sided read-out!
→ relative efficiency gain of 2 (if transport losses are small)
Costs for Design 2

- LS: 179 k€

- 6000 LS-filled boxes (10 x 50 x 50 cm³) → 6000 WOMs → 12000 SiPM
  Costs: 30 € x 12000 (SiPM) + 38 € x 12000 (power supply) = 816 k€

- PMMA-mirror box walls: 50 € x 6000 boxes = 300 k€

- Costs (w/o electronics and cabling) in k€:

<table>
<thead>
<tr>
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<th>10 cm</th>
<th>20 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>with mirror box walls</td>
<td>1295</td>
<td>1374</td>
</tr>
<tr>
<td>w/o mirror box walls</td>
<td>1028</td>
<td>1295</td>
</tr>
</tbody>
</table>
Design 3

Increase in box area wrt Design 2: $\frac{75^2}{50^2} \rightarrow$ Reduction in box numbers: 1/2.25

Increase in number of photosensors/box: 2/1
→ Reduction in number of photo sensors: 11%

WOM diameter $/ D_{\text{max}} = 0.032$

Two-sided read-out!
→ relative efficiency gain of 2
(if transport losses are small)

Two WOMs!
→ relative efficiency gain

About same efficiency as Design 1

Simpler WOM construction and their deployment in the SBT wrt Design 1
Costs for Design 3

- LS: 179 kEuro

- 2667 LS-filled boxes (10 x 75 x 75 cm$^3$) → 5333 WOMs → 10666 SiPM
  
  30 € x 10666 (SiPM) + 38 € x 10666 (power supply) = 725 k€

- PMMA-mirror inner box walls: 100 € x 2667 = 267 k€

- Costs (w/o electronics and cabling) in k€:

<table>
<thead>
<tr>
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<th>10 cm</th>
<th>20 cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>with mirror box walls</td>
<td>1171</td>
<td>1350</td>
</tr>
<tr>
<td>w/o mirror box walls</td>
<td>905</td>
<td>1083</td>
</tr>
</tbody>
</table>
Plans & ManPower (for Comprehensive Design Report)

- Purchase 1 ton of high-quality LAB + 1 kg PPO
- Construct boxes with and w/o PMMA mirror walls (or mirror foils?)
- Build different WOM types (also for vacuum tank solution → TP)
- Test different photo sensors (PMT R1924, SiPM S13360-6075PE)
- Test designs 0, 1, 2, and 3: efficiency, time resolution, light yield
- Simulation studies of SBT veto performance in offline analysis

- ManPower (@ HU Berlin):
  - H. Lacker (0.25 FTE)
  - Ievgen Korol (Postdoc, 1 FTE, Starting date: 01/09/2016)
  - Plamenna Venkova (PhD student, 1 FTE, Starting date: 01/09/2016)
  - Maik Daniels/O. Epler (Technicians, 0.25 FTE)