液体闪烁体光学性能对JUNO探测器的影响

周详 武汉大学

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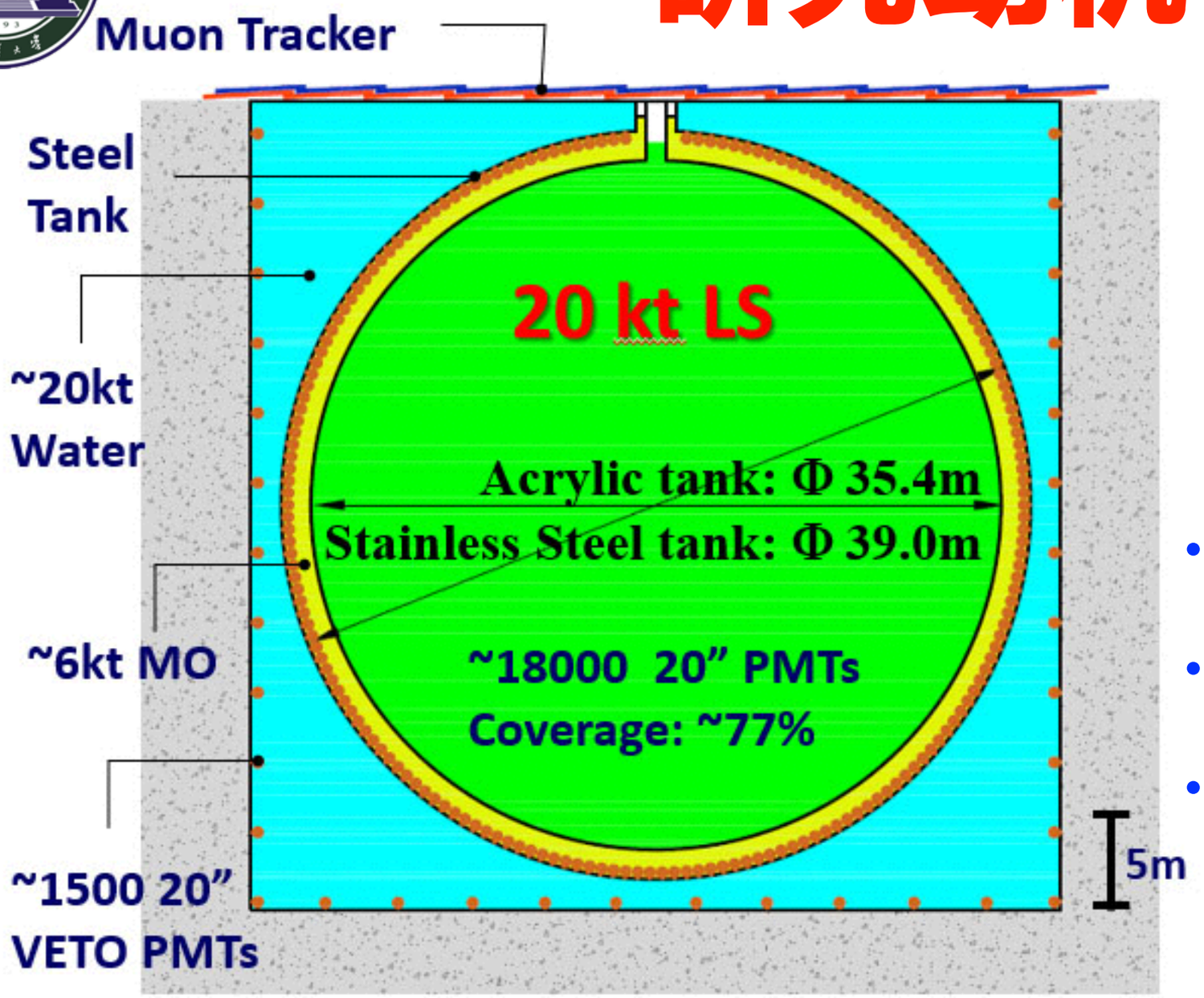
内容大纲

- 研究动机
- 液闪光学性能研究现状
- 液闪光学性能对JUNO的影响
- 总结和展望

研究动机



首要物理目标
中微子质量顺序

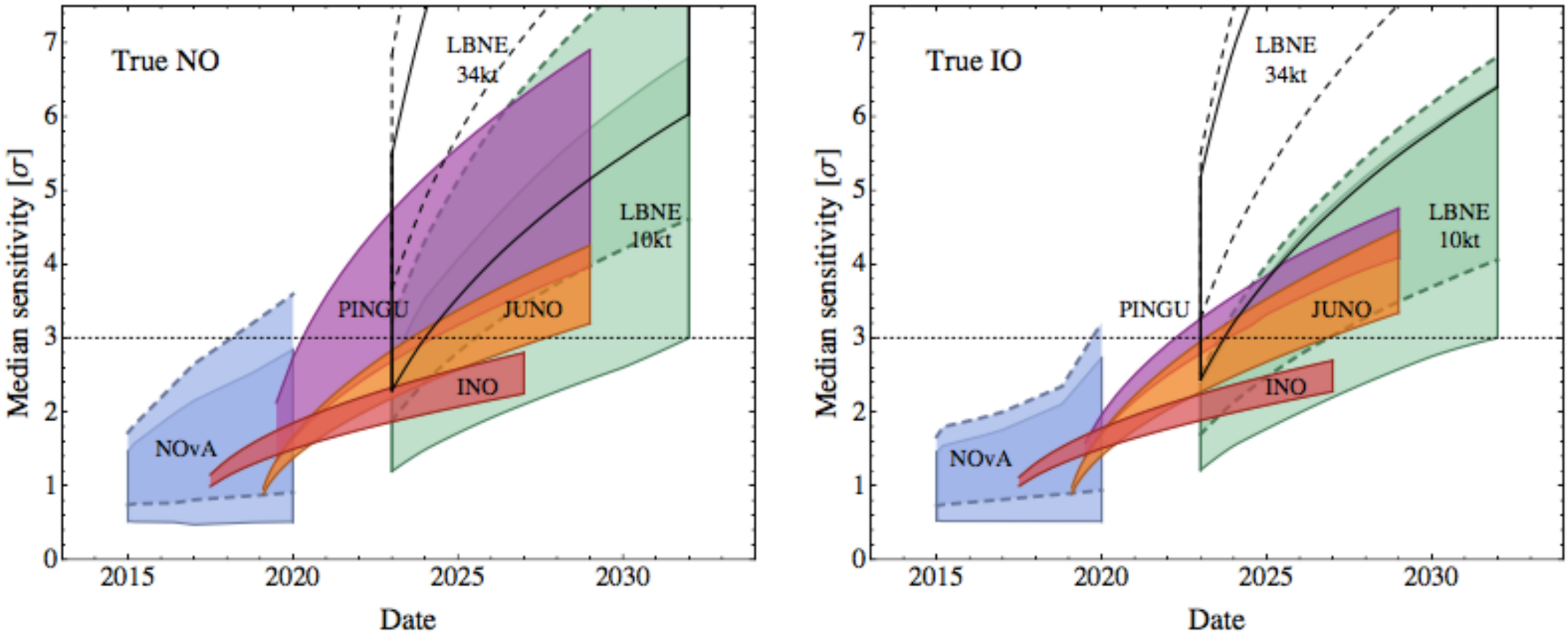
2万吨液闪，3%能量分辨率

Neutrino Physics with JUNO
J. Phys. G 43, 030401(2016)

- PMT覆盖率 ≥ 75%
- PMT量子效率峰值 ≥ 35%
- 衰减长度 ≥ 20 m@430nm
  - 衰减20 m = 吸收60 m + 散射30 m

	KamLAND	BOREXINO	JUNO
LS mass	1 kton	0.5 kton	20 kton
Energy resolution	6%/√E(MeV)	5%/√E(MeV)	3%/√E(MeV)
Light yield	250 p.e./MeV	511 p.e./MeV	1200 p.e./MeV

研究动机



Mattias Blennow, JHEP(2014)

There we give also the corresponding results for the same setup but with a slightly worse energy resolution of 3.5%√E, in which case significantly reduced sensitivities are obtained, highlighting once more the importance to achieve excellent energy reconstruction abilities.

研究动机

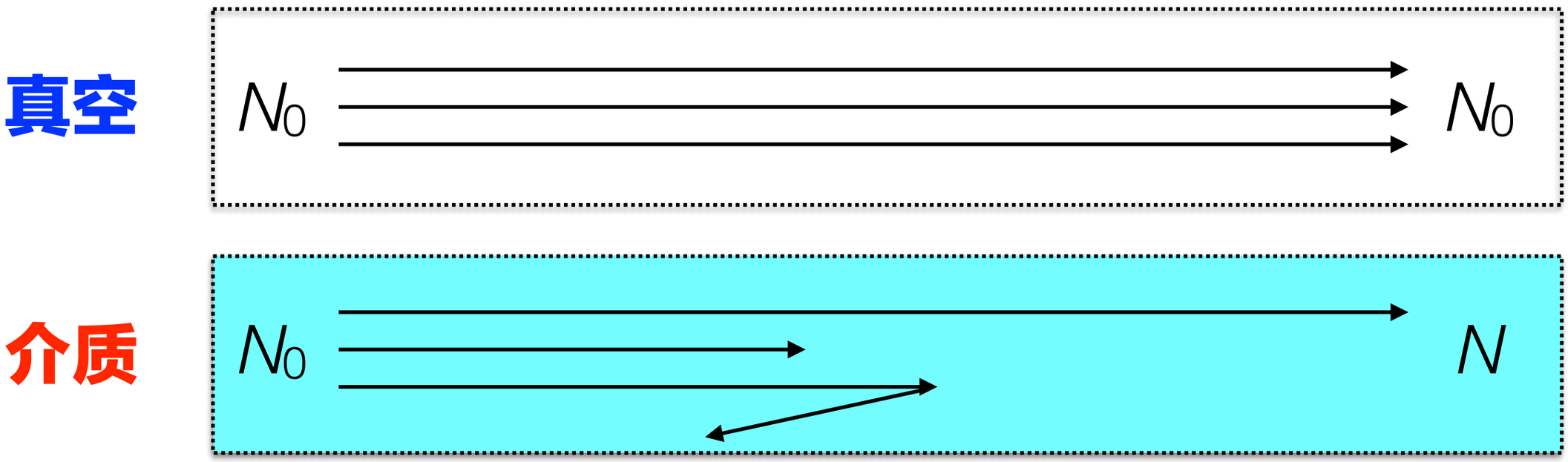
- **KamLAND:** Although the light yield and attenuation length of the LS were measured to be 57% anthracene and ~10 m, in the test experiments, when it is used in the KamLAND detector, the effective transparency and light yield ***significantly increased*** from these values, presumably due to the **scattering** and **re-emission** in the large scale LS.

F. Suekane, arXiv:physics/0404071

- **液闪探测器主要参数：PMT覆盖率，PMT量子效率，LS光学性能**

- **液闪光学性能对大型液闪探测器的影响?**

研究动机



衰减 = 吸收 ⊕ 散射

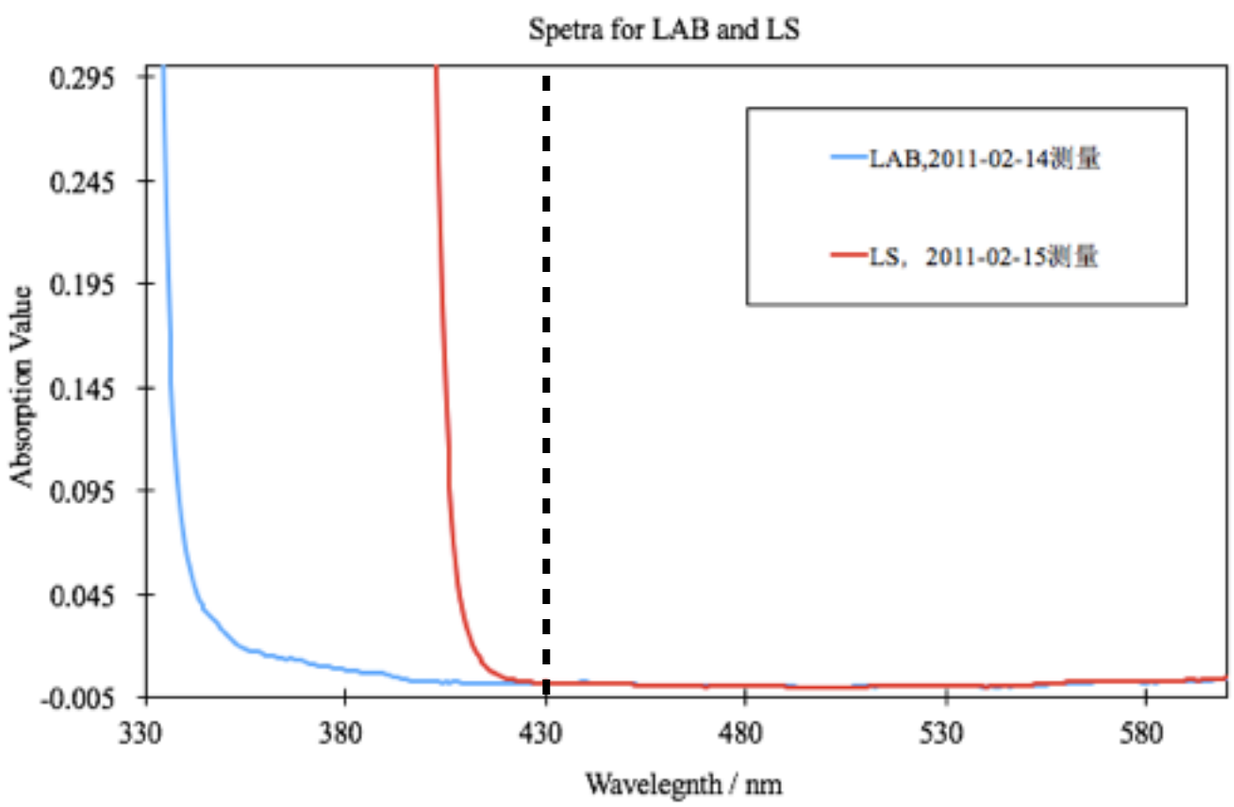
$$\frac{1}{L_{\text{att.}}} = \frac{1}{L_{\text{abs.}}} + \frac{1}{L_{\text{sca.}}}$$

Geant4: 吸收长度 & 散射长度

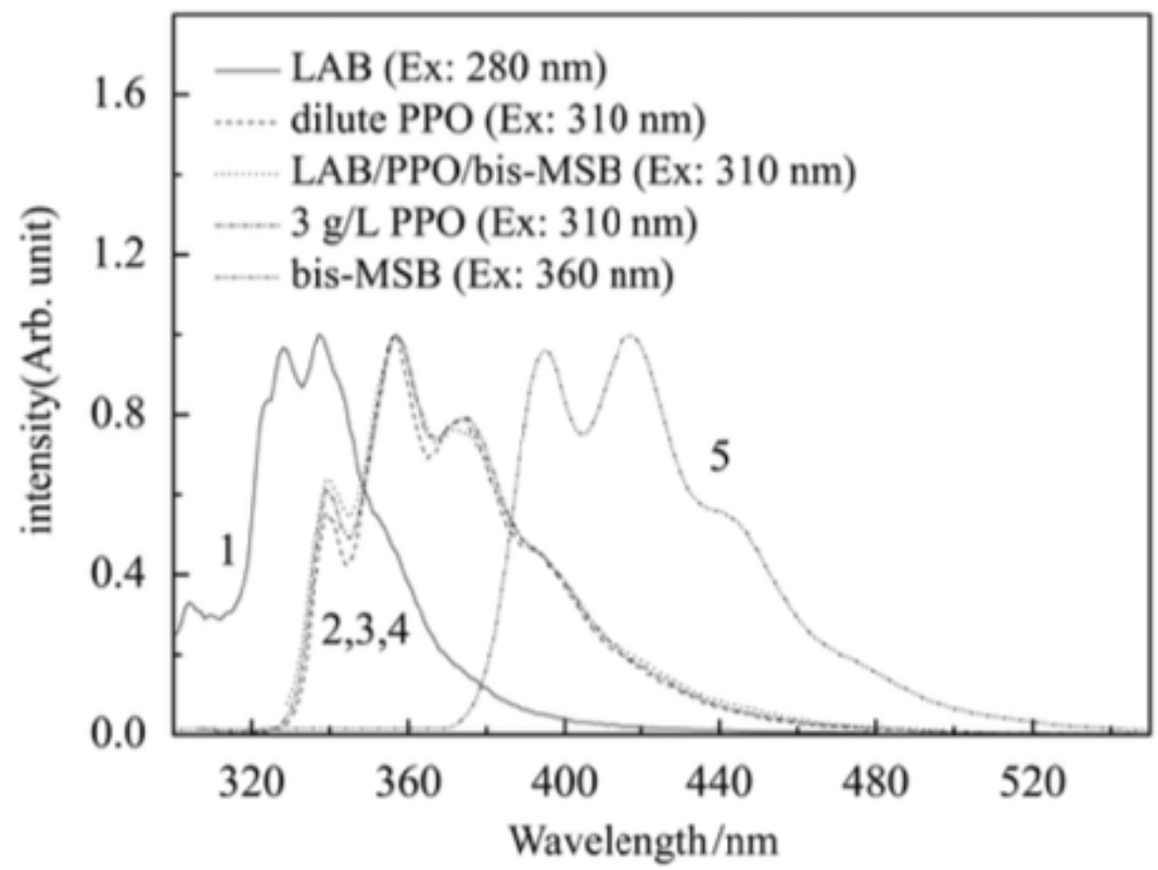
测量: 衰减长度 & 散射长度

研究动机

吸收谱

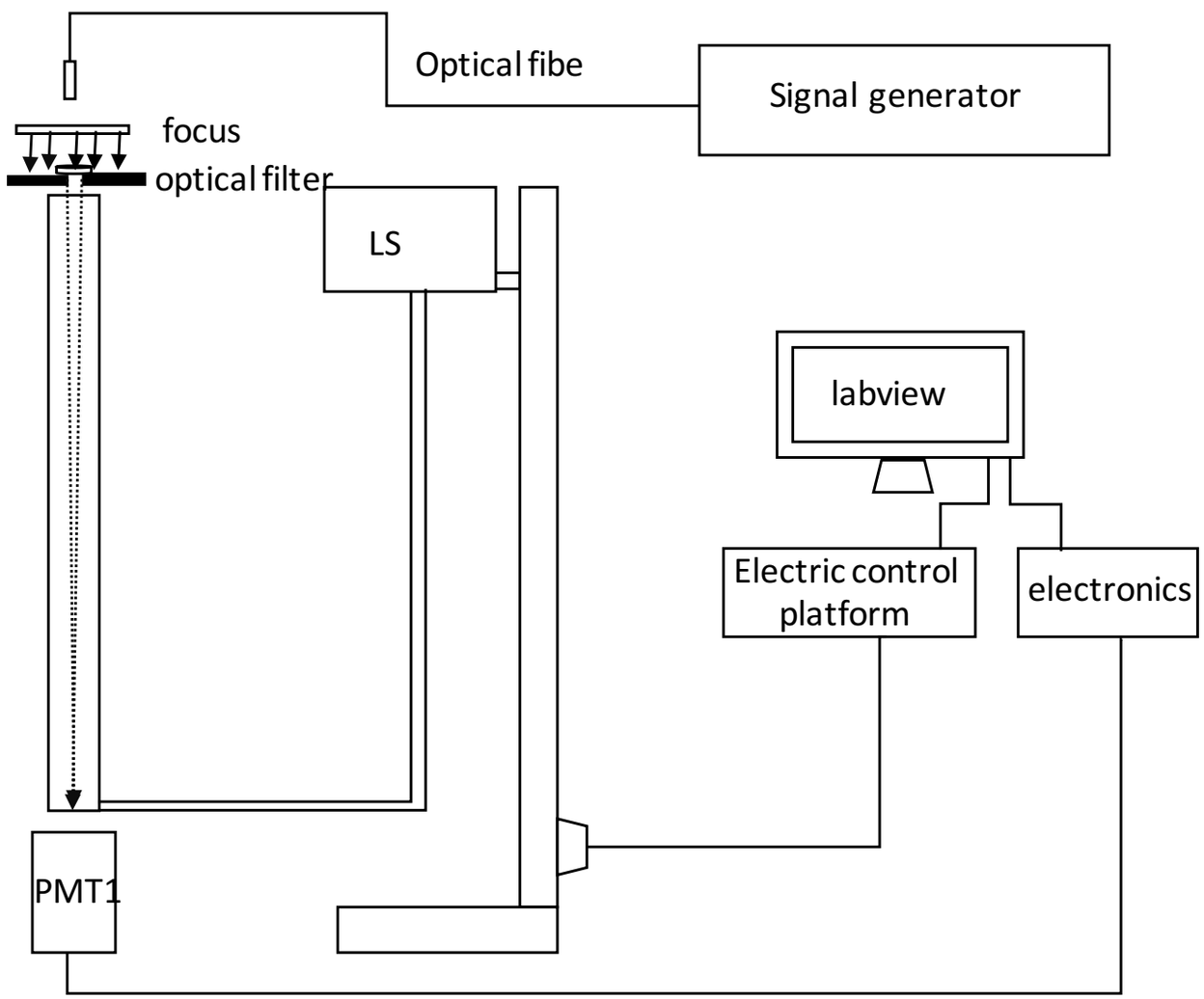


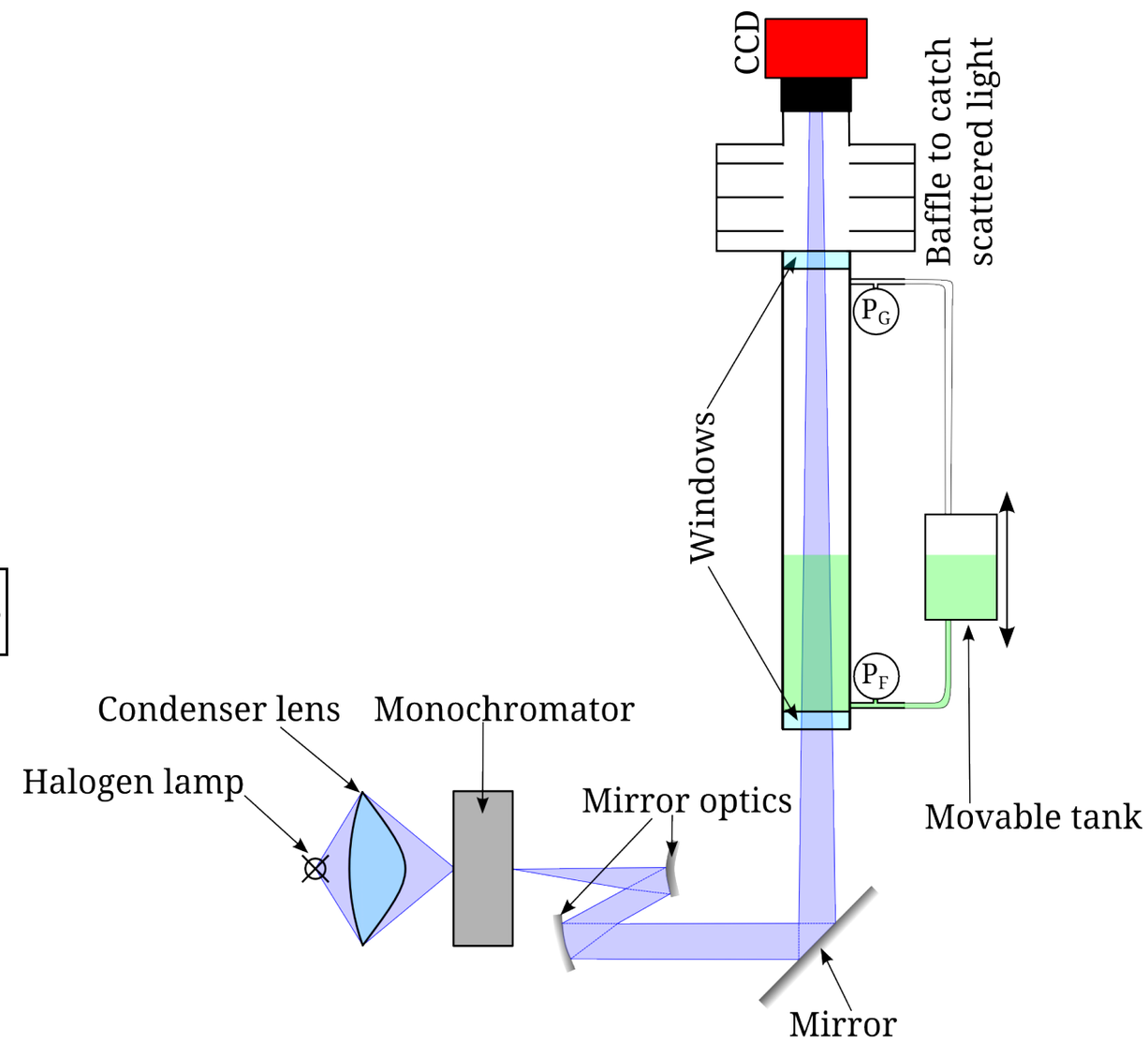
发射谱



LAB在430nm附近的吸收起源于(未知)光学杂质而非自身荧光物质发射谱和吸收谱的交叠会使A.L.(LS)<A.L.(LAB)

研究现状: 衰减





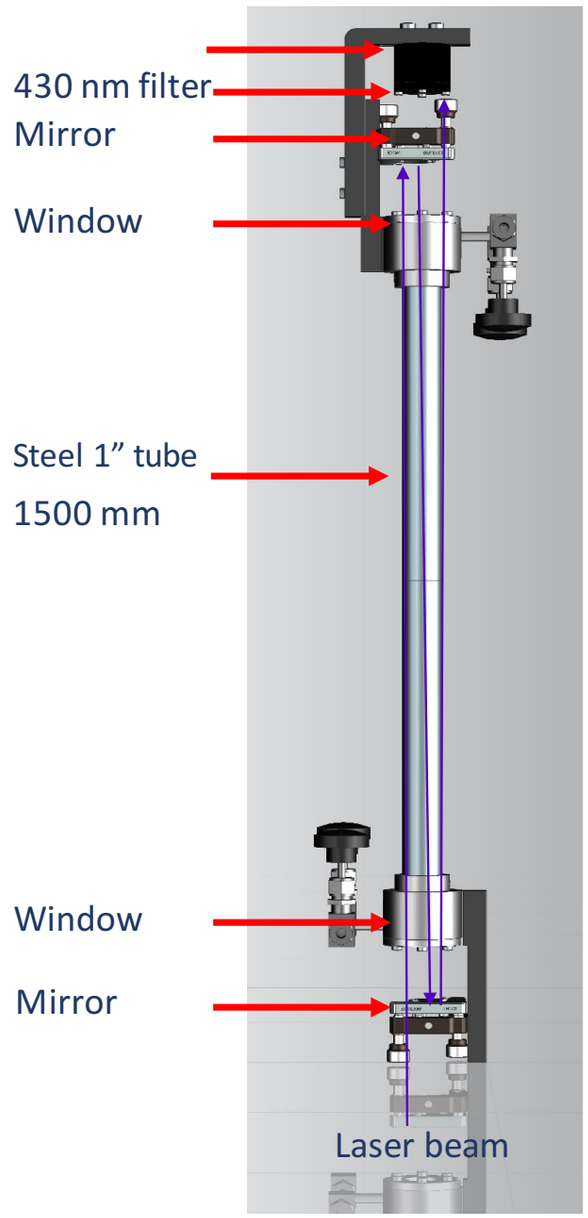
高能所-中国

TUM-Germany

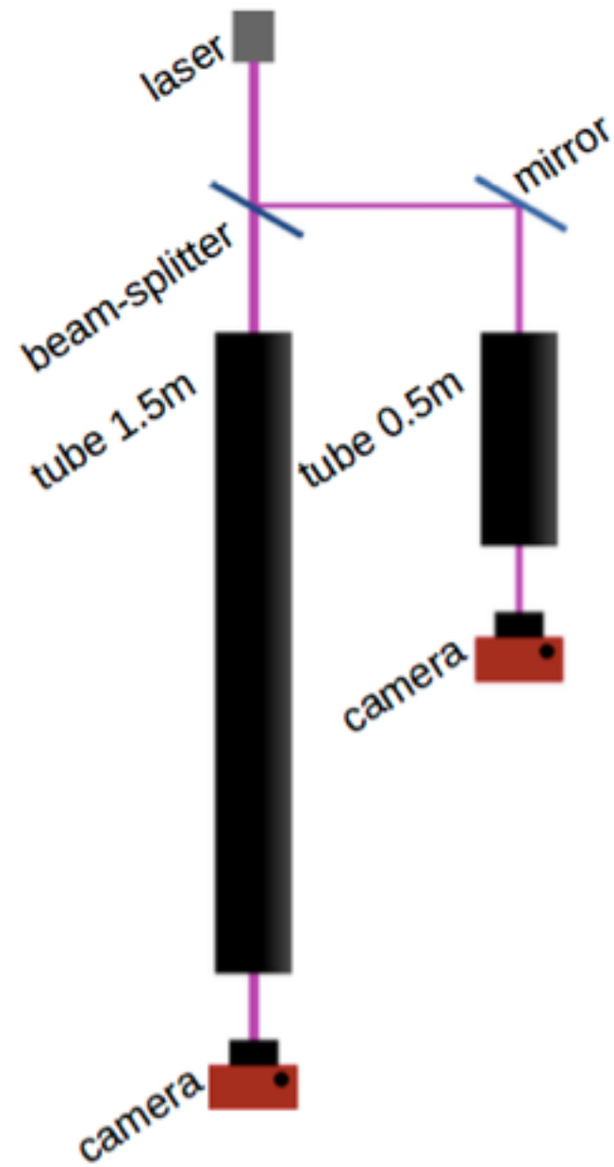
A.L. (LAB) ~ 25 m

A.L.(LS) ~ 18 m

研究现状: 衰减



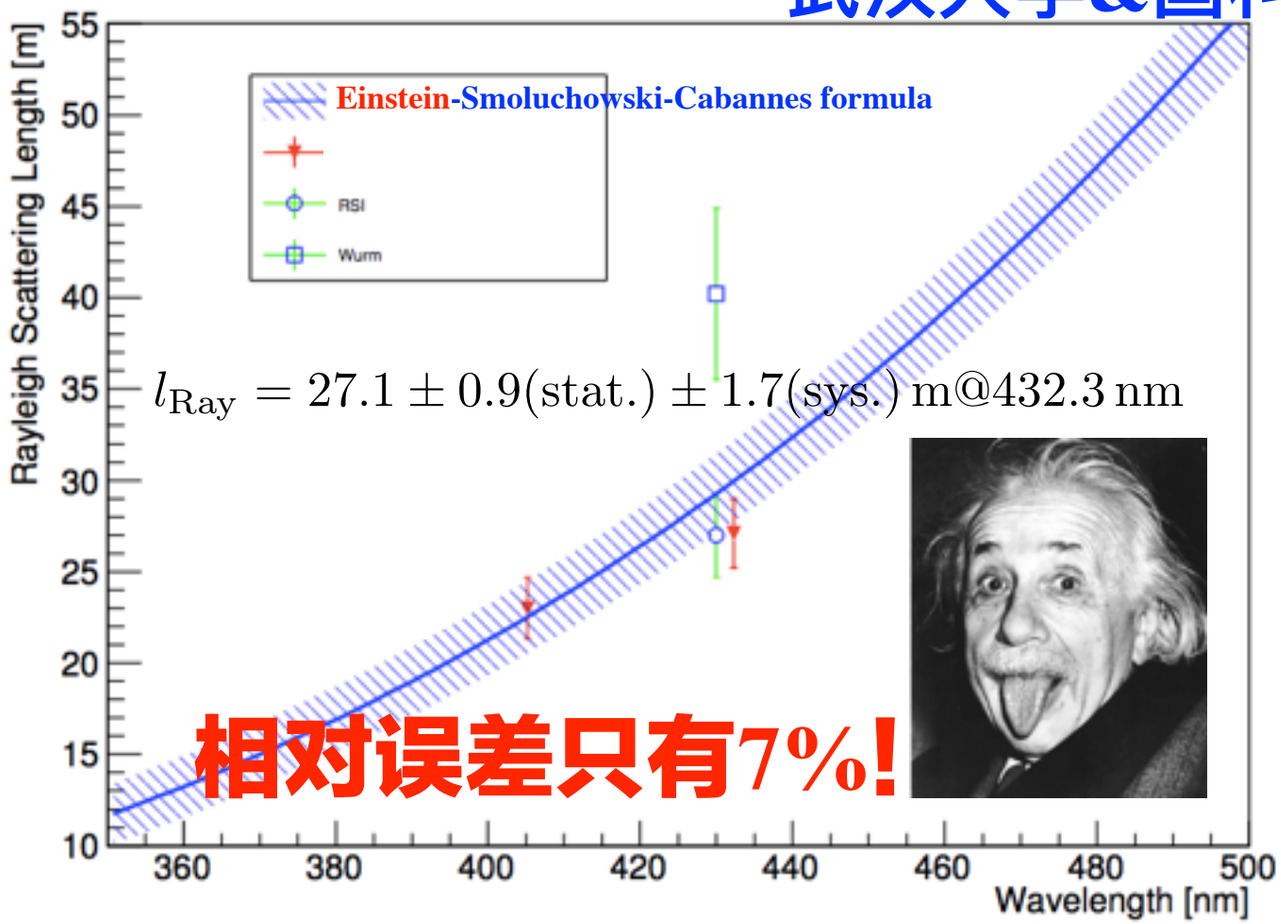
INFN Milano-Italy



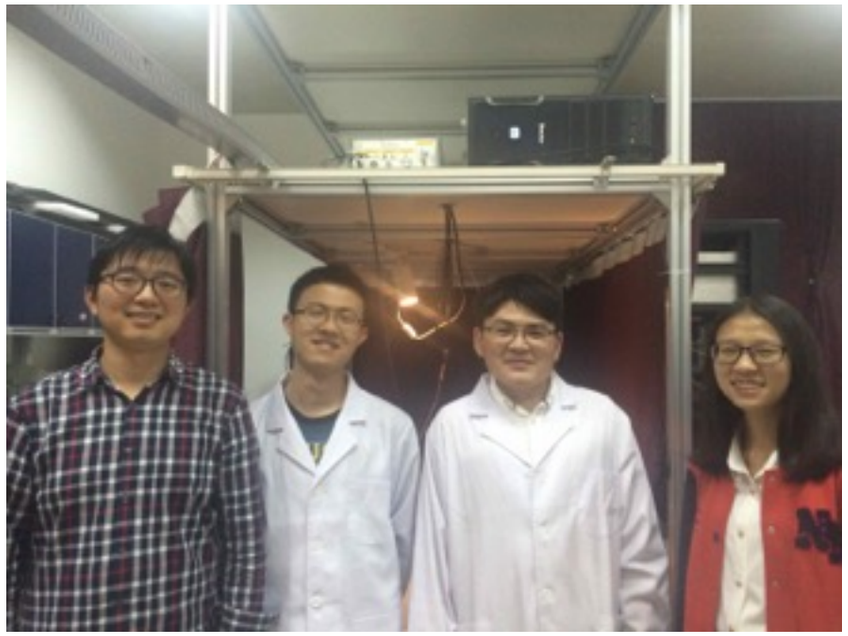
Mainz-Germany

研究现状: 散射

武汉大学&国科大(中国组)



相对误差只有7%!



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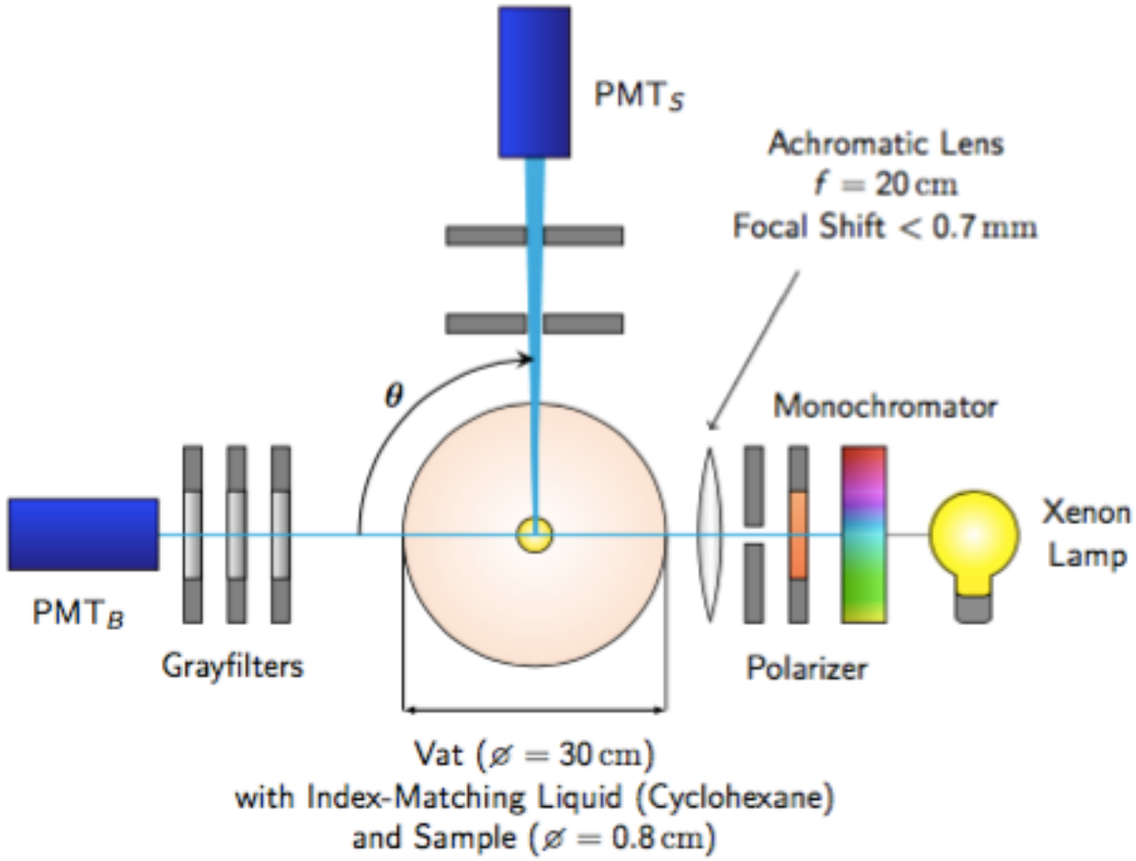
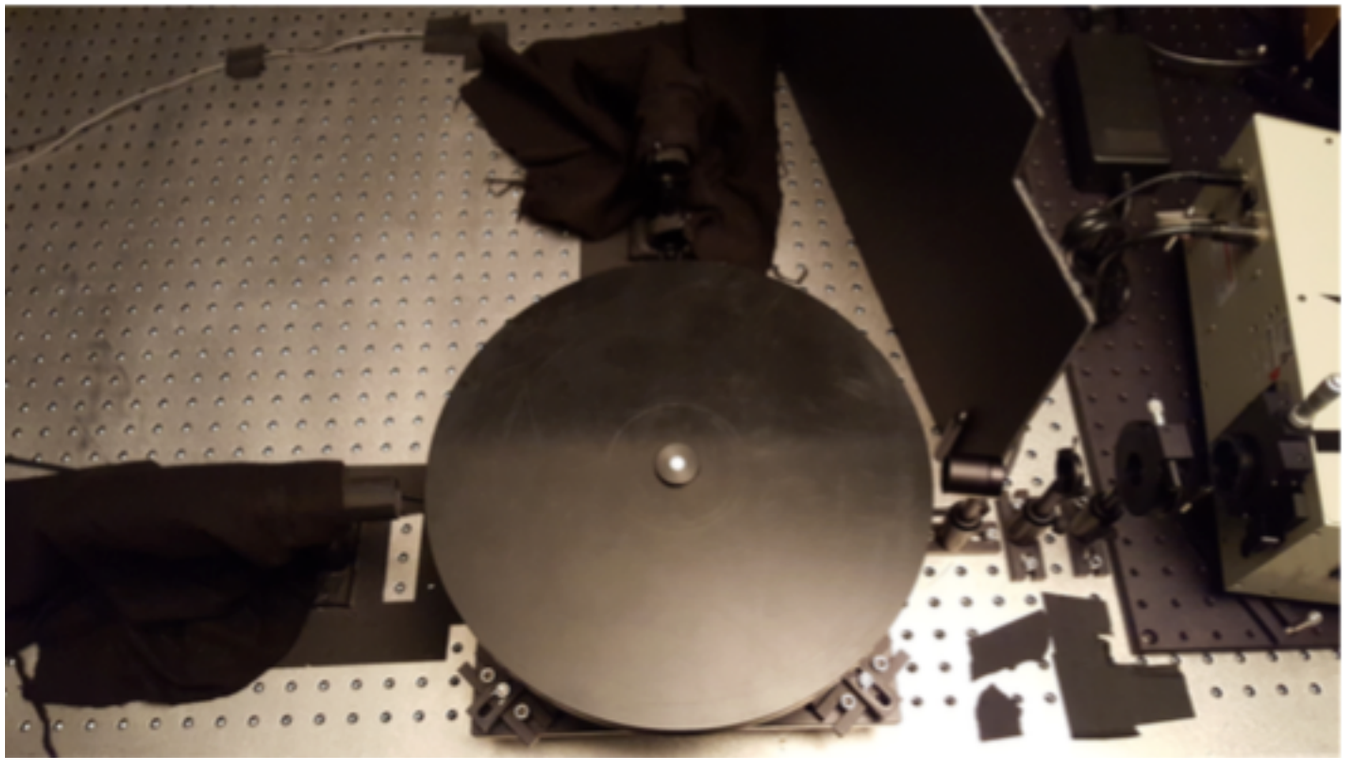




First Cyclohexane Results and Cross-Check

410 nm

Measured: $\Lambda_\perp = (42.0 \pm 1.9_{stat} \pm 8.4_{sys})\,\mathrm{m}$

Literature value: $\Lambda_{Ray} = 36.4\,\mathrm{m}$

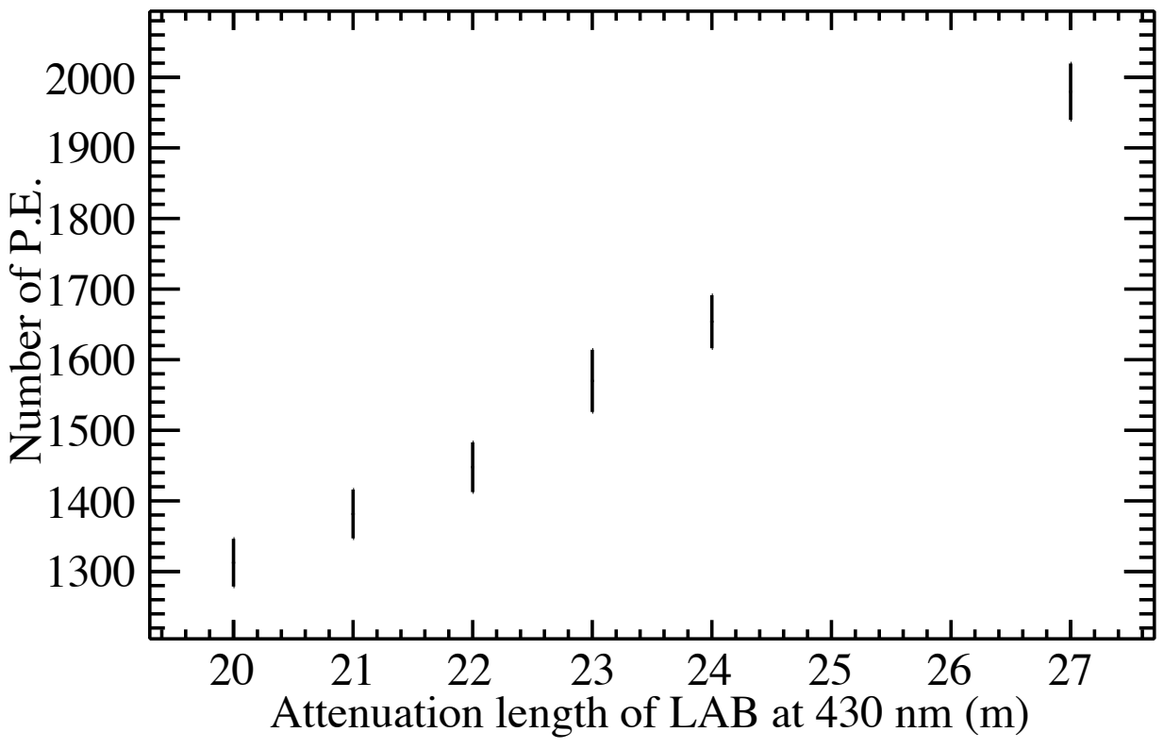
430 nm

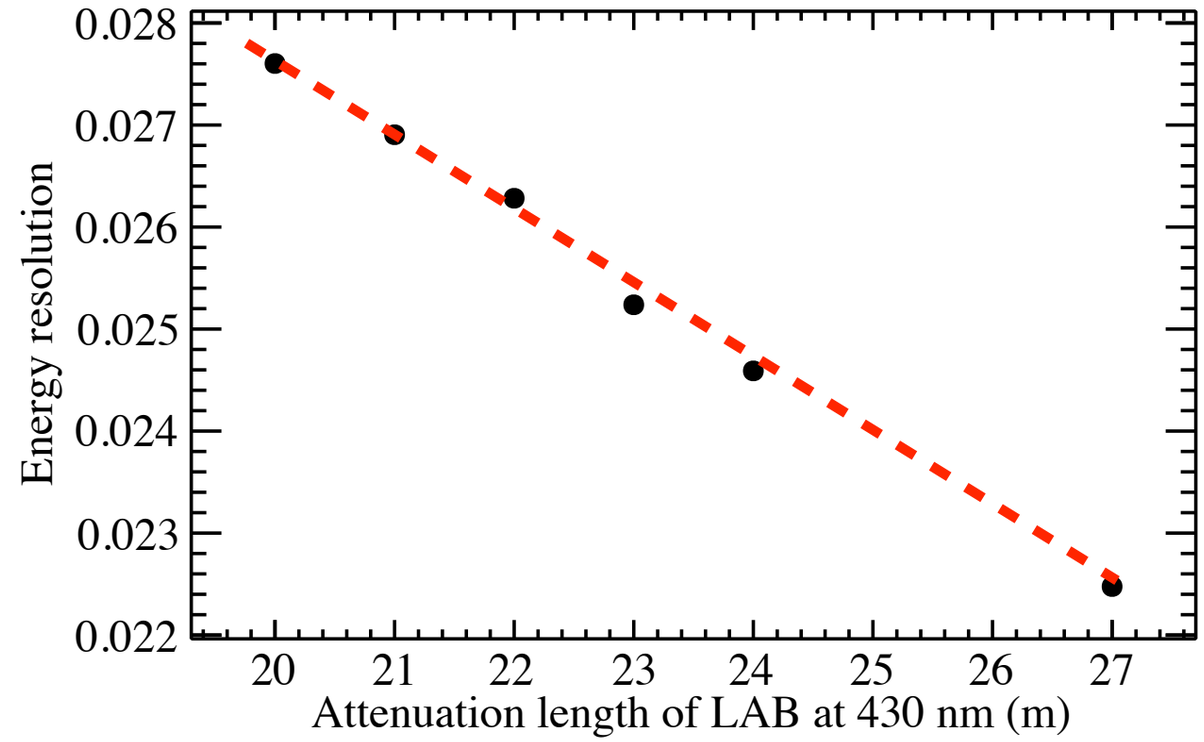
Measured: $\Lambda_\perp = (47.2 \pm 2.3_{stat} \pm 9.5_{sys})\,\mathrm{m}$

Literature value: $\Lambda_{Ray} = 44.0\,\mathrm{m}$

相对误差~21%!

液闪光学性能对JUNO的影响

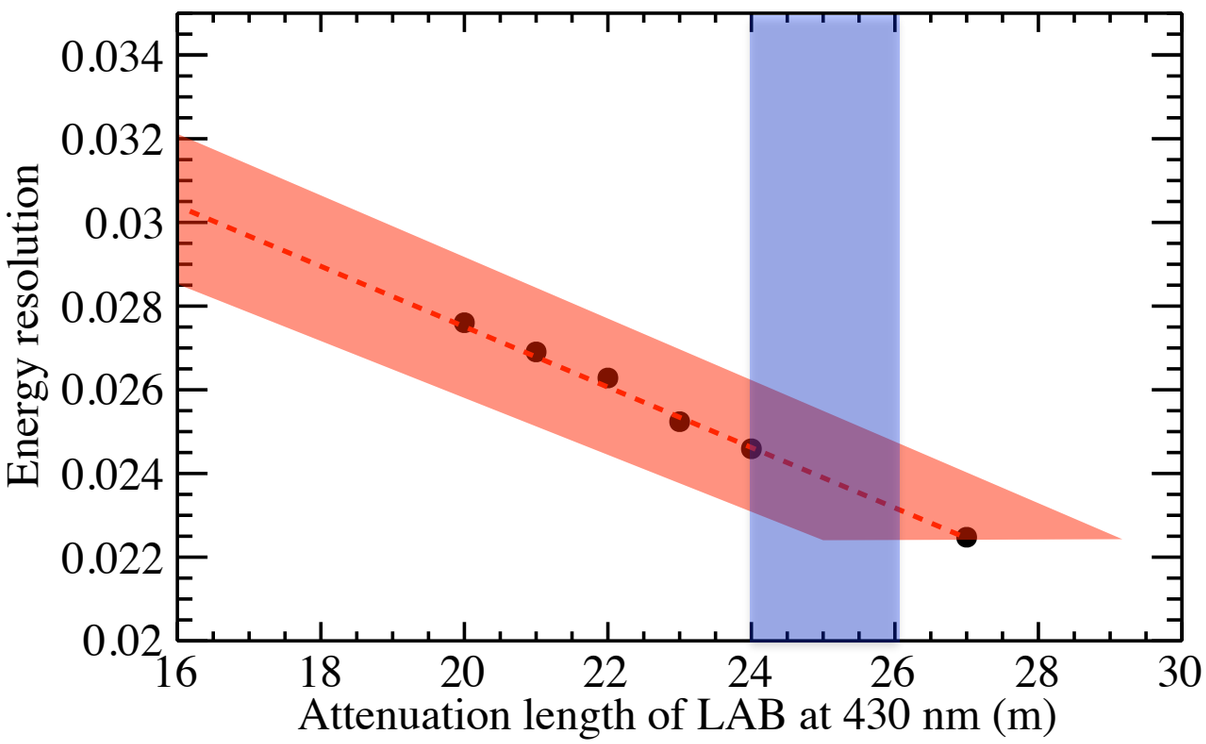


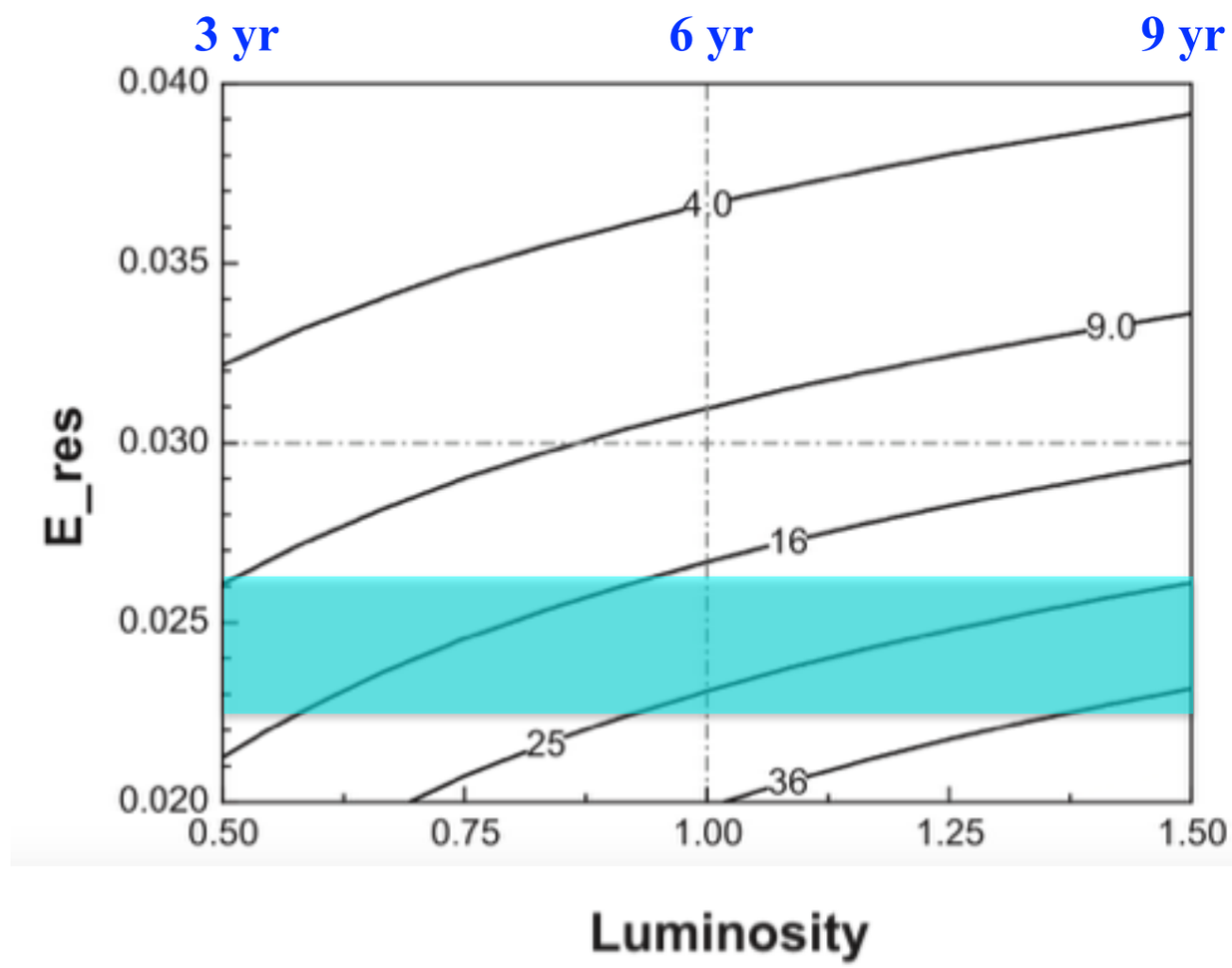


$$E_{\mathrm{res.}} \sim \frac{1}{\sqrt{N_{\mathrm{P.E.}}}}$$

Luminosity

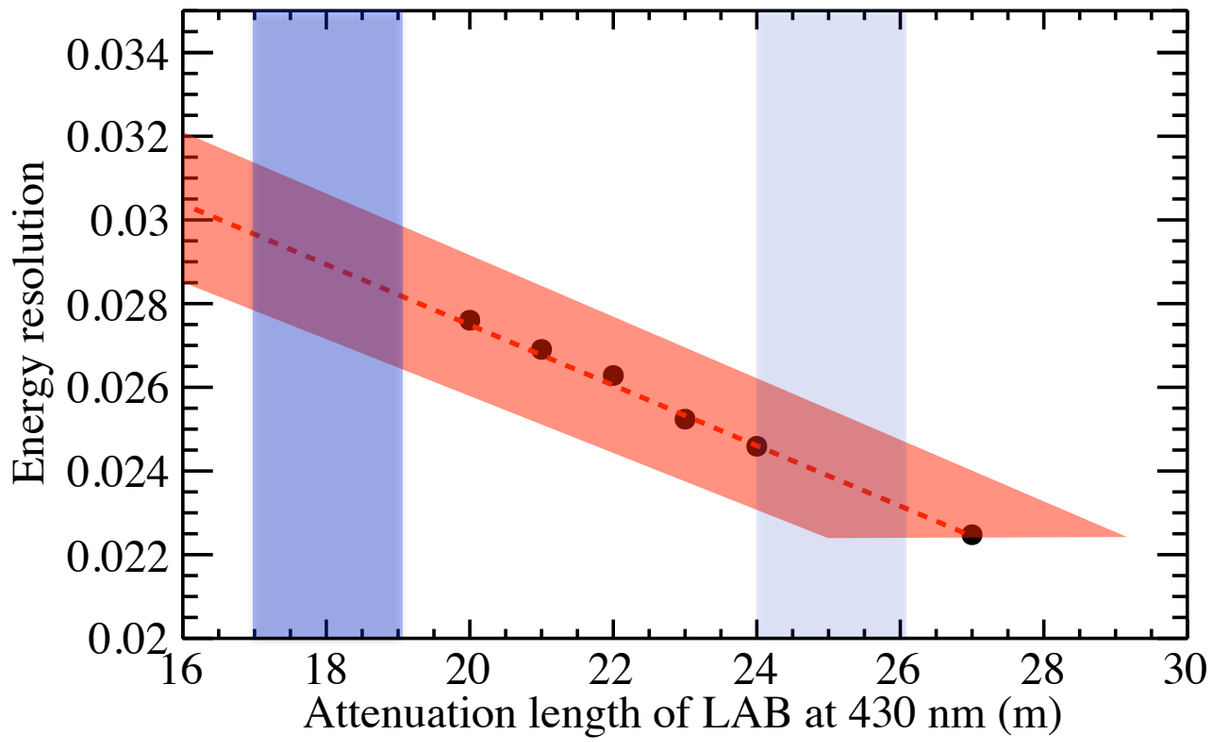
液闪光学性能对JUNO的影响

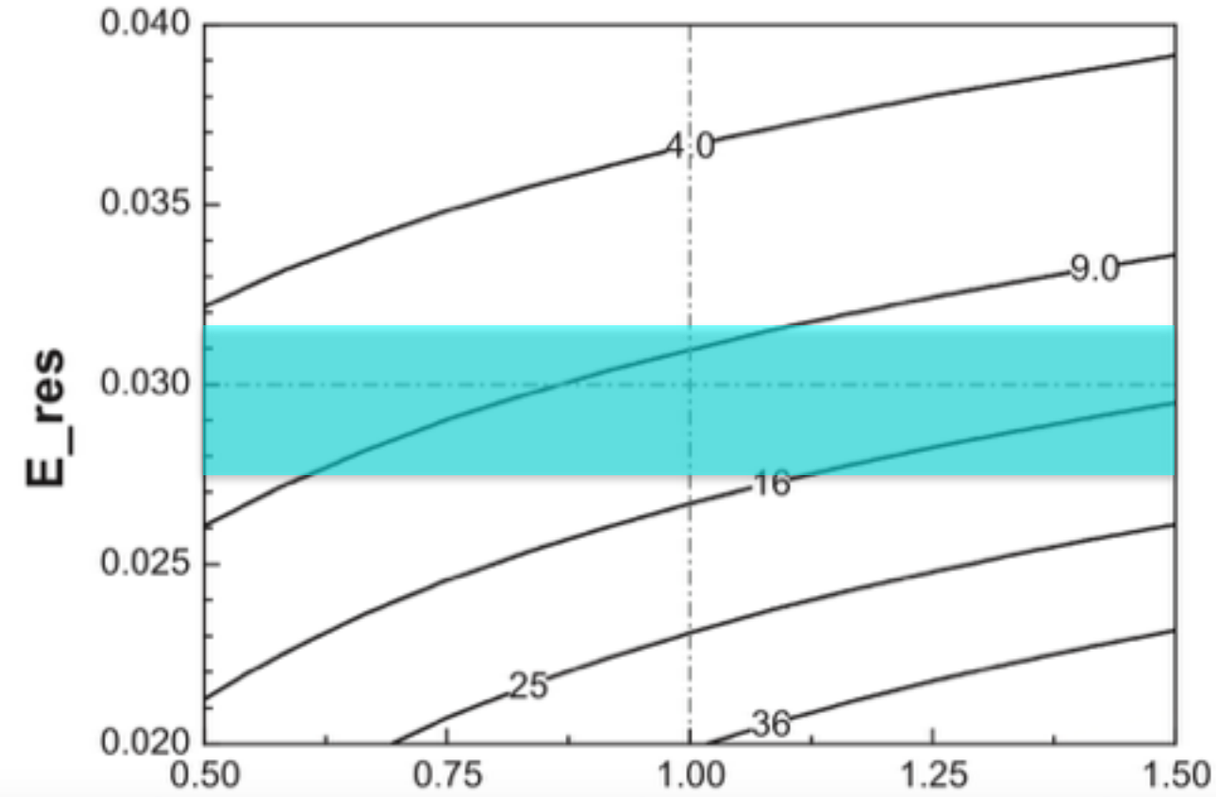


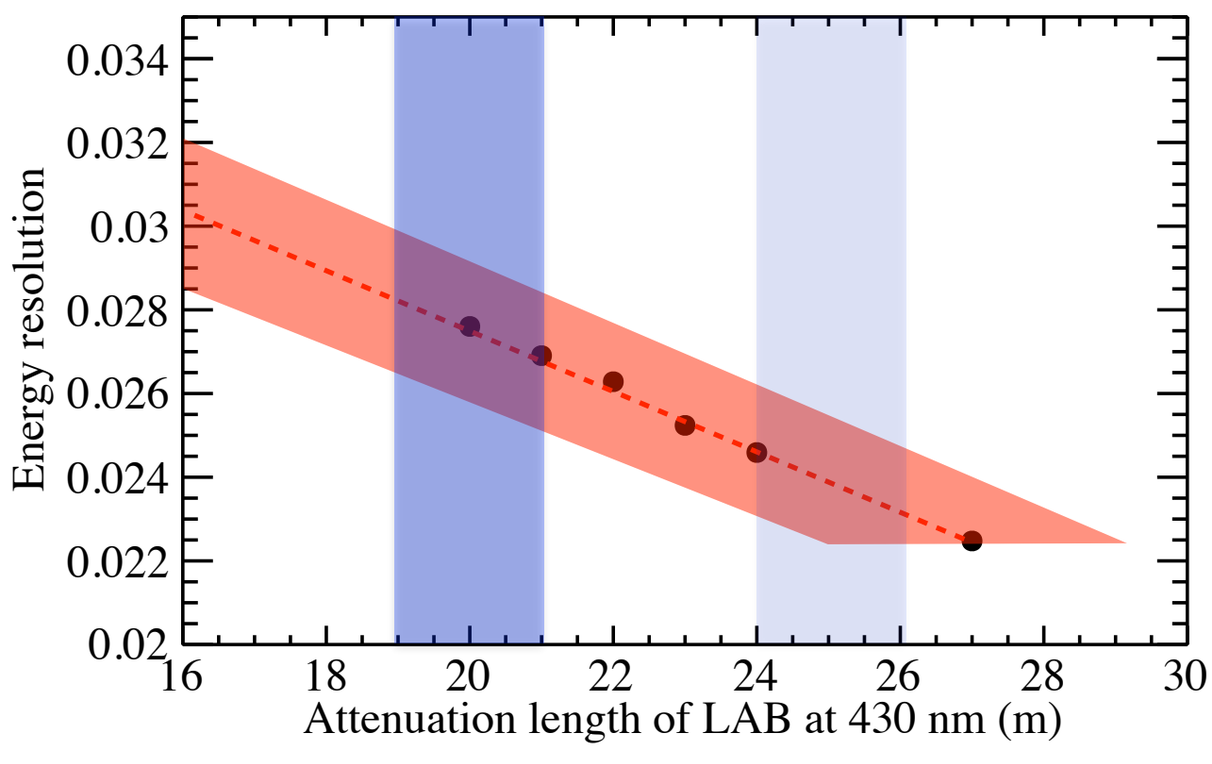


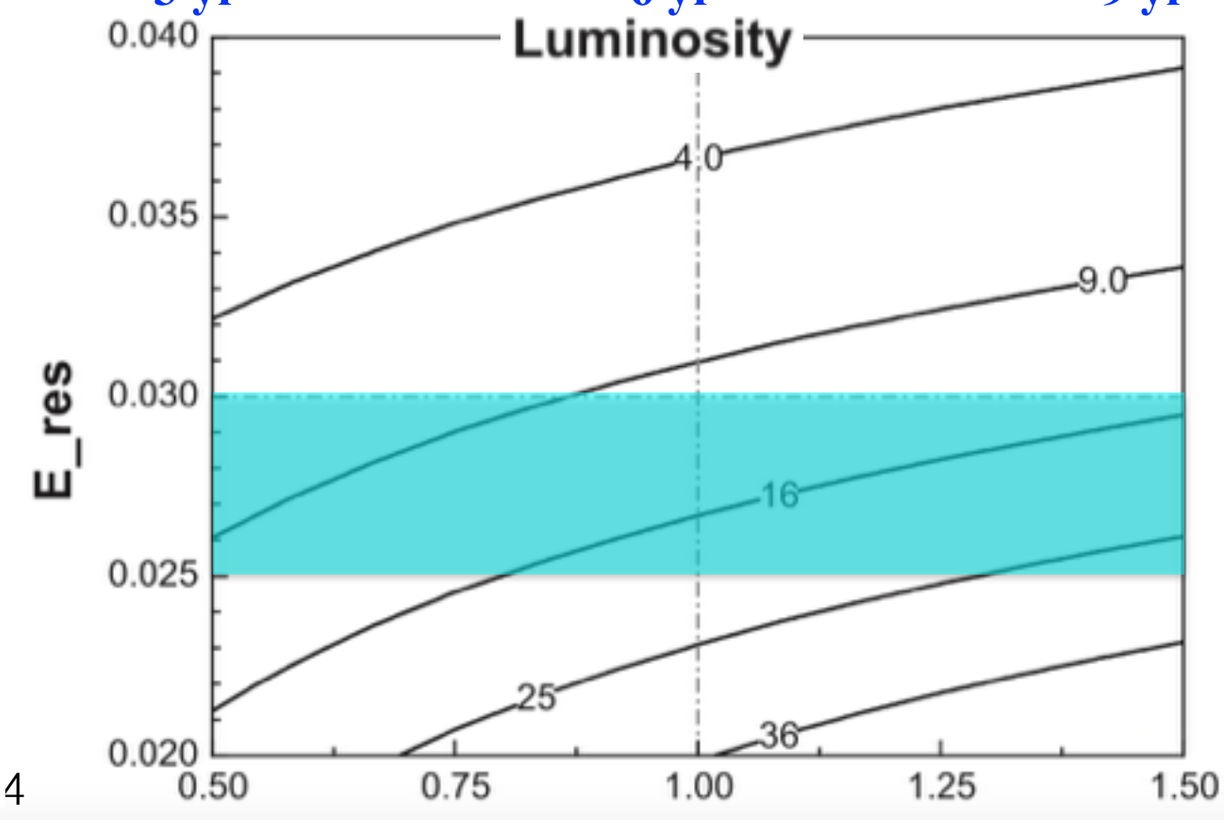
考虑散射和衰减测量的误差

液闪光学性能对JUNO的影响









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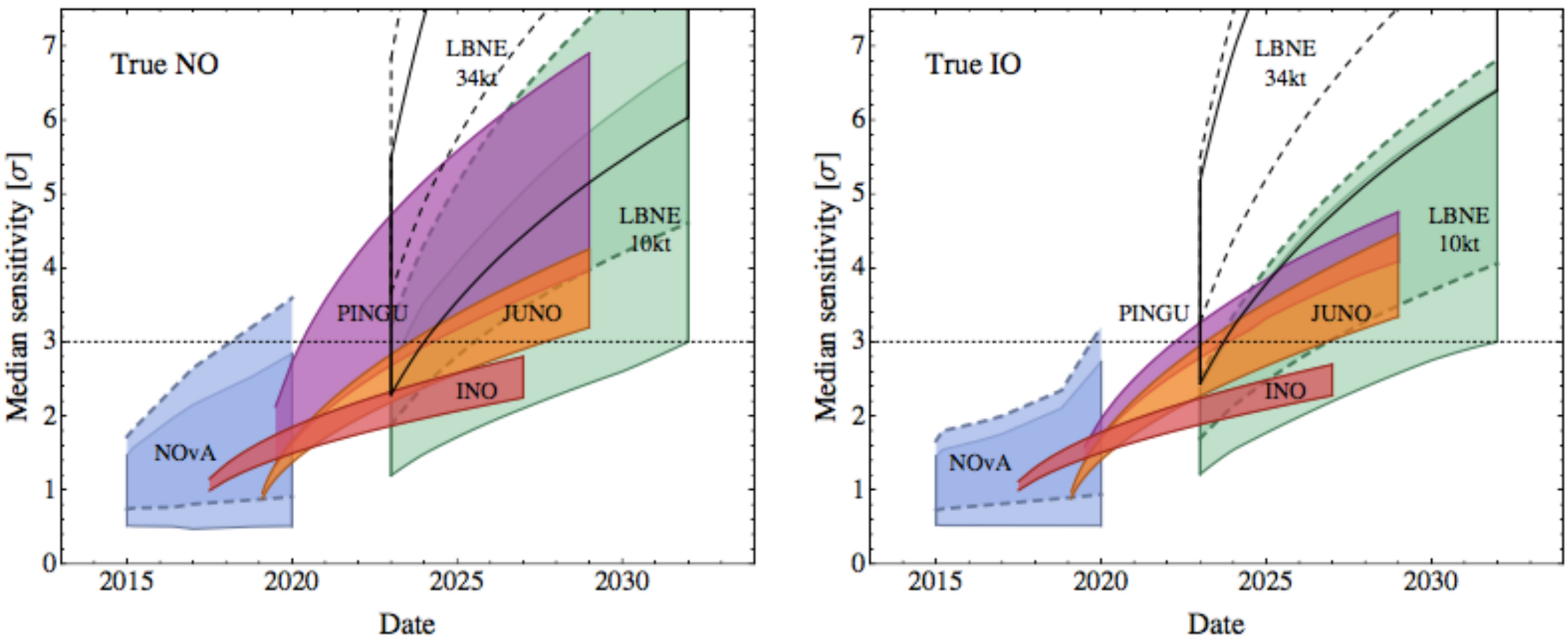
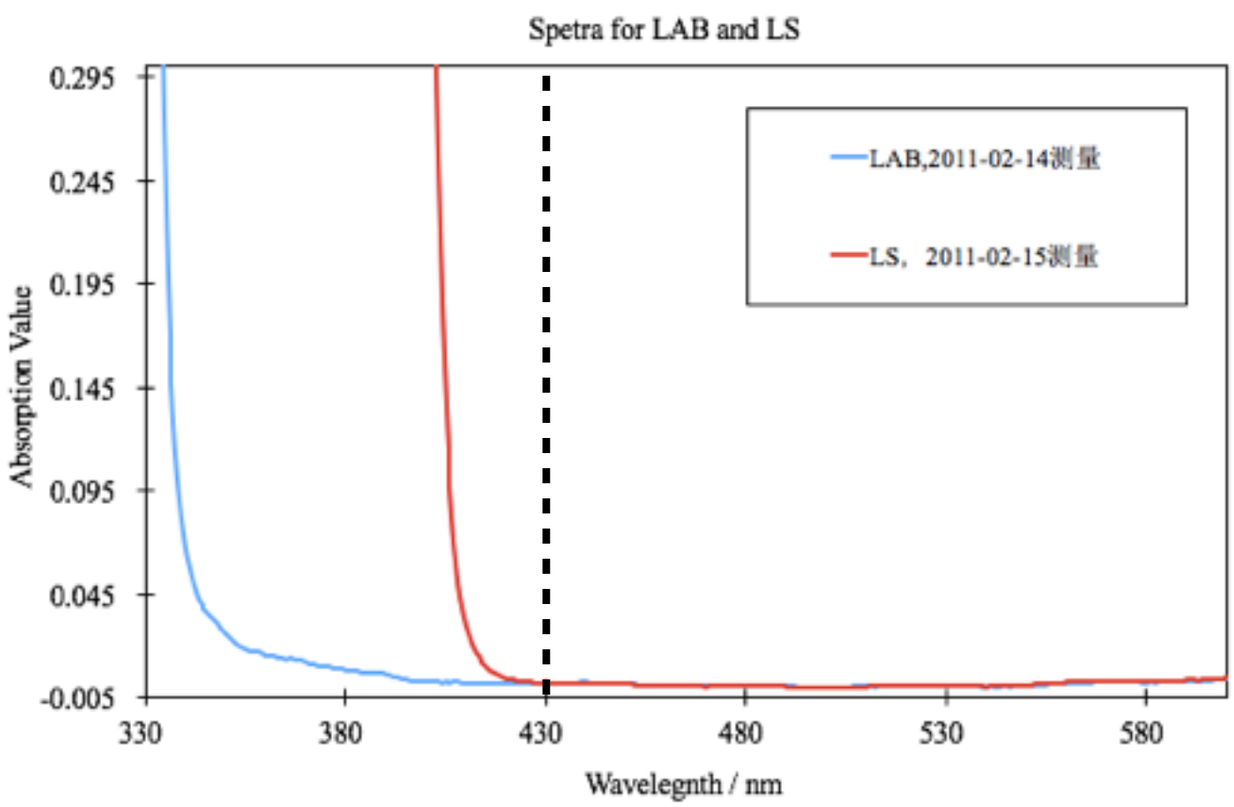


Mattias Blennow, JHEP(2014)

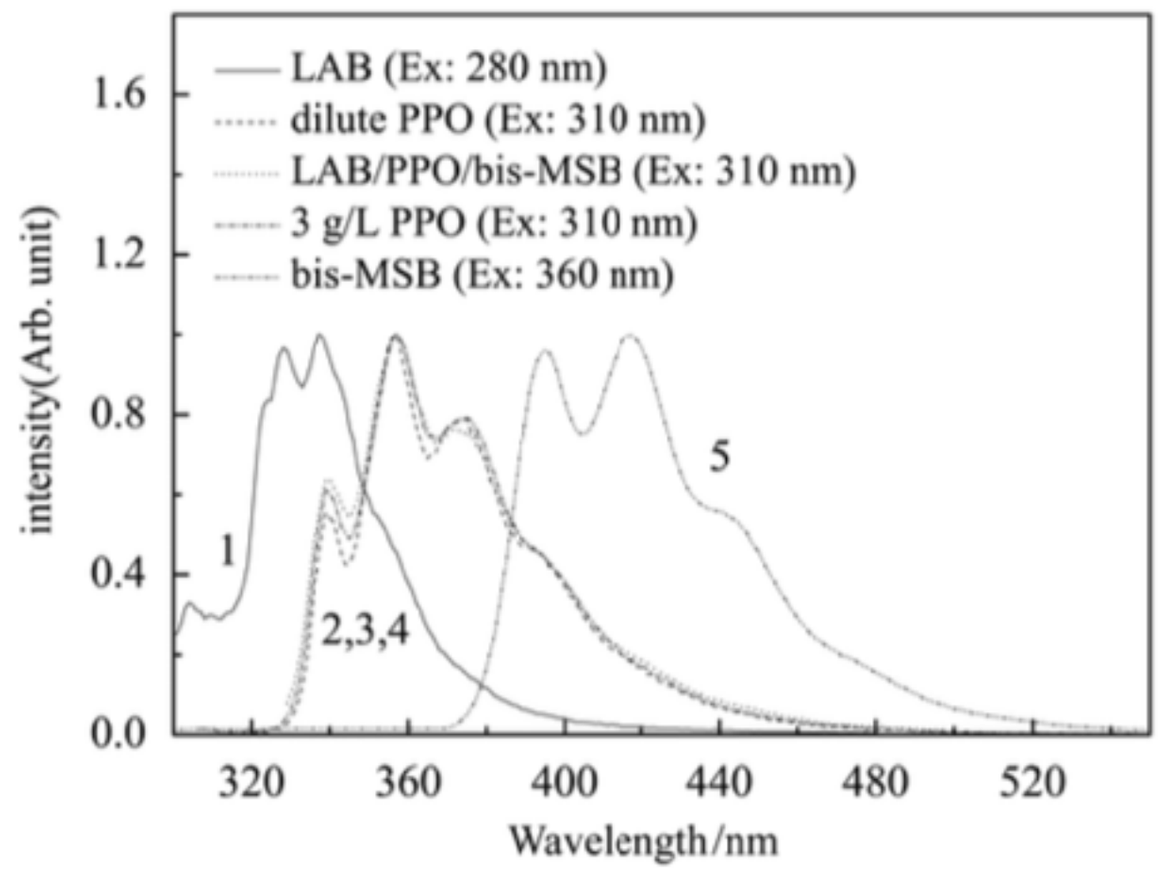
JUNO的测量能量是否还有提高的潜力?

液闪光学性能对JUNO的影响

吸收谱



发射谱



LAB在430nm附近的吸收起源于(未知)光学杂质而非自身

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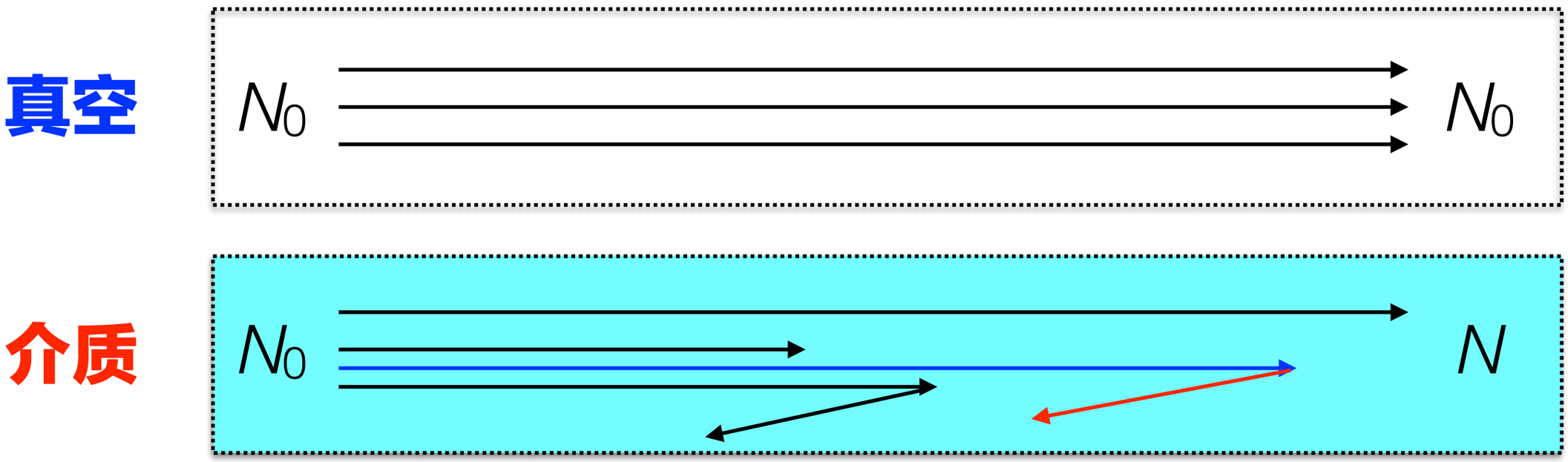


衰减 = 吸收 ⊕ 散射 ⇒ 衰减 = 吸收消失 ⊕ 吸收重发射 ⊕ 散射

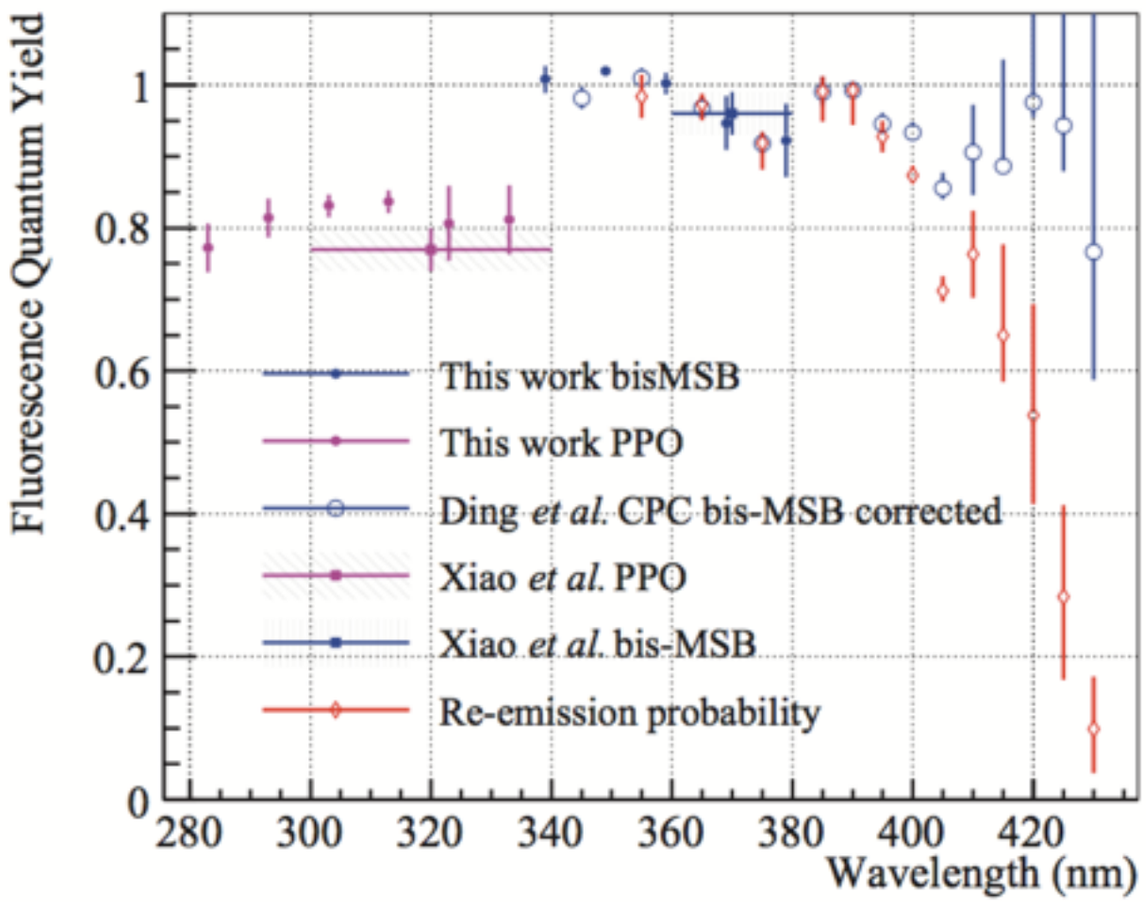
$$\frac{1}{L_{\text{att.}}} = \frac{1}{L_{\text{abs.}}} + \frac{1}{L_{\text{sca.}}} \Rightarrow \frac{1}{L_{\text{att.}}} = \frac{1}{L_{\text{abs.}}^{\text{van.}}} + \frac{1}{L_{\text{abs.}}^{\text{reem.}}} + \frac{1}{L_{\text{sca.}}}$$

$$\boxed{\frac{1}{L_{\text{att.}}^{\text{eff.}}} = \frac{1}{L_{\text{att.}}} - \frac{1}{L_{\text{abs.}}^{\text{reem.}}}} = \frac{1}{L_{\text{abs.}}^{\text{van.}}} + \frac{1}{L_{\text{sca.}}}$$

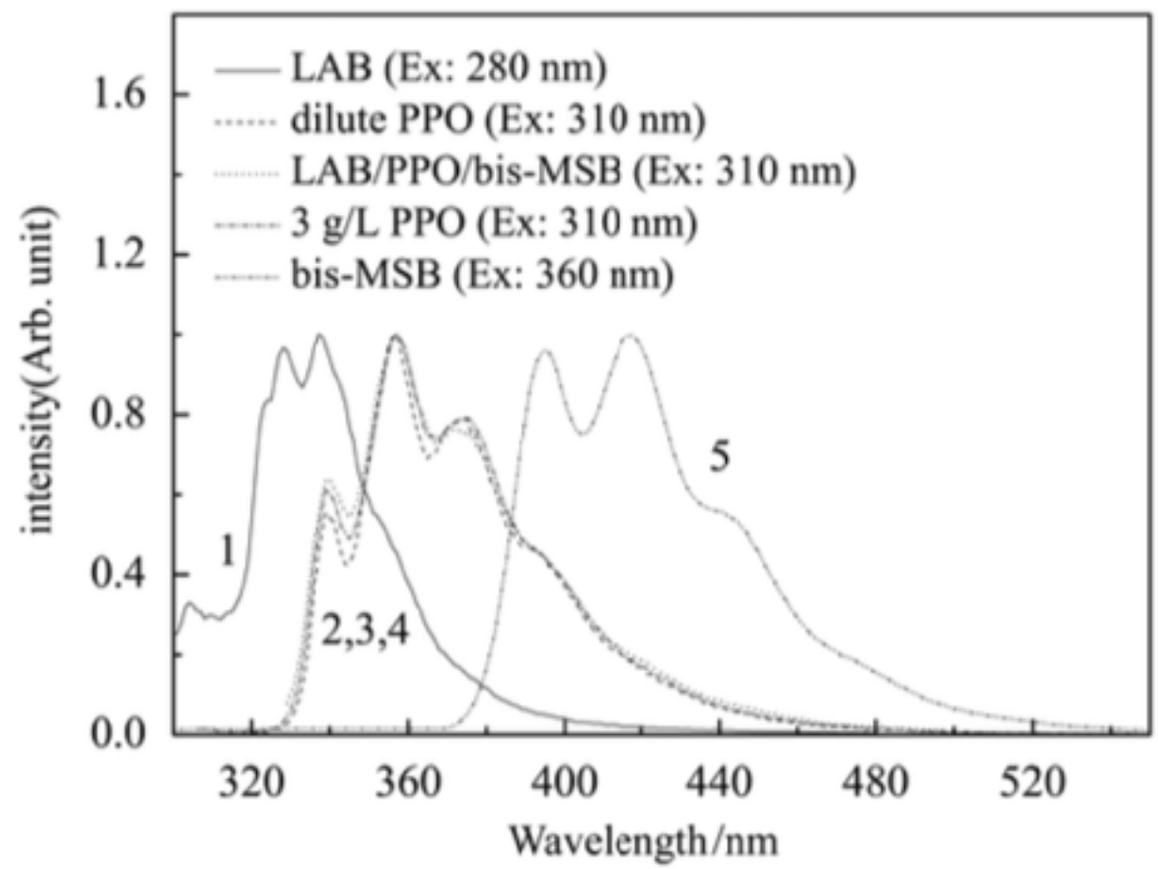
重发射能提高液闪透明度

液闪光学性能对JUNO的影响

重发射几率



发射谱



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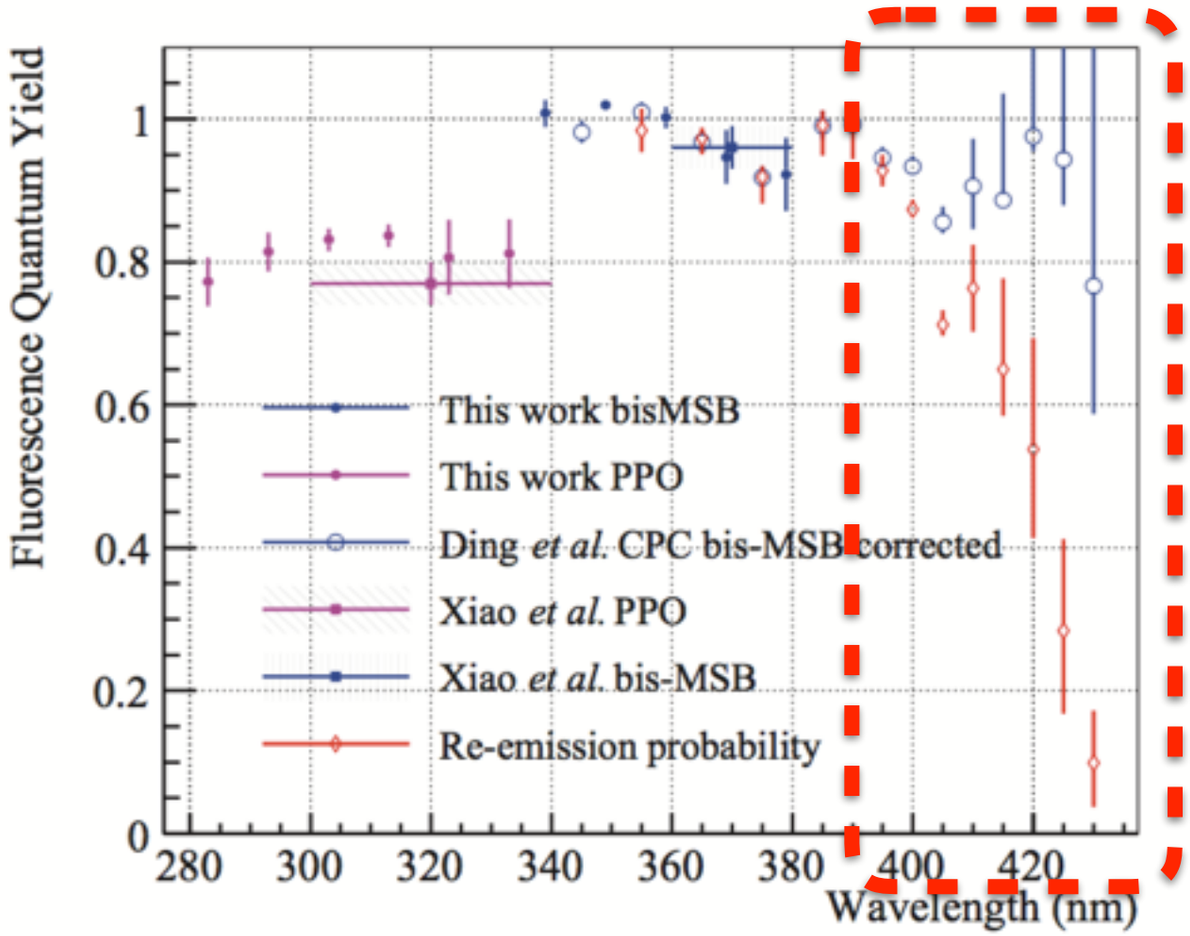

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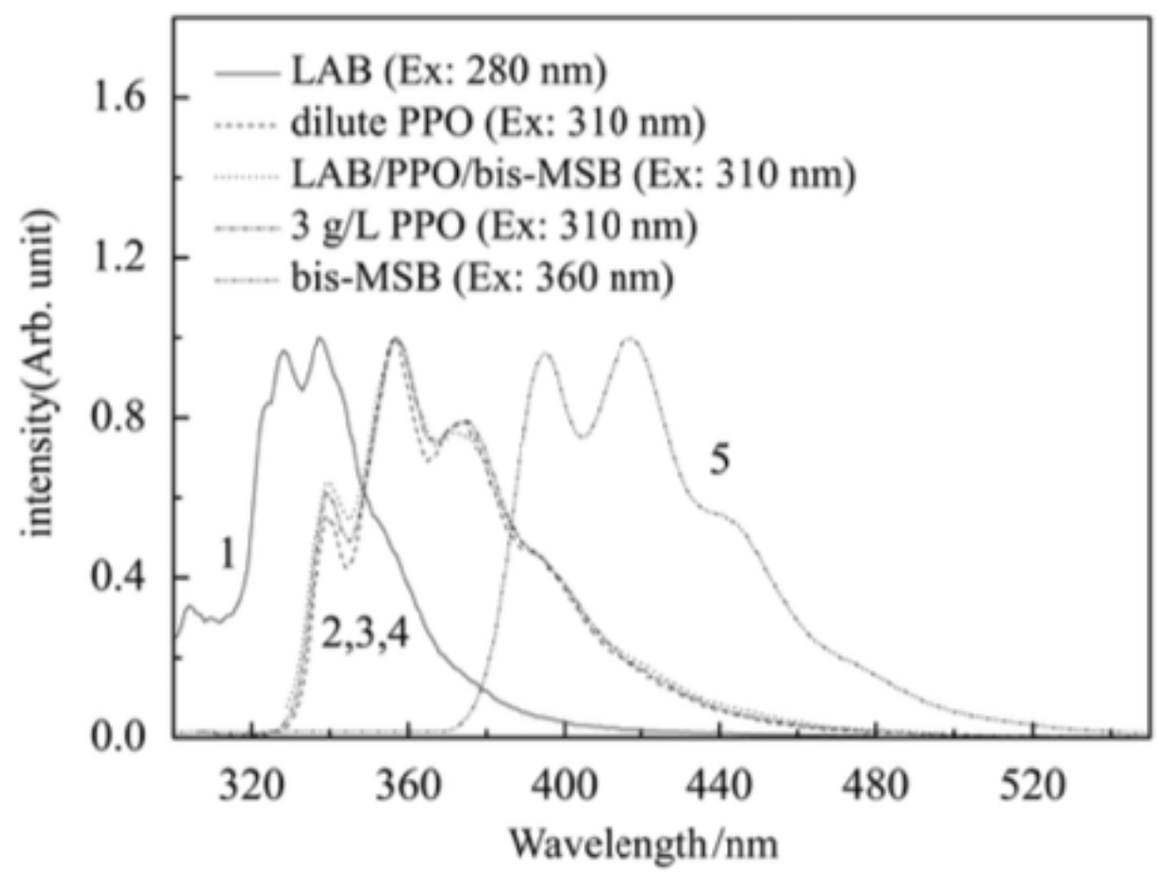

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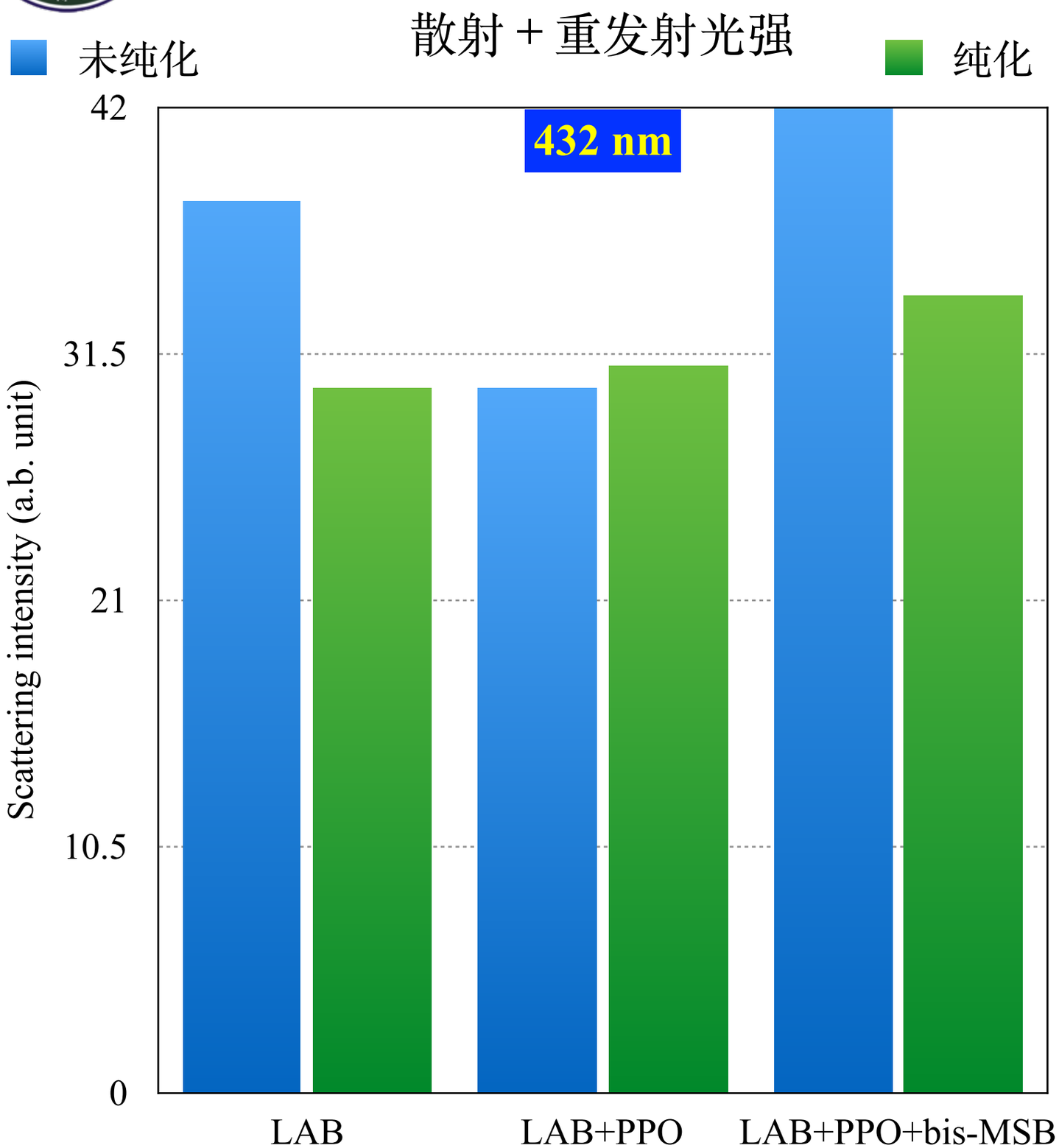
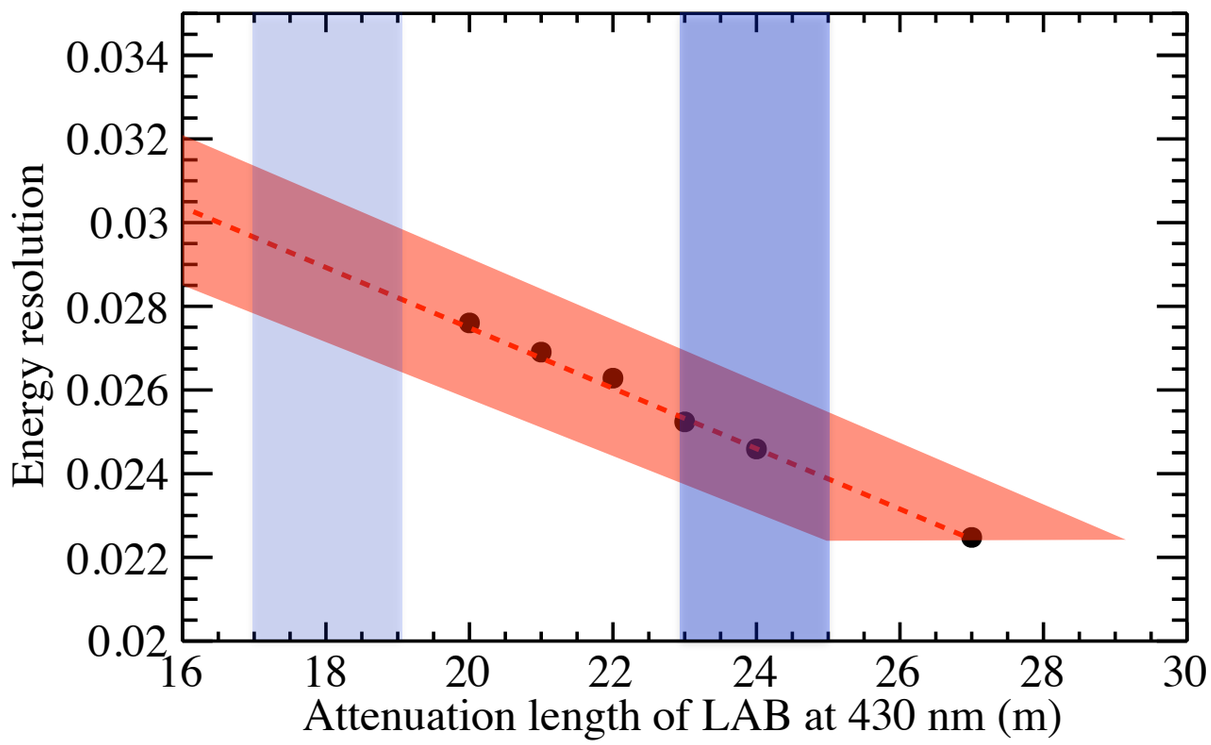
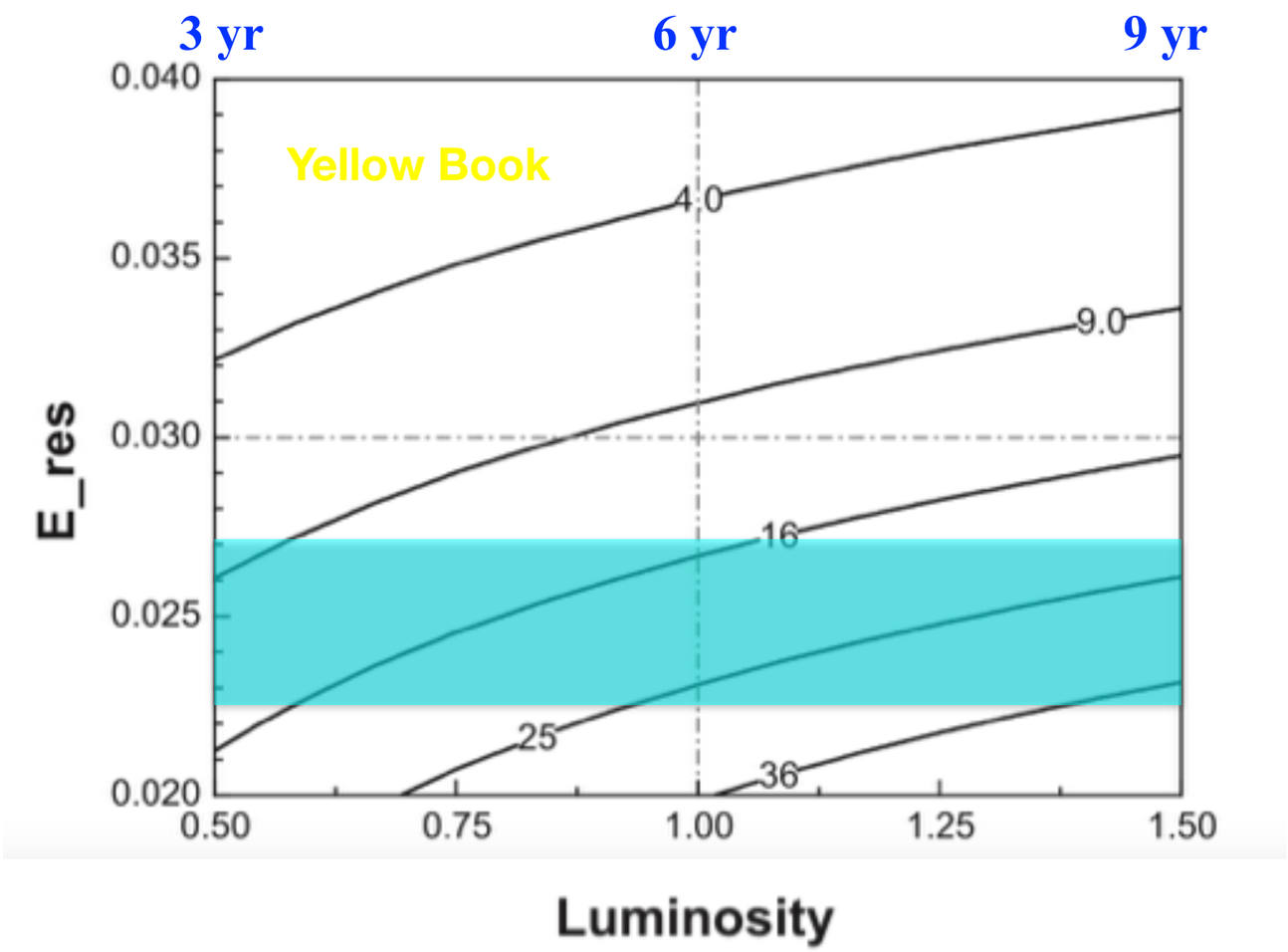


- 未纯化LAB存在杂质
- PPO和未知杂质有发光竞争
- bis-MSB有重发射迹象

液闪光学性能对JUNO的影响

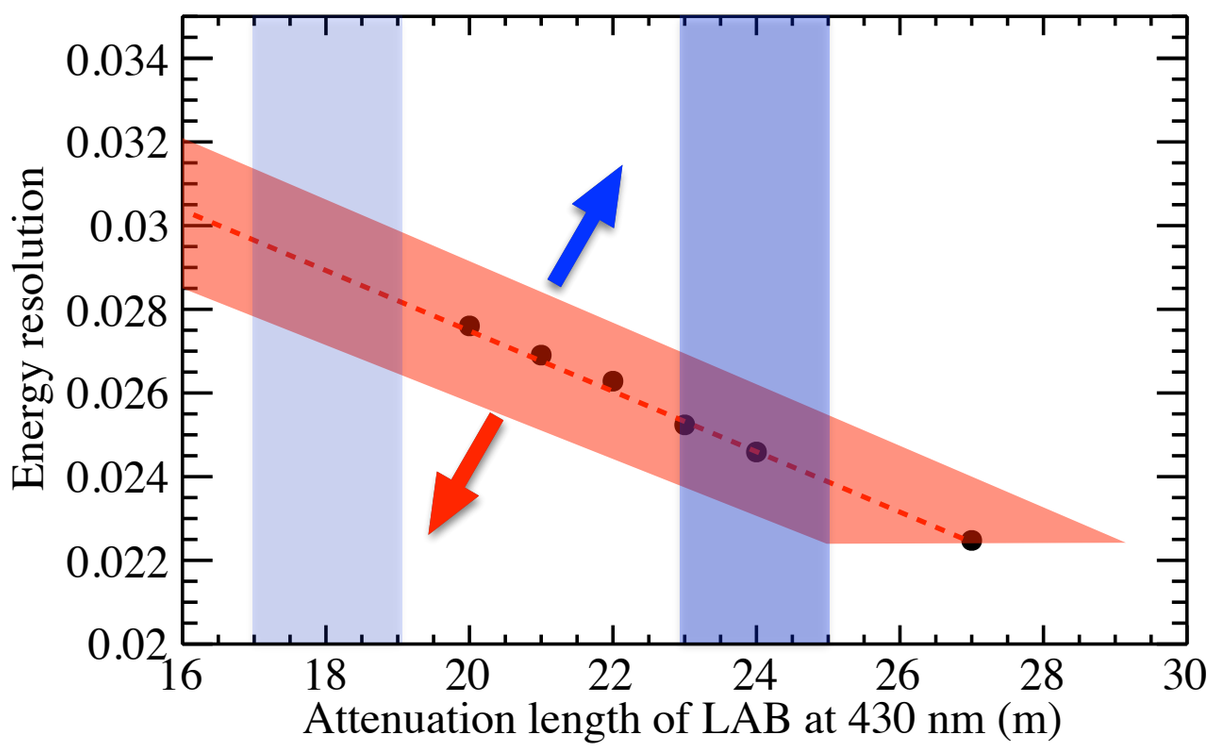


理论极限!



液闪光学性能对JUNO的影响

原初光产额将影响JUNO能量分辨率



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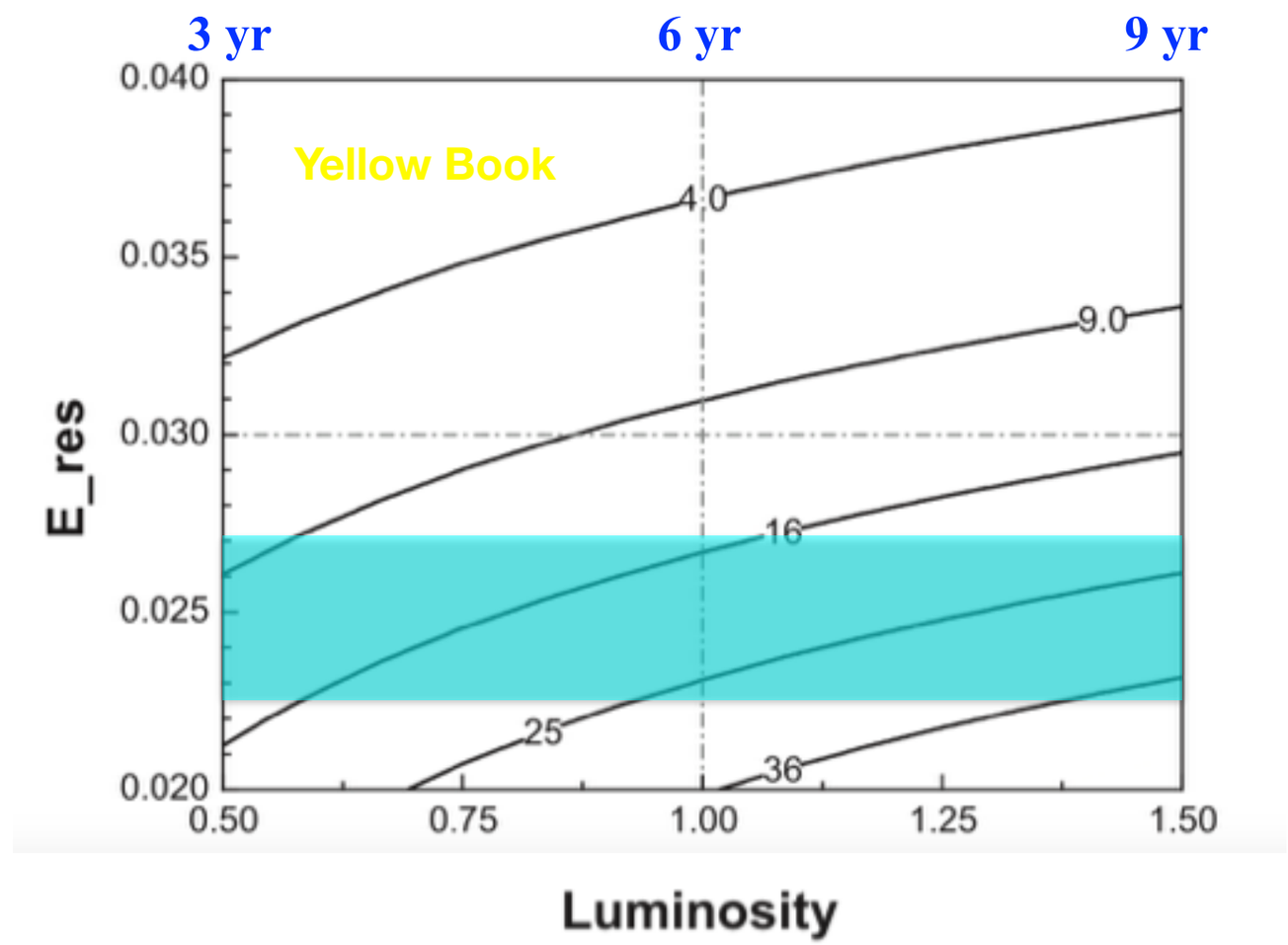

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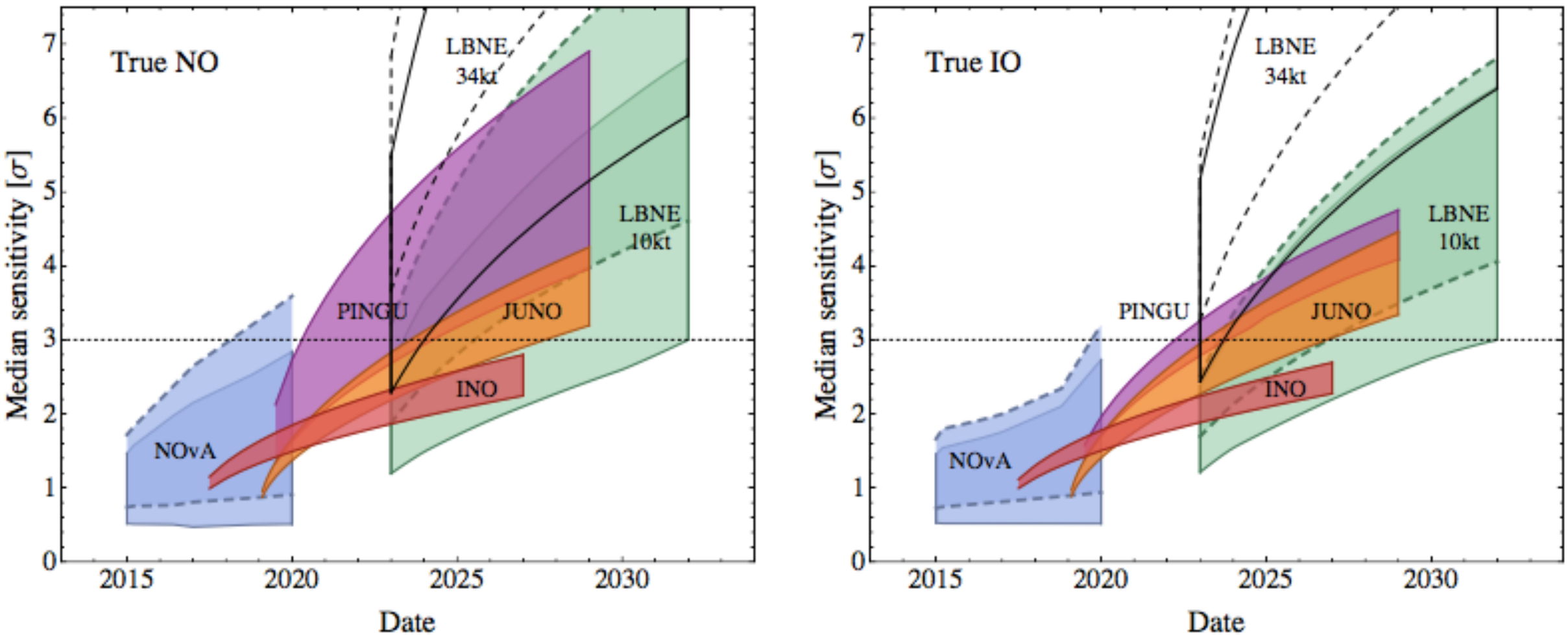
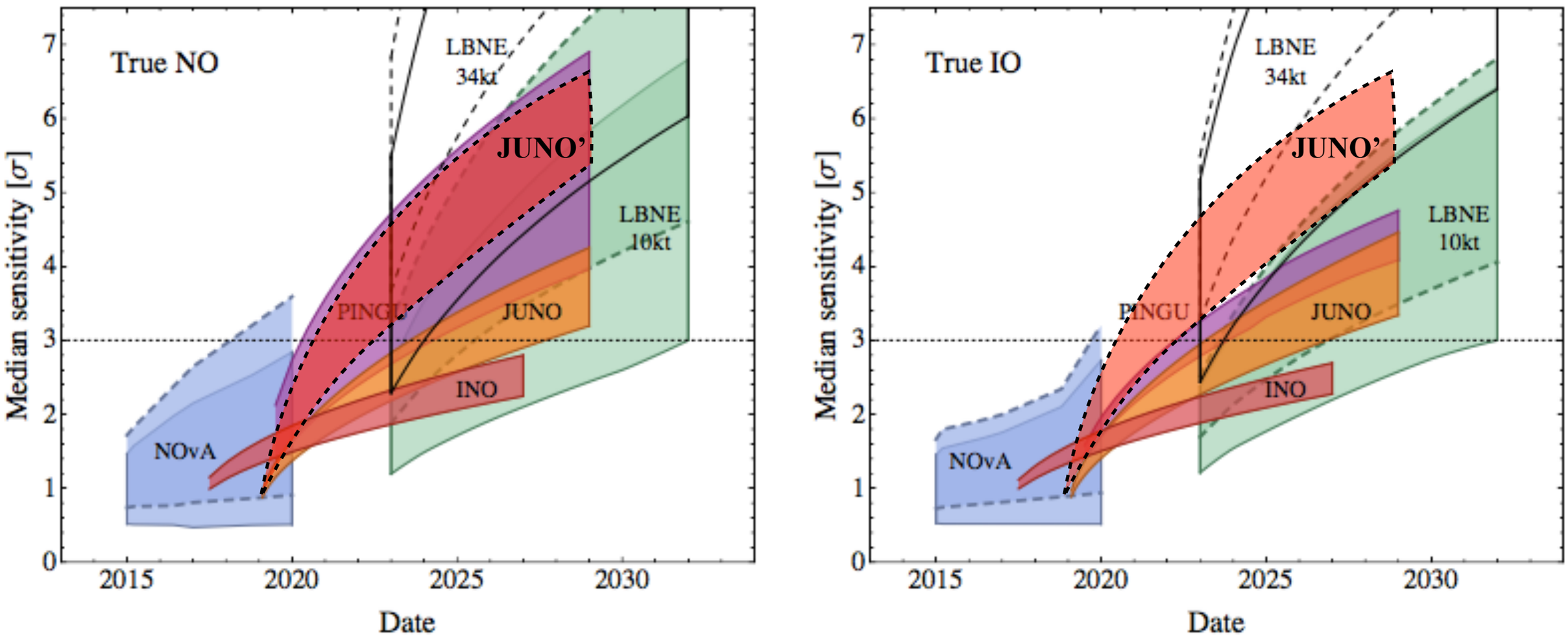


Mattias Blennow, JHEP(2014)

液闪光学性能对JUNO的影响

理论极限: JUNO'



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…highlighting once more the importance to achieve excellent energy reconstruction abilities

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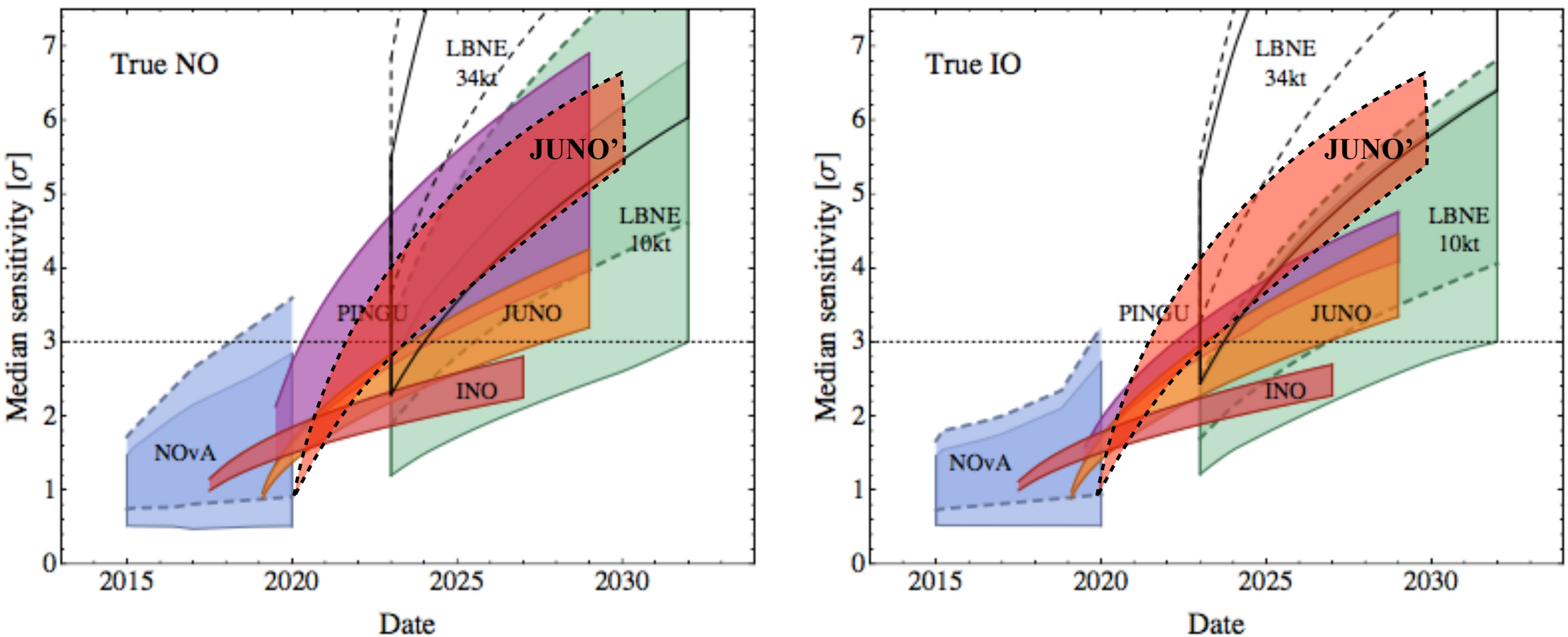

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…highlighting once more the importance to achieve excellent energy reconstruction abilities

总结和展望

- 纯化后的LAB衰减长度已接近散射长度 $\frac{1}{L_{\text{att.}}} = \frac{1}{L_{\text{abs.}}} + \frac{1}{L_{\text{sca.}}}$
- 武汉大学&国科大(中国组)给出当前最高精度的LAB散射长度测量结果
- 基于最新的测量结果，我们将液闪光学性质和JUNO的能量分辨率直观地关联

总结和展望

- 我们的测量显示液闪在430 nm附近有吸收重发射迹象
- 液闪的吸收重发射能进一步提高液闪透明度，JUNO的能量分辨率或许还有降低的潜力，从而有可能更快更准地测量中微子质量顺序
- 未来我们还将进一步提高LAB散射测量精度，定量测量液闪的吸收重发射

谢谢!