

CLAIMS:

1. Apparatus for detecting a particle, the apparatus comprising
a particle detector comprising:
 - 5 particle conversion means configured to convert an incoming ion into one or more secondary electrons upon impact thereon,
secondary electron amplification means configured to receive and amplify the one or more secondary electrons emitted by the particle conversion means and output an output signal,
 - 10 an amplifier configured to receive and amplify the output signal of the cross-field detector, and
digitizing means configured to receive and digitize the output of the amplifier,wherein the particle detector is a cross-field detector that is operable so as to limit the amplification of an incoming particle to secondary electrons to a maximum of about 10^7 ,
15 10^6 , 10^5 , or 10^4 secondary electrons per incoming particle.
2. The apparatus of claim 1, wherein the particle conversion means and the secondary electron amplification means are an integral unit.
- 20 3. The apparatus of claim 1 or claim 2, wherein the cross-field detector is a time-of-flight detector and the particle conversion means is an ion impact plate.
4. The apparatus of claim 3, wherein the time-of-flight detector is configured to provide a pulse width of less than about 2 ns, 1.5 ns, 1 ns, 0.9 ns, 0.8 ns, 0.7 ns, 0.6 ns, 0.5 ns or 0.4 ns
25 FWHM (full width half maximum).
5. The apparatus of claim 3 or claim 4, wherein the time-of-flight detector is configured to provide a highly uniform electrostatic field in the area extending from a detector input aperture through which an incoming particle is received to the ion impact plate.

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6. The apparatus of claim 5, wherein the highly uniform electrostatic field is provided at least in part by paired grids, each grid having a plane orthogonal to the ion impact plate, each grid fabricated from parallel conducting wires.
- 5 7. The apparatus of claim 5 or claim 6, wherein the highly uniform electrostatic field is provided at least in part by a ledge extending away from the ion impact plate, the ledge being at an edge of the ion impact plate over which secondary electrons emitted by the ion impact plate travel.
- 10 8. The apparatus of any one of claims 5 to 7, wherein the highly uniform electrostatic field is configured to reduce jitter in arrival times of particles transiting through the area extending from the detector entrance through which an incoming particle is received on the ion impact plate.
9. The apparatus of any one of claims 3 to 8, wherein the ion impact plate has a flatness controlled to within $\pm 10\mu\text{m}$, or within $\pm 5\mu\text{m}$.
- 15 10. The apparatus of any one of claims 3 to 9, wherein the ion impact plate is fabricated from approximately 3mm thickness stainless steel coated in a dynode material.
- 20 11. The apparatus of any one of claims 5 to 10, comprising one or more compensation apertures about the edge of the highly uniform electrostatic field to compensate for edge effects arising from field penetration through one or both of the paired grids.
12. The apparatus of any one of claims 3 to 11, wherein the time-of-flight detector is configured to provide a non-uniform magnetic field which functions to guide electrons emitted from the particle conversion means toward the electron multiplication means.
- 25 13. The apparatus of any one of claims 3 to 12, wherein the time-of-flight detector is a MagneTOFTM detector or a functional equivalent thereof, including model DM291 and model DM167, or a functional equivalent thereof.
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14. The apparatus of claim 1 or claim 2, wherein the cross-field detector is, or comprises, a channel electron multiplier.
15. The apparatus of any one of claims 1 to 14, wherein the cross-field detector is operable so as to limit the amplification of an incoming particle to a maximum of about 10^3 , 10^2 , or 10^1 .
16. The apparatus of any one of claims 1 to 14, wherein the cross-field detector is operable so as to limit the amplification of an incoming particle to a maximum of about five-fold.
17. The apparatus of any one of claims 1 to 16 wherein the amplification of the cross-field detector is settable by an operating voltage thereof.
18. The apparatus of claim 17, wherein the operating voltage is settable so as to prevent or inhibit the generation of a carbonaceous layer on a secondary electron emitting surface of the particle conversion means and/or the secondary electron amplification means.
19. The apparatus of any one of claims 1 to 18, wherein the cross-field detector has an output and the amplifier has an input, and the amplifier input is disposed proximal to the cross-field detector output.
20. The apparatus of claim 19, wherein the amplifier input is disposed at a maximum of about 100 cm, 90 cm, 80 cm, 70 cm, 60 cm, 50 cm, 40 cm, 30 cm, 20 cm or 10 cm from the cross-field detector output.
21. A method for detecting a particle, the method comprising
providing a particle detector comprising:
particle conversion means configured to convert a incoming ion into one or more secondary electrons upon impact thereon,
secondary electron amplification means configured to receive and amplify
the one or more secondary electrons emitted by the particle conversion means and output an output signal,

providing an amplifier configured to receive and amplify the output signal of the cross-field detector, and

providing digitizing means configured to receive and digitize the output of the amplifier,

5 wherein the particle detector is a cross-field detector that is operated so as to limit the amplification of an incoming particle to secondary electrons to a maximum of about 10^7 , 10^6 , 10^5 , or 10^4 secondary electrons per incoming particle.

22. The method of claim 21, wherein the particle conversion means and the secondary electron
10 amplification means are an integral unit.

23. The method of claim 21 or claim 22, wherein the cross-field detector is a time-of-flight detector and the particle conversion means is an ion impact plate.

15 24. The method of claim 23, wherein the time-of-flight detector is configured to provide a pulse width of less than about 2 ns, 1.5 ns, 1 ns, 0.9 ns, 0.8 ns, 0.7 ns, 0.6 ns, 0.5 ns or 0.4 ns FWHM (full width half maximum).

25. The method of claim 23 or claim 24, wherein the time-of-flight detector is configured to
20 provide a highly uniform electrostatic field in the area extending from the detector input aperture through which an incoming particle is received to the particle conversion means.

26. The method of claim 25, wherein the highly uniform electrostatic field is provided at least in part by paired grids, each grid having a plane orthogonal to the ion impact plate, each grid
25 fabricated from parallel conducting wires.

27. The method of claim 25 or claim 26, wherein the highly uniform electrostatic field is provided at least in part by a ledge extending away from the ion impact plate, the ledge being at an edge of the ion impact plate over which secondary electrons emitted by the ion impact plate
30 travel.

28. The method of any one of claims 25 to 27, wherein the highly uniform electrostatic field is configured to reduce jitter in arrival times of particles transiting through the area extending from the detector entrance through which an incoming particle is received to the ion impact plate..
- 5 29. The method of any one of claims 23 to 28, wherein the ion impact plate has a flatness controlled to within $\pm 10\mu\text{m}$, or within $\pm 5\mu\text{m}$.
30. The method of any one of claims 23 to 29, wherein the ion impact plate is fabricated from approximately 3mm thickness stainless steel coated in a dynode material.
- 10 31. The method of any one of claims 25 to 30, comprising one or more compensation apertures about the edge of the highly uniform electrostatic field to compensate for edge effects arising from field penetration through one or both of the paired grids.
- 15 32. The method of any one of claims 23 to 31, wherein the time-of-flight detector is configured to provide a non-uniform magnetic field which functions to guide electrons emitted from the particle conversion means toward the electron multiplication means.
33. The method of any one of claims 23 to 32, wherein the time-of-flight detector is a
20 MagneTOFTM detector or a functional equivalent thereof, including model DM291 and model DM167.
34. The method of any one of claims 21 to 33, wherein the cross-field detector is, or comprises, a channel electron multiplier.
- 25 35. The method of any one of claims 21 to 34, wherein the cross-field detector is operated so as to limit the amplification of an incoming particle to a maximum of about 10^3 , 10^2 , or 10^1 .
36. The method of any one of claims 21 to 34, wherein the cross-field detector is operated so
30 as to limit the amplification of an incoming particle to a maximum of about five-fold.

37. The method of any one of claims 21 to 36, wherein the amplification of the cross-field detector is set by an operating voltage thereof.

38. The method of claim 37, wherein the operating voltage is set so as to prevent or inhibit the generation of a carbonaceous layer on a secondary electron emitting surface of the particle conversion means and/or the secondary electron amplification means.

39. The method of any one of claims 21 to 38, wherein the cross-field detector has an output and the amplifier has an input, and the amplifier input is disposed proximal to the cross-field detector output.

40. The method of any one of claims 21 to 39, wherein the amplifier input is disposed at a maximum of about 100 cm, 90 cm, 80 cm, 70 cm, 60 cm, 50 cm, 40 cm, 30 cm, 20 cm or 10 cm from the cross-field detector output.